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# Creating Optimal Conditions for the Development of Agribusiness by Scenario Modeling of the Production and Industry Structure of Agricultural Formations

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**ABSTRACT**

Nowadays model formulations aimed at the optimal use of production resources at the management level of individual agricultural formations, taking into account the construction of promising scenarios for the development of agricultural production, are becoming increasingly popular. In this study, it is supposed to present a scientific justification for the use of modeling methods and cluster technologies in determining the optimal production structure of agricultural formations at the rural level. The methodological basis of the study is the method of economic and mathematical modeling, with the help of which it is supposed to develop an algorithm for optimizing the production and sectoral structure in certain sectors of the agro-industry. The algorithm for optimizing the production and industry structure proposed in this paper makes it possible to determine the most effective options for conducting agricultural activities for each business entity. The conceptual novelty of the study is determined by the development of an algorithm for optimizing the production and industry structure in the system "agricultural formations are a rural territory"; clarification of methodological approaches and recommendations for the use of cluster technologies to identify typical agricultural organizations within rural areas. The article shows that the methods of economic and mathematical modeling and multidimensional statistical analysis in the agro-industrial sector can become an effective tool in the development of strategic plans for the development of agricultural formations.

## 1. INTRODUCTION

The problems of research of the development processes of agricultural formations are an actual direction of economic science and a necessary component of the state functioning. It can be stated that the current context of economic development is characterized by an unprecedented aggravation and manifestation of global problems, the emergence of new risks, a pandemic incidence on the example of large-scale coronavirus diseases and appears to be a new challenge for agricultural formations.

The key task of achieving sustainable development of agricultural formations is of strategic importance in the planning system of the economic sphere of the leading countries in the world, and its solution directly consists of the effective use of the total production potential of agricultural producers. Of course, for agricultural producers to perform all their functions, it is necessary to develop and implement a strategy that objectively ensures the formation of "growth points" and drivers in rural areas in the context of key components of achieving sustainable development.

At the same time, under the influence of various political and socio-economic challenges, there is a transformation of the scientific concepts and fundamental approaches, conceptual provisions to strategic goals, mechanisms, tools, technologies and trajectories of designing a strategy for the development of agricultural formations. The emerging trends caused by the economic and technological modernization of the global economic structure determine the positive trends in the development of the digital economy in rural areas and the activation of the processes of introducing innovative technologies and developments in agricultural formations, the use of new tools for analyzing big data (Big Data), artificial intelligence (AI), blockchain and smart contracts, digital agroclusters and the introduction of model developments [1-3].

It should be emphasized that over the past three decades, the Nobel Prizes in Economics have been awarded mainly for scientific developments using modeling methods. The model designs compiled by the researchers are aimed at protecting their own consumers of agri-food products and agricultural producers [4]. One of the main goals of such models is to determine the reaction (response) of rural territorial systems to the adoption of political and managerial decisions and actions of the external economic environment.

Especially strongly developed and developed methods of analysis and decision-making in conditions of uncertainty, simulation modeling, in such countries as Germany, Canada and the United States [5]. Also, depending on the class of economic and mathematical models, it is necessary to take into account that in European countries (especially in France, Great Britain and Germany), econometric models are more developed and used, and in the United States, optimization models (or optimization models combined with simulation) are more used [6-8].

It should be noted that in some economically developed countries, in particular in Canada, Ireland, Finland and Germany, researchers pay considerable attention to the formation and implementation of econometric models that allow to simulate the adoption of real political decisions in relation to the functioning of the agricultural sector. The formation of special programs aimed at realizing the potentials and supporting model projects for the functioning of rural territorial entities, similar to the European programs CLLD (Community-Led Local Development), Leader 1 (Liaison Entre Actions de Developement del Economie Rurale), Leader 2, Leader +, is certainly to be one of the effective measures for the development of rural development strategies.

It should be noted that there are positive trends towards expanding the possibilities of using digital technologies and methods of economic and mathematical modeling in the activities of analytical departments of the world's largest companies and organizations in relation to the management processes of agricultural production [9, 10]. Of course, model designs developed on the basis of linear programming are still in demand today and are used in various industrial and scientific fields [11, 12]. This is due to several advantages. Firstly, they have application software packages for their solution, which can be used by managers even without serious mathematical training (in contrast, for example, to methods of nonlinear programming). Secondly, specialists can easily interpret the economic results from optimization calculations.

The purpose of the research is to substantiate scientifically the use of modelling methods and cluster technologies in determining the optimal production structure of agricultural formations at the level of rural areas. The formulated purpose of the research led to the formulation and solution of the following tasks:

- generalization of the experience of scientific research on economic and mathematical modelling of strategic parameters of the development of agricultural formations;
- development and implementation of an algorithm for optimizing the production and industry structure in the system of "agricultural formation - rural territory".

This paper presents a step-by-step algorithm for optimizing the production and industry structure using scenario modeling methods. The latter allows you to determine the most effective options for conducting agricultural activities for each business entity. The novelty of the proposed algorithm lies in the fact that it allows to reduce the arrays of real economic data for further calculations and the number of agricultural organizations selected as objects of further optimization. Combining agricultural organizations into cluster groupings based on the methods of multivariate statistical analysis, taking into account various economic and production parameters (characteristics), makes it possible to identify typical agricultural organizations in the composition of the studied population of rural areas.

## 2. LITERATURE REVIEW

We have carried out a content analysis of modern scientific publications for 2018-2022 on the studied issues. The assessment of the content of literary sources makes it possible to form the following promising areas of scientific research of economic and mathematical modelling of the development of agricultural formations, presented in Figure 1.

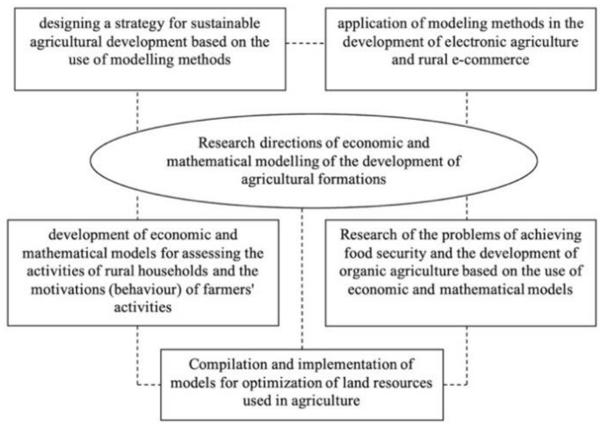


**Figure 1.** Research directions of economic and mathematical modelling of the development of agricultural formations

As can be noted, promising areas of research can be roughly divided into five categories, presented below.

1. Designing a strategy for sustainable agricultural development based on the use of modelling methods. Within the framework of the 2030 Agenda for Sustainable Development (The 2030 Agenda for Sustainable Development), the achievement of sustainable development is considered as a priority task of the international community and obliges the Member States of the United Nations to collectively achieve by 2030 the 17 most important Sustainable development goals (SDGs, sustainable development goals (SDGs)) in the social, economic and environmental fields. In turn, the achievement of the SDGs determines the need to develop a system of more than 100 targets. It should be emphasized that the traditional and dominant approach to assessing the system of sustainable development targets studied within the synthesis of multi-indicator systems of cardinal variables is the use of an aggregative-compensative approach.

In turn, to achieve this goal, some scientists suggest using the method of synthesizing multi-indicator systems over time based on the theory of partial order (method of synthesizing multi-indicator systems over time based on the Partial Order Theory) [13, 14]. So, when assessing the degree of achievement of the Sustainable Development Goals, Alaimo justifies the use of the adjusted Mazziotta-Pareto Index (AMPI) and on this basis further determines the calculation of the composite index for the design of a synthetic indicator of economic sustainability [15]. When making calculations, statistical data generated by the European Foundation for the Improvement of Living and Working Conditions (Eurofound) are used. Also, within the framework of this study, the assessment of the main parameters of the SDGs can be carried out taking into account their temporal dynamics of development using methods of correlation analysis and principal components (principal component analysis, PCA) [16].

2. Application of modelling methods in the development of electronic agriculture and rural e-commerce. The use of modern methods of econometric modelling and, in particular, the construction of regression models makes it possible to effectively assess the opportunities and prospects for the development of rural e-commerce. Thus, the results of heterogeneous analysis made by foreign specialists determine the following dependence: rural households located closer to local settlements "benefit" more and benefit from the introduction of e-commerce and trade achievements [17].

The FARMSIM simulation model developed by scientists allows us to economically assess the potential consequences that may arise when introducing new agricultural technologies at the level of individual farms in ex-ante and ex-post conditions [18]. The presented model development is directly based on the use of the Monte Carlo method. The conducted studies have shown that the use of large volumes of fertilizers by rural producers in combination with optimal irrigation of agricultural fields for growing vegetables makes it possible to get a higher profit compared to the actual development scenario.

3. Development of economic and mathematical models for assessing the activities of rural households and the motivations (behaviour) of farmers' activities. Chinese scientists, based on the development of RLC models, effectively assess the activities of low-income households located in rural areas. It is necessary to highlight the extensive statistical material used by specialists in compiling RLC models, based on a survey of 562 rural households in the Chinese provinces of Hubei and Guizhou. This research determines the imitation of the behaviour of "poor" households in the design of two scenarios, namely: the use of a model with a dominant role of the state in regulating the processes of rural poverty and the use of a poverty reduction model based on the mechanism of public-private partnership [19].

It is necessary to single out an integrated dynamic model compiled by foreign specialists based on the Sen methodology [20]. This model development makes it possible to carry out spatial and temporal analysis and develop an assessment of individual indicators of the quality of life of the population of rural areas. The results of model calculations also help to design directions for improving the efficiency of using financial resources for rural areas, taking into account the sub-regional differences of the area under consideration.

4. Compilation and implementation of models for optimization of land resources used in agriculture. Foreign researchers emphasize that remote sensing is a powerful tool for analyzing and monitoring spatio-temporal transformations in agriculture [21]. For example, an effective scientific development of the study of land management processes and the dynamics of changes in the parameters of LULC (Land Use Land Cover) can be a hybrid model of logistic regression. The implementation of this model development makes it possible to summarize that the modelling of land use processes is the most important component of agricultural planning and management decision-making in the agricultural sector of the economy.

As effective examples of optimization of agricultural industries, one can cite model developments applicable to the largest agricultural district of Kern County in California (and the USA as a whole) [6]. These models take into account the balancing of agricultural production development goals, the efficient use of groundwater reserves for agricultural needs and biodiversity based on certain environmental priorities. It should be emphasized that such optimization models are an integral part of the modern concept of strategic planning of environmental protection activities and their practical application contributes to the effective distribution of land-use objects in conditions of water scarcity.

5. Research of the problems of the development of organic agriculture, green economy and the achievement of food security based on the use of economic and mathematical models. Currently, the problems of achieving food security can be effectively solved through the use of modelling methods and the development of models of agricultural systems. Foreign researchers determine the need for wider use of dynamic models of agricultural systems, which should include key parameters reflecting the state of food security, both at the regional level and at the household level (household level) [22].

In our opinion, one of the promising areas of foreign economic research is the modelling of the production consequences of the transition of the agricultural sector to organic agriculture. The linear programming model proposed by scientists for the development of typical farms takes into account factors such as soil condition, precipitation, and the need for feed used for certain groups of farm animals [8]. The final model results of this study determine a significant reduction in the actual production of wheat and barley, despite the fact that the production of oats and rye compared with the actual indicators needs to be increased. At the same time, the planned volumes of vegetable production are generally comparable with actual indicators. According to the results of the study, it is summarized that to compensate for the production consequences of the transition of agriculture in England and Wales to organic farming, significant changes in the diets of cattle and a reduction in the amount of food waste used will be required.

Based on a review of relevant sources, it can be noted that, despite a significant contribution to interdisciplinary research at the intersection of economic and agricultural sciences, most of them are of an applied nature, without clarifying the research methodology. There is insufficient scientific substantiation of methodological approaches to the use of modeling methods and cluster technologies in determining the optimal production structure of agricultural formations, which is supposed to be filled in this work. The hypothesis of the research is reflected by the scientific position of the authors of the manuscript, according to which the use of scenario modelling methods makes it possible to determine the most effective options for conducting agricultural business for each business entity.

## 3. MATERIAL AND METHODS

The object of the research is the rural territories of the Non-Black Soil zone of the Republic of Bashkortostan (Bashkortostan) that is typical agro-industrial region of the Russian Federation. The modeling of agricultural formations as key production and economic systems located within rural areas is of key importance for the strategic vision and future of the region. From a scientific point of view, the considered zonal system of rural territorial formations represents a certain model territory for achieving its sustainable development and effective growth, a set of theoretical, methodological and practical problems associated with this process, the results achieved and a palette of new opportunities [23, 24].

To achieve the goal and solve the tasks set, special complementary research methods were used:

– when identifying typical agricultural organizations, methods of multidimensional statistical analysis and econometric modelling were used;

– determination of the optimal variant of development of agricultural organizations of rural territories was based on methods of economic and mathematical modelling;

– the calculation of the level of self-sufficiency of the population of rural areas with basic foodstuffs was based on scenario forecasting, balance and regulatory research methods;

– when designing the production volumes of agri-food products by farms of all categories for the period up to 2030, scenario forecasting and foresight methods were used.

In our opinion, the approach that determines the optimization of the production structure is the approach that involves the use of the conceptual scheme "agrarian formations are a rural territory", which most fully reflects the specific relationships and conditions for modeling agricultural production at the zonal level. When considering this approach, first of all, one should start to develop mathematical models to optimize (intra) the structure of agricultural production, i.e., lower hierarchical levels of management.

Based on the integrated application of modeling methods and cluster technologies, we have developed a step-by-step algorithm for optimizing the production and industry structure in the "agricultural formations are a rural territory" system (Figure 2).

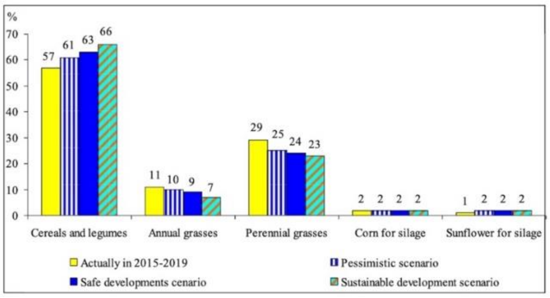


**Figure 2.** Structure of sown areas of agricultural crops in agricultural formations

The economic and mathematical model compiled for each agricultural formation of rural territories was a general linear programming problem. The main objective of the solved economic and mathematical model was based on the formulation of the chosen optimization criterion (optimality), namely, achieving the maximum amount of profit received by farms from the sale of agricultural products. The optimal solution of the economic and mathematical problem is accompanied by the establishment of dual estimates, as objectively determined estimates, to verify in the models the fullest use of production resources and the adequacy of the results obtained.

The formed systems of restrictions ensure the full use of the volumes of each considered production resource and the balance linking of the number of resources with their availability in agricultural formations. At the same time, the constraints and conditions introduced in the model include both "bottom" and "top" constraints. When modelling agrotechnical conditions for growing crops, taking into account scientifically based crop rotation systems, it is envisaged to impose restrictions on the acreage of individual crops, depending on the nature and specifics of agrotechnical requirements. When imposing zootechnical restrictions (restrictions on the size of livestock industries), the actual structure of the herd in each specific agricultural formation and the real possibilities of increasing the number of farm animals for a short-term period of development are taken into account.

When compiling economic and mathematical models, the following methodological provisions were considered:

– the predicted parameters used in model developments are projected at the end of the production cycle or year;

– the production volumes of agri-food products are calculated with the most complete use of the production capabilities of agricultural organizations;

– the formation of an optimal feed base during the model tests of balanced and full-fledged feeding of farm animals on the maximum and minimum boundaries of two high-quality nutrients (digestible protein and feed units) and eighteen types of feed;

– a key aspect in the design of the structure of farmland and crops is their compliance with the actual established system of crop rotations and the scientifically based system of agriculture for agricultural organizations;

– the use of parameters that reflect the actual volume of land resources of agricultural formations determines their determinability and quantitative immutability in the short term.

The use of this algorithmic scheme helps to determine the optimal production parameters of the branch structure of agricultural formations within rural areas based on the choice of scenario options. Taking into account the fact that agricultural production is characterized by alternative and multivariate development trajectories, a specialist of any agricultural organization can apply any projected model option. On the basis of the scenario approach, the following model variants were considered when solving the economic and mathematical problem of determining the optimal production and industry structure of agricultural formations:

The model version of sustainable development involves the use in model developments of partly actual and mainly forecast parameters of the development of agricultural formations. This option determines a significant increase in the level of economic efficiency of production, an increase in the level of animal productivity and crop yield in the studied agricultural organizations.

When designing a model version of safe (inertial) development, the parameters that determine the actual state of the studied agricultural formations are mainly used. The considered model variant of inertial development is based on the possibilities of preserving the conditions of functioning of agricultural organizations without significant changes.

The pessimistic (conservative) model variant is mainly focused on an unfavorable combination of internal and external conditions for the development of agricultural organizations and it is based on a high probability of implementing a conservative forecast.

## 4. RESULTS

The main goal of the economic and mathematical problem was to determine the optimal production structure of agricultural formations in the Non-Black Soil Zone of the Republic of Bashkortostan, the use of which allows agricultural producers to get the maximum profit. Achieving this goal, the scientifically-based projected resources that are expected to be available in the studied agricultural organizations in the future are taken into account. When conducting model calculations for typical agricultural organizations, the optimal sizes of the crop and livestock industries considered as variables in the model matrices are determined.

The requirements and conditions for the long-term sustainable development of crop production industries formulated in the economic and mathematical models fully correspond to the projected structure of crops of individual crops of the studied agricultural formations. The simulated structure of the acreage of most of the agricultural organizations in the zone determines the full use of pasture, hayfields and arable land and differs from the actual parameters.

Determining the optimal size of individual crops according to the methods and types of cultivation is one of the central and key aspects that currently determines the effective development of agricultural production. According to the results of model calculations for agricultural organizations, the optimal size of the acreage of effective crops is designed according to three scenario options (Table 1).

**Table 1.** Use of arable land in agricultural organizations of the Non-Black Soil zone of the Republic of Bashkortostan, thousand hectares

| Types of agricultural lands and crops | In fact, in 2015-2019 | Model variants | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Total crops | 422.9 | 422.2 | 422.2 | 422.2 |
| Cereals and legumes | 241.2 | 258.1 | 264.3 | 277.7 |
| – including winter cereals | 60.0 | 57.4 | 54.3 | 51.2 |
| – spring cereals | 167.5 | 184.7 | 192.4 | 208.1 |
| – legumes | 13.7 | 16.0 | 17.6 | 18.4 |
| Sunflower for grain | 1.0 | 1.3 | 1.5 | 1.5 |
| Rapeseed | 3.7 | 4.0 | 4.2 | 4.3 |
| Outdoor vegetables | 0.1 | 0.1 | 0.1 | 0.,1 |
| Annual herbs | 44.5 | 39.9 | 35.9 | 30.2 |
| Perennial herbs | 119.4 | 106.2 | 103.6 | 97.0 |
| Corn for silage | 8.4 | 7.0 | 6.5 | 5.0 |
| Sunflower for silage | 4.6 | 5.6 | 6.1 | 6.4 |
| Vapours and deposits | 54.0 | 54.7 | 54.7 | 54.7 |
| Arable land | 476.9 | 476.9 | 476.9 | 476.9 |

Note: Model variants: 1 – pessimistic, 2 – safe development, 3 – sustainable development

The feasibility of optimal use of grain crops in the agricultural formations of the zone is directly determined by the model variations of their actual sizes. The largest amount of full-fledged feed obtained from each hectare of farmland is provided on the basis of establishing the optimal structure of the sown areas of crops in the studied agricultural organizations. Optimization of feed production in agricultural formations is primarily due to an objective increase in the level of economic efficiency of animal husbandry. According to the obtained model solutions, the increase in the acreage of the most economically profitable cash crops, the optimization of the structure of animal feed rations and the introduction of a rational structure of feed production determine the reduction in the acreage of feed crops in the studied agricultural organizations.

Optimization of feed production is directly determined by the need to increase the level of economic efficiency of animal husbandry of the considered agricultural formations. In turn, an increase in the number of livestock in agricultural formations can be achieved by using optimal feed rations and balanced feeding of farm animals (Table 2).

**Table 2.** The number of animals in agricultural organizations of the Non-Black Soil zone of the Republic of Bashkortostan, thousand heads

| Indicators | In fact, in 2015-2019 | Model variants | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| The number of cattle, total | 96.8 | 102.2 | 107.9 | 113.0 |
| – including cows | 36.6 | 39.3 | 41.7 | 43.2 |
| – young cattle on fattening | 60.2 | 62.9 | 66.2 | 69.8 |
| Number of pigs | 38.8 | 41.1 | 43.4 | 45.4 |
| Number of sheep | 1.4 | 1.5 | 1.5 | 1.7 |
| Number of horses | 7.7 | 8.3 | 8.6 | 9.0 |
| Accounts for 100 hectares of agricultural land, head.: – cattle, total | 15.5 | 16.3 | 17.2 | 18.0 |
| – including cows | 5.8 | 6.3 | 6.7 | 6.9 |
| There are pigs per 100 hectares of arable land, head | 8.1 | 8.6 | 9.1 | 9.5 |

Note: Model variants: 1 – pessimistic, 2 – safe development, 3 – sustainable development

It should be noted that the optimal combination of primary and secondary industries in the agricultural enterprises is subject to variable changes in the proportions of the structure of commodity products and deepening of on-farm specialization. The strengthening of production specialization and the redistribution of production costs from less efficient branches of agricultural production determine a significant increase in the level of economic efficiency of agricultural organizations. According to the obtained model solutions, a significant increase is necessary to note in the production of commercial grain, meat and milk when compared with the actual level of production of this product (Table 3).

**Table 3.** Sales volumes in agricultural organizations of the Non-Black Soil zone of the Republic of Bashkortostan, thousand tons

| Types of products | In fact, in 2015-2019 | Model variants | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Grain, total | 116.3 | 129.1 | 134.0 | 138.4 |
| Sunflower | 0.7 | 0.9 | 1,1 | 1.1 |
| Rapeseed | 1.1 | 1.2 | 1.4 | 1.5 |
| Potato | 1.9 | 2.4 | 2.8 | 3.1 |
| Meat | 19.3 | 20.9 | 22.4 | 23.4 |
| Milk | 112.3 | 119.6 | 128.6 | 135.2 |

Note: Model variants: 1 – pessimistic, 2 – safe development, 3 – sustainable development

The model calculations reflect a significant increase in production and economic indicators that characterize (per unit of land area) the output of marketable agricultural products in the studied agricultural formations at the zonal level of the region. The increase (per 100 ha of arable land) output of commodity grain will be 11 to 19%, depending on the choice of the model variant, the predicted yield of the sunflower will grow up to 1.3–1.5 times.

The projected meat yield indicators (per 100 hectares of farmland) will exceed similar actual indicators by 6-19%, and the projected milk yield indicators will increase by 7-21%, respectively. Modeling of the branch structure of agricultural organizations and its subsequent transformational change in optimal proportions determines a significant improvement in the economic efficiency of production in all the considered scenarios (Table 4).

**Table 4.** Economic efficiency of production in agricultural formations

| Indicators | In fact, in 2015–2019 | Model options* | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Revenue from the sale of agricultural products, billion rubles | 5.9 | 6.6 | 6.9 | 7.1 |
| Profit from the sale of agricultural products (including compensation and subsidies): – per 1 ha of arable land, rubles | 870 | 983 | 1021 | 1061 |
| – per 1 ha of farmland, rubles | 663 | 749 | 777 | 808 |
| – total, million rubles | 415 | 469 | 487 | 506 |
| Output per 100 ha of arable land, c: – commercial grain | 244 | 271 | 281 | 290 |
| – sunflower seeds | 1.5 | 1.9 | 2.3 | 2.3 |
| Output per 100 ha of farmland, c: – milk | 179 | 191 | 205 | 216 |
| – meat | 31 | 33 | 36 | 37 |

* Model options: 1-pessimistic, 2 – safe development, 3-sustainable development

It should be noted that a key condition for model calculations should be the achievement of full provision of residents with the main types of agricultural products produced within the studied rural areas. In our opinion, the solution to the problem of providing rural residents with food can be based on scenario forecasting of possible production and consumption of basic types of food.

In this respect, an increase in the volume of agricultural food produced can be achieved by optimizing the production and industry structure of farms. Scenario forecasting of the development of the studied population of rural territorial entities determines the full consideration of such key parameters of the agri-food sector as:

– the total per capita income and the normative needs of the population for basic types of food, taking into account the subsistence minimum established in Russia, as well as scientifically based consumption diets recommended by the World Health Organization and the Ministry of Health of Russia;

– actual and projected volumes of agricultural food produced by farms;

– regulatory indicators that were established to reflect the consumption of agricultural raw materials for the production of certain types of food;

– the actual and projected number of rural residents.

Designing scenarios for the development of the agri-food sector of the studied population of rural areas takes into account the following aspects:

Import (provision) of certain types of agricultural raw materials and agri-food products and the largest filling of the food market with food products, the volume of production which is insufficient to meet the demand of the population of specific rural areas.

Scenario forecasting of the development of the agri-food sector is carried out taking into account the actual and projected needs of the population in food products produced within rural areas, available and planned labor, material and production resources.

The parameters of achieving scientifically-based norms of consumption of urban and rural residents of food products produced by agricultural organizations are presented by target indicators that reflect the level of food security. In 2019, at the zonal level, the actual consumption of milk by rural residents was 83%, and vegetables – 54% of the norms recommended by the World Health Organization. The comparison of the actual volume of food nutritional standards of the Ministry of Health of Russia shows the lack of consumption of milk and dairy products (92% of the recommended standards of the Ministry of Health of Russia) and vegetables (54%) (Table 5).

In our opinion, determining the optimal production and industry structure and increasing the level of economic stability of agricultural formations should be based on the use of a scenario approach. In turn, the use of foresight reflects the expert opinions of stakeholders, a separate part of rural residents (considered as consumers of food products produced by agricultural formations), specialists, representatives of the scientific community, agribusiness, which are a kind of alternative to the expertise of the rural community [23, 25].

**Table 5.** Consumption of agri-food products by the population in accordance with scientifically-based nutrition standards, thousand tons

| Indicators | Food products | | | | | | |
|---|---|---|---|---|---|---|---|
| | Bread | Potatoes | Vegetables | Meat | Milk | Eggs, million | Oil |
| Actual consumption in 2019 | 61.3 | 46.1 | 38.5 | 39.5 | 151.9 | 150.4 | 7.7 |
| Subsistence rate standards | 64.1 | 50.9 | 58.1 | 29.6 | 146.9 | 106.4 | 5.5 |
| Standards of the Ministry of health of Russia | 48.6 | 45.5 | 70.9 | 36.9 | 164.7 | 131.6 | 6.0 |
| Norms recommended by the World Health Organization | 61.0 | 49.0 | 71.1 | 35.5 | 182.3 | 123.1 | 6.7 |

The level of residents' provision with food from the studied rural areas was determined with regard to optimization results to achieve the maximum level of production efficiency. For this, the scenario approach and foresight technologies were used. Based on the use of econometric modeling and foresight, we have designed the volume of production of agri-food products by farms of all categories of ownership of rural territories on a zonal scale within the framework of a long-term sustainable development scenario (Table 6).

**Table 6.** Scenario forecasting of production volumes of agricultural products by farms of all categories for the period up to 2030

| Years | Grain | Potato | Vegetables | Sunflower for grain | Meat (live weight) | Milk | Eggs |
|---|---|---|---|---|---|---|---|
| Scenario of pessimistic development | | | | | | | |
| 2000 | 528 | 200 | 32 | 1.4 | 108 | 510 | 125 |
| 2005 | 603 | 341 | 61 | 0.9 | 114 | 634 | 122 |
| 2010 | 231 | 116 | 43 | 1.7 | 144 | 615 | 112 |
| 2015 | 547 | 243 | 51 | 3.6 | 114 | 512 | 78 |
| 2016 | 620 | 216 | 45 | 2.8 | 99 | 480 | 96 |
| 2017 | 617 | 195 | 48 | 2.1 | 110 | 480 | 80 |
| 2018 | 588 | 258 | 52 | 2.3 | 106 | 482 | 66 |
| 2019 | 572 | 258 | 48 | 1.8 | 99 | 476 | 65 |
| Scenario of pessimistic development | | | | | | | |
| 2025 | 536 | 221 | 42 | 1.7 | 99 | 473 | 60200 |
| 2030 | 504 | 204 | 34 | 1.4 | 94 | 468 | 54400 |
| Scenario of safe development | | | | | | | |
| 2025 | 611 | 266 | 55 | 2.6 | 111 | 490 | 72300 |
| 2030 | 625 | 273 | 58 | 2.8 | 115 | 495 | 78200 |
| Scenario of sustainable development | | | | | | | |
| 2025 | 632 | 273 | 59 | 3.2 | 122 | 513 | 82400 |
| 2030 | 659 | 286 | 65 | 3.7 | 136 | 546 | 91100 |

In interpreting the above indicators, the following should be noted:

- according to the results of the optimization, the amount of profit from the sale of agricultural products (taking into account subsidies and compensations) in the whole area under consideration will increase from 415 million rubles to 469-506 million rubles or by 13-22 %, depending on the choice of the model variant;
- according to scenario calculations, by 2025, the population will be fully provided with food products such as milk, meat, potatoes and bread on a zonal scale. In the long term, when implementing the forecast parameters of the sustainable development scenario, it should be noted that the level of rational provision (subsistence minimum) of the population has been achieved in terms of the production of the main types of agricultural food, with the exception of vegetable oil.

Herewith, it should be noted that when implementing scenario forecasting, the provision was taken into account, according to which the production and economic activities of agricultural formations, with certain available resources used, are inherent in various forecast (alternative) development options. Therefore, as an alternative to build a basic scenario of sustainable development, additional scenarios of pessimistic and safe development are designed.

## 5. DISCUSSION

The content analysis of the model and forecast developments developed by the researchers [26-29] allowed us to distinguish two fundamental methodological approaches to the construction of economic and mathematical models. The first direction includes such key stages of model development as the definition of the target function, systems (subsystems) of constraints and variables; the formation of an information base; conducting repeated model calculations to verify the correctness of the results obtained. The specificity of this conceptual modeling scheme is the fact that the compilers of models are independently engaged in the implementation of model solutions and act independently and autonomously from the management and direct performers of the research objects under consideration. The use of the second approach determines that the manager (manager) of the object under study should be both the performer and the "modeler" (compiler) of the model experiment being implemented, if there is his full interest in the final results of the modeling process being carried out.

The approach proposed in the article corresponds to the modern principles of modeling, systematization and planning and determines the possibility of taking into account the multivariance and alternativeness of the projected scenarios for the development of rural territorial entities [30, 31]. The novelty of the proposed algorithm is that it allows reducing the arrays of real-life economic data for further calculations and the number of agricultural organizations selected as objects of subsequent optimization. Combining agricultural organizations into cluster groupings based on the methods of multidimensional statistical analysis, taking into account various economic and production parameters (characteristics), allows us to distinguish typical agricultural organizations within the studied population of rural territories. During the subsequent calculations, the conclusions and results obtained in the modeling of typical agricultural organizations are projected on the remaining farms within rural areas.

The proposed approach in the framework of the development of the author's algorithm for optimizing the production and industry structure, firstly, determines the compilation and implementation of model structures in the interconnected system "agricultural formations are a rural territory". Secondly, the application of this approach allows us to clarify the methodology for the formation of placement of agricultural production scheme in the model of the rural areas economy. It is important to emphasize that the formation and implementation of integer, multi-criteria, multi-period, linear-dynamic and linear model developments requires the comprehensive consideration of the features and nature of the agricultural organizations' development at the rural level. However, it should be noted that a number of model developments formed for the level of the subjects of the Russian Federation are not effective in practice, and they do not allow us to project the likely consequences of the implementation of management decisions in the agricultural sector of the economy.

The economic and formal analysis of the obtained model results, of course, takes into account the potential possibilities of multi-vector functioning of the economy of rural territorial entities. In our opinion, the solution of optimization models adapted to modern economic conditions, considering scenario development options, determining the implementation of model solutions based on "smart specialization" ("smart specialization") and the optimal combination of agricultural production sectors of economic entities, indicates their unused strategic potential in improving the financial and economic condition of agricultural formations.

## 6. CONCLUSIONS

Economic and mathematical models in scientific terms are an effective applied tool for strategic planning and forecasting of management decisions to determine the optimal production and industry structure of agricultural formations. Herewith, modeling the development of production in the agricultural sector determines the use of not only more methodologically practical models, but also the improvement of the methodology for forecasting the development of agricultural sectors both at the regional level and at the level of agricultural enterprises and rural areas. Conceptually, the implementation of the methodological approaches and model developments proposed in the article has a high degree of adequacy and practical acceptability of implementation in the interconnected optimized system "agricultural formations are a rural territory".

As can be noted, the algorithm for optimizing the production and sectoral structure proposed in this paper makes it possible to determine the most effective options for conducting agricultural activities for each business entity. In this case, there is considered a scenario in which there are reduced the arrays of real economic data for further calculations as well as the number of agricultural organizations, chosen as objects of subsequent optimization.

Based on the examples given in the work there was given a scientific justification the use of modelling methods and cluster technologies in determining the optimal production structure of agricultural formations at the level of rural areas. Within the framework of achieving the goal, the following tasks were solved: the experience of scientific research on economic and mathematical modelling of strategic parameters of the development of agricultural formations was summarized and a review of literary sources on the subject area of the research was carried out; an algorithm for optimizing the production and industry structure in the system of "agricultural formations – rural territory" has been developed and implemented.

The formed scenario variants demonstrate higher values of target indicators and strategic parameters of the development of agricultural production at the zonal level when compared with the actual state and reflect positive trends in the development of the agricultural organizations under consideration. The implementation of the presented algorithm for optimizing the production and industry structure with the complex use of methods of correlation-regression and multidimensional statistical analysis, optimization and identification of typical agricultural organizations makes it possible to determine the potential reserves of sustainable development of the agricultural sector of rural areas in various scenarios for the future.

The main limitations of the research were: available resources, the number of simulated agricultural formations in the considered zonal environment, the coverage area and the time frame of the research. Further scientific developments in the field of modeling the development of production in the agro-industry should be devoted to such issues as improving the methods for forming the layout of agricultural production in the model of the rural economy, increasing the profitability of agricultural production, taking into account long-term planning horizons.

The applied value of this manuscript and, in particular, the presented scientific development lies, firstly, in clarifying and supplementing methodological approaches to the use of modelling methods in determining the optimal production structure of agricultural formations at the level of rural territories. Secondly, according to the results of the research, the author's hypothesis is confirmed, according to which the use of scenario modelling methods makes it possible to determine the most effective options for conducting agricultural business for each business entity.

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**NOMENCLATURE**

| | |
|---|---|
| AI | artificial intelligence |
| CLLD | Community-Led Local Development |
| SDGs | Sustainable development goals |
| AMPI | adjusted Mazziotta-Pareto Index |
| PCA | principal component analysis |
| LULC | Land Use Land Cover |