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Parameters of the strategy for managing the economic growth of agricultural production in Russia

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Abstract: Agricultural economic growth requires management due to poor structurization. The study aimed to determine the parameters of the management strategy for the economic growth of agriculture in Russia. The research methodology relies on cognitive technologies of modelling the strategic alternatives of the economic development of the industrial complex using fuzzy cognitive logic. Static and dynamic analysis of the fuzzy cognitive maps on structural and dynamic indicators of agricultural economic growth in Russia allowed the forecast of the industry trends, influenced by various management factors. The option of an integrated management strategy for the economic growth of agriculture in Russia is proposed together with strategic maps, justified as a tool for its implementation. The created strategic alternative will allow the Russian agricultural and industrial complex to use the existing agricultural potential to achieve the target growth indicators and ensure sustainability.

Keywords: cognitive modelling; economic growth; fuzzy cognitive maps; strategic alternatives; strategic maps

Russian agriculture has been demonstrating positive growth results over the past few years. The positive dynamic is fundamentally programmed by the growth of allocated budget funds, which, unlike the financing of other sectors of the economy, rose in 2018 to 3.7 billion USD. However, the economic growth of agriculture in Russia cannot be called unambiguous and flawless. In 2018, there was a failure to provide economic growth of agriculture; the decline in agricultural production amounted to 0.6%. The modern trajectory of economic dynamics of the agricultural sector is characterized by uneven development of the agricultural complex (30% of agriculture is backward), high dependence of a number of agricultural sectors on foreign technologies and innovations (in some cases approaching 100%), depopulation of most rural areas with pronounced negative social trends (in some subjects of the Russian Federation, the share of depopulated villages exceeded 20%). The modern practice of managing the economic growth of agriculture in Russia has several serious problems that limit the country's ability to form and use its agricultural potential. This is proved by macroeconomic ratios that contradict national interests and cause economic vulnerability of Russia, which, having 9% of the world's productive arable land, 20% of the world's freshwater reserves, producing 8.5% of the world's mineral fertilizers, ranks only seventh in the world in terms of value-added produced in agriculture, while importing food worth nearly 28.8 billion USD. Complicated and turbulent nature of changes in agricultural production, a vast number of growth factors, necessity to take into account the links between the parameters of economic development present several essential requirements to the methodology of economic growth management as a tool base for decision-making in achieving sustainability and high dynamism of agricultural progress:

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(i) should take into account the specifics of agricultural production as a weakly structured system, the stability of the dynamics of which is achieved over a sufficiently long period;
(ii) allow an efficient combination of traditional approaches based on formalized research methods with subjective models developed with expert assessments, "common sense" logic, intuition, and heuristics;
(iii) rely on the basics of system analysis of the information concerning the dynamics in agrarian production and available management strategies;
(iv) ensure the impact of various growth strategies is assessed beforehand, avoid unacceptable alternatives, and suggest the most effective options.

The methodology of cognitive modelling meets most of the requirements. Axelrod (1976) and Roberts (1978) proposed a cognitive approach to the study of poorly structured systems. Axelrod participated in the development of methodology, whereas Roberts in his research, mostly focused on mathematical apparatus development.

Later, the cognitive approach actively developed in the direction of finding mechanisms combining different concepts of research of decision-making in the management of weakly structured systems (Kosko 1986; Huff 1990); identifying problems that are particularly effective using cognitive technology (Özesmi and Özesmi 2004); development of the instrumental base for constructing fuzzy cognitive maps (Stach et al. 2010).

Fuzzy cognitive maps (FCM) can be useful in various areas, including ecosystem prediction (Solana-Gutiérrez et al. 2017), environmental problems (Gray et al. 2015), sustainable development (Dodouras and James 2007), software development (Stach et al. 2004), risk management (Mezei and Starling 2016), methodology of studying the future (Jetter and Kok 2014). Using a cognitive approach is also characteristic for solving problems in several areas of the agricultural sector, such as crop management in agriculture (Papageorgiou et al. 2009), environmental regulation of agricultural production (Christen et al. 2015), creating a sustainable social and ecological systems in agriculture (Kokkinos et al. 2018). However, there is virtually no scientific advancement in using the cognitive approach to the management of economic dynamics processes in agriculture. Hence, the author conducted a computational experiment to substantiate the content of the management strategy for the economic growth of agriculture in Russia.

The author developed the algorithm of cognitive analysis using approaches to studying a complicated situation presented in the works by Kosko (1986), Khan and Quaddus (2004), Aguilar (2005), Olazabal et al. (2018). The content of analysis relies on the concept of managing the agricultural economic growth proposed by Anokhina (2017).

The study includes the Silov's fuzzy cognitive maps (Silov 2005). FCM is a weighted oriented graph, where the nodes are the concepts describing in terms the author's concept of managing economic growth of agriculture; the edges show relations and the degree of influence reflecting the causal relationship between these concepts. This choice is conditioned by the attempt to provide higher accuracy of modelling, use combination of the quantitative and qualitative characteristics of the situation in the agricultural sector, to carry out collective, rather than individual estimation of model parameters, to generate and dynamically model strategic alternatives for provision of a given sustainable economic dynamics of the industrial complex. Figure S1 presents a schematic illustration of the methodology of cognitive modelling of the management process of economic growth in agriculture [Figure S1 in electronic supplementary material (ESM); for the supplementary material see the electronic version].

MATERIAL AND METHODS

Mathematical apparatus of cognitive modelling strategy. The static analysis of the fuzzy cognitive map (Kosko 1986; Kulinich 2014) was performed using the operation of the transitive closure of the corresponding cognitive matrix and calculation of the main system indicators according to the method, presented in Table S1 [Table S1 in electronic supplementary material (ESM); for the supplementary material see the electronic version].

The FCM behaviour was analyzed by employing the mathematical apparatus of impulse process (Aguilar 2005; Kulinich 2014; Lopez and Salmeron 2014). This apparatus allows predicting the value of concepts in discrete moments. The following model of impulse process was used in the study:

$$v_i(t+1) = S\left(v_i(t) + q_i(t+1) + o_i(t+1) + \sum_{j=1}^{K} T\left(w_{ij}, p_j(t)\right)\right) \quad (1)$$

where: $v_i(t + 1)$ – value of the i^{th} concept at time $(t + 1)$; $v_i(t)$ – value of the i^{th} concept at time t; $q_i(t + 1)$ – external impact on the i^{th} concept at time $(t + 1)$; $o_i(t + 1)$ – control action on the i^{th} concept at time $(t + 1)$; $w_{ij} = w(e_j, e_i)$

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– the power of connection between the j^{th} and the i^{th} concept; $p_j(t)$ – change of the value of the j^{th} concept at time t; T – T-norm operation (operation of multiplication); S – S-norm operation (Lukasevich's S-norm).

Through this algorithm, the impulse process simulates the management system's impact on the properties of the system and allows analyzing its behaviour.

The dynamic analysis of the cognitive map suggests the development of various alternatives, allowing to bring the state of the system to a target value (level). By alternative, we mean the vector of the possible impact on controllable concepts. Only these concepts are considered as open for direct management influence. Other concepts do not fall under direct management and can change (strive for the goal) only through an impact on controllable concepts. Each of the concepts, given as controllable, can take values within limits set for it. The vector of an impact can include a reduction and an increase in the concept, and its fixation at a certain level.

The purpose of cognitive modelling in the conducted study is to obtain strategic alternatives of control effects on the processes of economic dynamics of agriculture in Russia, allowing to provide a high level of parameters of economic growth in agricultural production.

RESULTS AND DISCUSSION

Building cognitive maps for economic growth management in agriculture. Following the adopted algorithm of cognitive modelling, FCM was developed and analyzed in the structural and dynamic block of parameters of economic growth in agriculture.

The results of the study of management processes of economic growth in agriculture revealed that the economic dynamics of the agricultural sector as a system is defined in the structural aspect through fifteen concepts that act as tools of management and are divided into three groups:

(i) fundamental indicators of economic growth in agriculture, reflecting the level of valid parameters of economic dynamics processes in the industrial complex – agricultural production index, the gross added value per employee in agriculture and profitability of agricultural organizations. These concepts were identified as the target;

(ii) factors of economic growth of agriculture, which are the root cause of changes in the volume and content of social product in the agricultural sector and that form the basis for social and economic development of the industrial complex as an economic system – the number of people employed in agricultural sector, competence of agriculture personnel, material and technical situation in agriculture, livestock and poultry, agricultural land resources. The concepts of this group were identified as uncontrollable;

(iii) determinants of economic growth of agriculture, which act as determinants of economic growth and provide reproduction of primary growth factors and their more efficient use – innovation in agriculture, investment in agriculture, infrastructure support for the agriculture, technological support for the agriculture, the disparity in intersectoral relations, stable development of agriculture. These concepts were identified as controlled parameters.

The concept of climate conditions of agricultural production as an external uncontrollable parameter was introduced, considering the industrial characteristics of agriculture.

According to the results of this stage, a cognitive matrix containing estimates of intensity of influences and a fuzzy cognitive map of the structural block of management of economic growth in agriculture was produced [Figure S2; in electronic supplementary material (ESM); for the supplementary material see the electronic version].

Then, the FCM was built for the dynamic block of parameters of economic growth in agriculture, which defines the target priorities and includes seventeen concepts, divided into four groups:

(i) fundamental indicators of economic growth in agriculture to ensure the logic of research following the author's concept were the same as in the structural block of parameters;

(ii) parameters of quantitative dynamics of agriculture – milk production, meat production, a gross harvest of crucial crops, production of gross agricultural output at comparable prices. The concepts of this group were identified as uncontrollable;

(iii) parameters of qualitative dynamics of agriculture, such as the yield of principal crops, the productivity of livestock and poultry, labour productivity index in agriculture, the competitiveness of domestic agricultural production. These concepts were also classified as uncontrollable parameters;

(iv) parameters of generating agricultural dynamics – the differentiation of rural and urban populations, the quality of living of rural populations, greening of agricultural production and products, concentration of value-added in knowledge-intensive segments of agriculture, depth of processing

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of agricultural products. These concepts were identified as controllable.

In addition to four groups of factors, just like in the structural block of parameters, the concept of climatic conditions of agricultural production as an uncontrollable external concept was introduced.

According to the results of this stage, a cognitive matrix, containing estimates of intensity of influences and a fuzzy cognitive map of the dynamic block of management of economic growth of rural areas was created [Figure S3; in electronic supplementary material (ESM); for the supplementary material see the electronic version].

Static and dynamic analysis of economic growth management in agriculture FCM. The system indicators of a fuzzy cognitive map of economic growth management in agriculture for structural and dynamic blocks of parameters are illustrated in Tables S2–S3 [Tables S2–S3 in electronic supplementary material (ESM); for the supplementary material see the electronic version]. Their values allow verification of the fuzzy cognitive model (FCMod).

Dynamic analysis of the developed cognitive maps for each block of parameters allowed to define strategic alternatives of economic growth management of agriculture in Russia. Using the software system of decision support "Intelligent Generator of the Best Alternatives" (SSDS "IGLA" 2019) we generated 728 strategic alternatives to managing the economic growth of agriculture for a structural block of parameters. As a result of the simulation, 44 alternatives were found to be undominated. Analyzing visually undominated alternatives in terms of the difference of final target concepts, the power of control effects, and the speed of change of concept values, we selected five alternatives that mostly met those requirements.

These alternatives were ranked in order to choose the most suitable strategy for managing agricultural economic growth and to conduct impulse modelling to find optimal impacts on managed concepts. The best was Alternative 330. However, given the scarcity of resources, weak scientific and technical base, the deficient innovative activity of economic subjects of agriculture in current conditions, an option of strategy based on Alternative 330 was suggested. The proposed strategy developed based on impulse modelling assumes a step-by-step change of controllable concepts "Innovation in Agriculture" and "Investment in Ag-

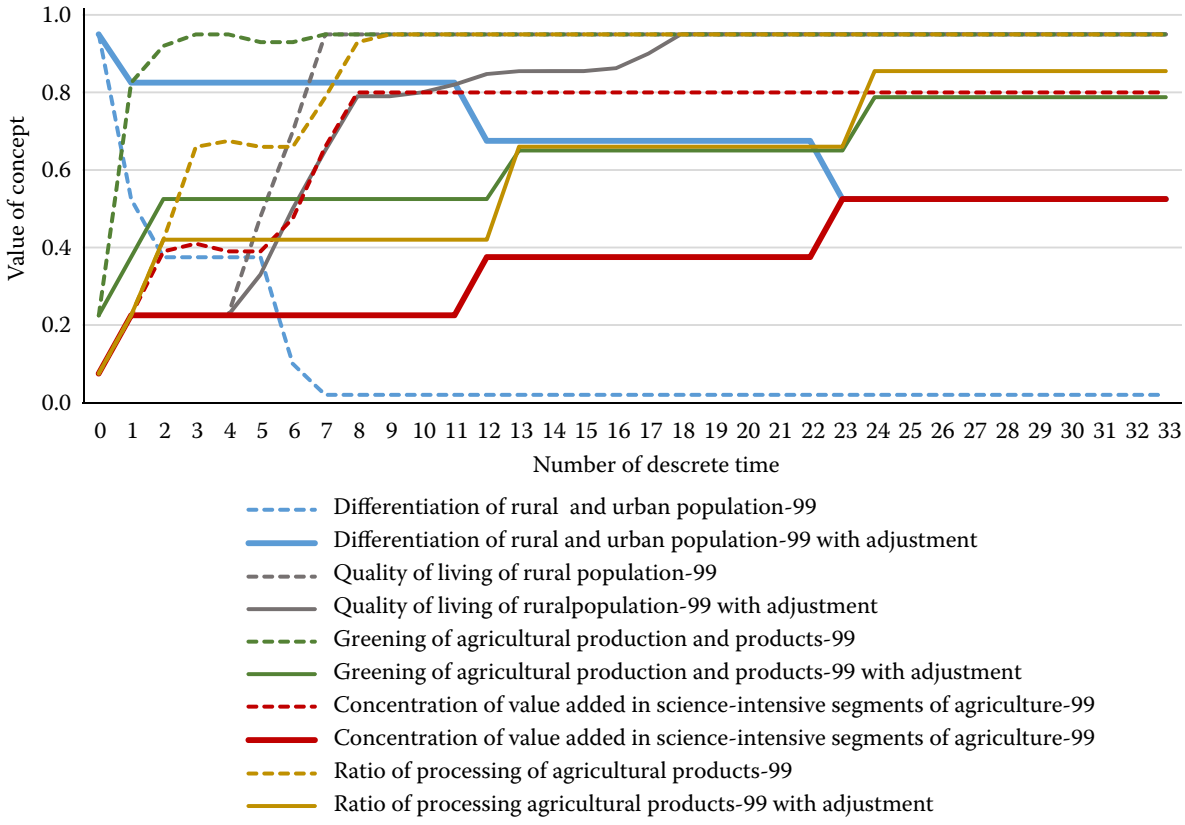

Figure 1. Strategy for managing economic growth of agriculture for the structural block for controllable concepts

Source: Own calculation using SSDS "IGLA" (2019)

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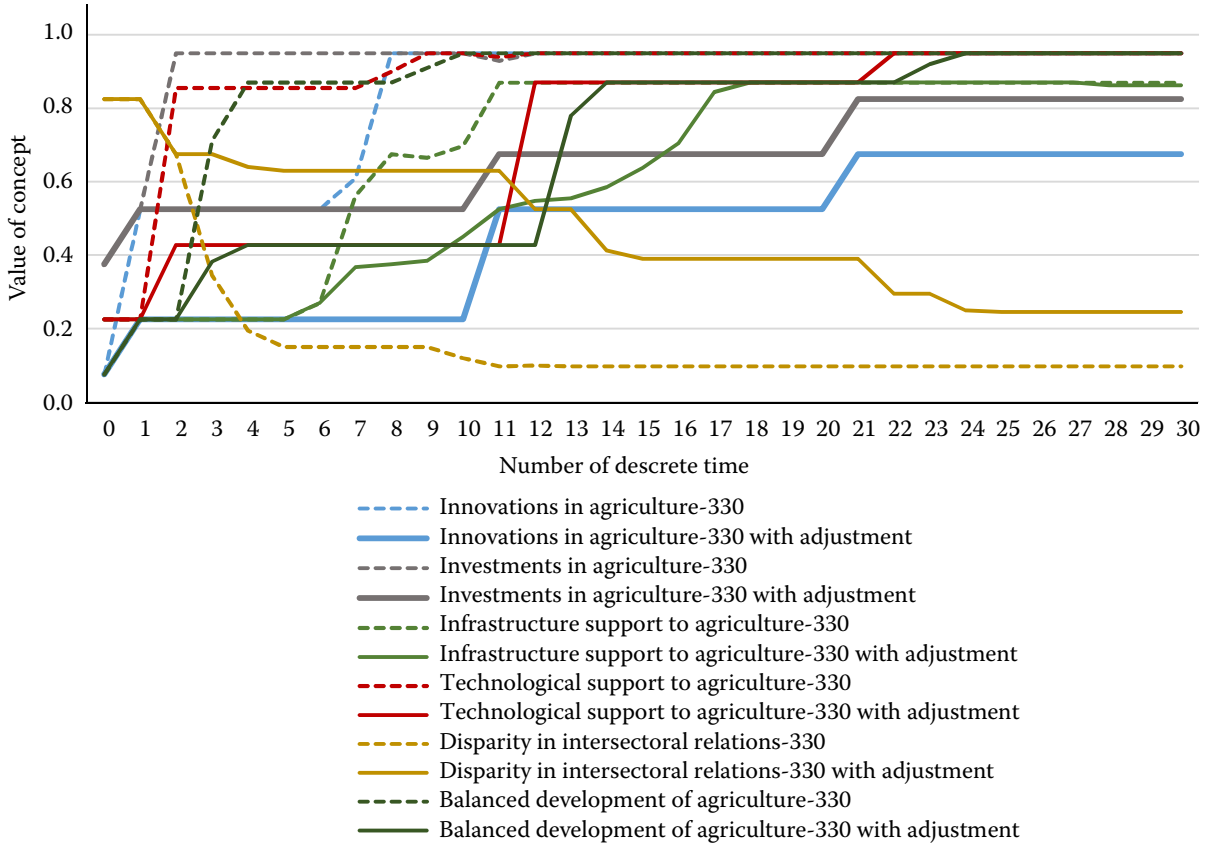

Figure 2. Strategy for managing economic growth of agriculture for the dynamic block for controllable concepts

Source: Own calculation using SSDS "IGLA" (2019)

riculture" taking into account the real opportunities for the development of the industrial complex.

The impulse of changes of these concepts taking into account the connections identified as a result of static modelling leads to the desired level of change of other controllable concepts. The content of the best strategies for managing the economic growth of agriculture for the structural block for controllable concepts is presented in Figure 1.

In the course of the dynamic analysis for the parameters of the dynamic block of agricultural economic growth management, it is necessary to determine changes in priorities in the implementation of the strategy of impact on economic dynamics processes in the industrial complex. When developing the alternatives to the management of economic growth of agriculture for the dynamic block of parameters according to the rules of FCMod dynamic analysis from the whole set of controllable concepts, the concept "Differentiation of Rural and Urban Population" was considered as impeding, therefore in all generated alternatives taking into account its content in modern conditions it is desirable to weaken this concept. Other controllable concepts are assigned to the group of supporting and, accordingly, in strategies for managing the economic growth of agriculture for the dynamic block, need strengthening. Using SSDS "IGLA" (2019), we generated 242 strategic alternatives to managing the economic growth of agriculture for the dynamic block of parameters, 16 of which were undominated. Visual analysis of these alternatives on the criteria of the level and sustainability of achievement of target concepts, the magnitude of the power of management actions made it possible to identify the Alternative 99 as the best one unambiguously. However, implementing this alternative in modern business practice due to relatively rapid and notable changes in controllable concepts is limited by the availability of resources. Therefore, we used impulse modelling to develop an option of strategy based on Alternative 99 taking into account the real possibilities, assuming a step-by-step change of individual controllable concepts, similarly to the structural block of parameters. With this purpose, we selected the concepts "Differentiation of Rural and Ur-

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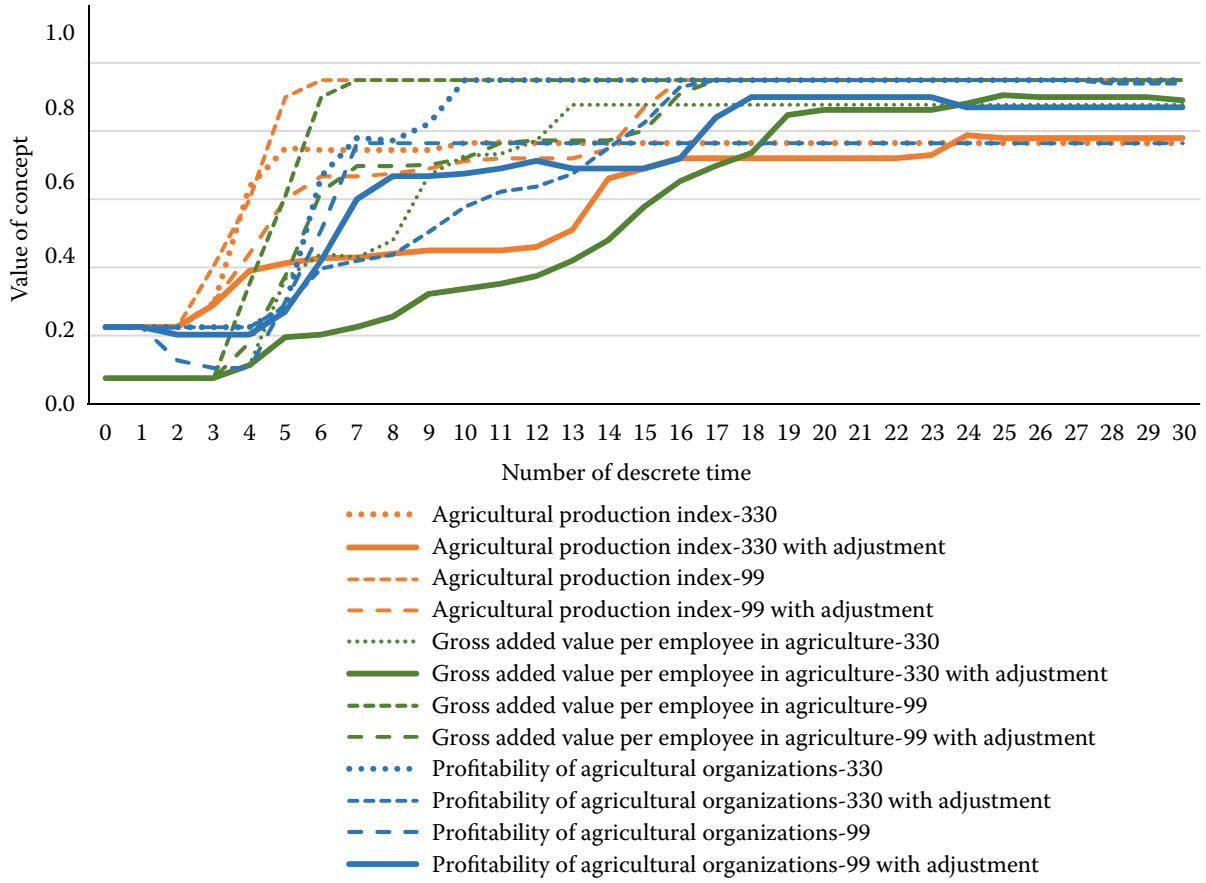

Figure 3. Dynamics of agricultural economic growth target concepts for structural and dy-namic block of parameters

Source: Own calculation using SSDS "IGLA" (2019)

ban Populations" and "Concentration of Value Added in Knowledge-Intensive Segments of Agriculture." This choice relied on the power of influence of these concepts on the FCM system, and the established relationships of mutual positive and negative influence between the concepts identified during the static analysis. The content of the best strategies for managing the economic growth of agriculture for the dynamic block for controllable concepts is presented in Figure 2.

A comprehensive strategy for managing the economic growth of agriculture is developed based on a significant combination of strategies for a structural and dynamic block of parameters. Cognitive modelling of strategies for the corresponding blocks assumes that target concepts are familiar to them. However, the obtained values of these concepts for each of the blocks are different (Figure 3). When developing the integrated strategy, the lower level of the general concepts was chosen as quantitative values. Supposedly, the better values of general concepts to some extent, guarantee the achievement of the target level and, under more favorable conditions, determine the possibility of creating additional growth capacity for the industrial complex.

Development of strategic maps as tools for implementation of agriculture economic growth management strategy. Following the basic management principles and the content obtained by FCMod, the process of managing the economic growth of agriculture should comprise several stages. The content of stages is expedient to be determined depending on the selected priorities in agrarian policy, the general target points in the national system of management and the availability of appropriate resource opportunities.

Taking into account the importance of ensuring economic growth of national agriculture in modern conditions and positive – in comparison with the previous period of management – actions to support the industrial complex by the government, the process of economic dynamics management should be divided into three strategic blocks and include three stages: building growth capacity; ensuring the sustainability of eco-

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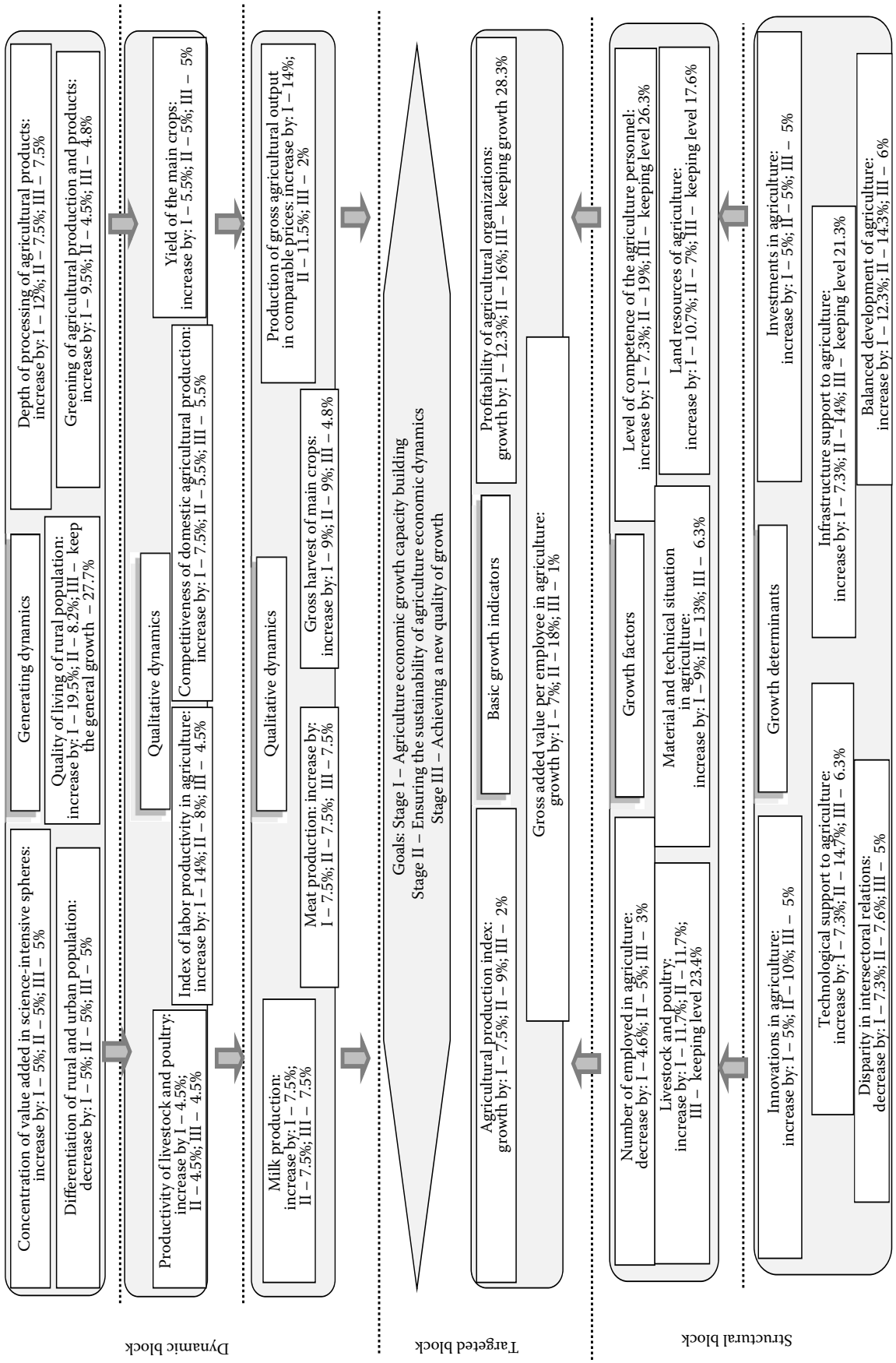

Figure 4. Combined strategic map for agriculture economic growth management at stages: I – agriculture economic growth capacity building, II – ensuring sustainability of agriculture economic dynamics, III – achieving a new quality of growth
Source: Developed by author

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nomic dynamics; bringing agricultural production to a new level of quality growth.

Strategic maps are proposed as a tool for agriculture economic growth management (combined map for three stages is presented Figure 4. A strategic map is a tool for managing economic growth in agriculture based on cause-effect relationships between projections of structural and dynamic blocks of parameters. The available opportunities and targets set the level of impulse change of selected controllable concepts for each block of parameters. The presented experiment has set the following values of concept changes [Table S4; in electronic supplementary material (ESM); for the supplementary material see the electronic version].

During the first stage, "Growth capacity building" as a result of the influence force of controlled concepts for the structural and dynamic block of parameters – identified in the process of cognitive modelling – "Agricultural Production Index" as the leading indicator of economic growth of agriculture will be increased by at least 7.5% (1 level), "Gross Added Value per Employee in Agriculture" – 7% (2 levels) and "Profitability of Agricultural Organizations" – 12.3% (2 levels). The main emphasis as a controlling impact on the processes of economic dynamics in agriculture for the structural block should be placed on the structural determinant and accordingly "Balanced development of agriculture" should be increased by 12.3% (2 levels).

During the second stage, "Ensuring the sustainability of economic dynamics of the industrial complex" concept "Agricultural production index" will rise by at least 9% (2 levels), but will not reach the target value. For the other two target concepts "Gross added value per employee in agriculture" and "Profitability of agricultural organizations" with significant dynamics (increase to 18% and 16%, respectively, by 3 levels), the target will be achieved. Notably, stage II requires significant efforts to ensure action of virtually all determinants. However, the main impact on the processes of economic dynamics in the industrial complex should be provided by the infrastructure, technological, and structural determinants.

At stage III, "Achieving a New Quality of Growth," all target concepts reach the target level. According to the results of cognitive modelling, the intensity of increasing the influence of determinants for the structural block of parameters can be reduced at this stage (in general, the recommended change is 1 level). However, the structural and technological determinants (respectively the concepts of "Balanced Development of Agriculture" and "Technological Support of Agriculture") in their influence should reach growth values of 6.0 and 6.3% respectively. The parameter "Innovations in Agriculture," as one of the concepts that significantly influence the system, assumes the least strengthening of all controllable concepts for the structural block (initially set – during impulse modelling – growth rate of 5%). Based on the results of the modelling at the stage of "Ensuring a New Quality of Growth," the negative impact of the natural and climate conditions of agricultural production will continue to decrease, and as a whole, the implementation of the strategy will achieve at least a 7.5% reduction in this concept.

CONCLUSION

The study presents suggestions on the parameters of the economic growth management system, taking into account the causal relationships between the parameters of different groups. The present paper includes modelling and analysis of possible situations in the agricultural sphere of Russia, using impulse modelling and scenario analysis, in line with the study and evaluation of various mechanisms of managerial impact on the development of agriculture in the country. The strategic alternatives were developed from the perspective of the system approach, and efficient strategy for agriculture economic growth management in Russia was selected to achieve the growth targets at a high level. Such a strategy as the primary management impacts should include increasing the level of infrastructure and technological support by 21% and 28%, respectively, and agricultural innovation by 20%. As the fundamental indicators of progressive changes in the dynamics of the agricultural sector, we should consider an increase in the concentration of value-added in the knowledge-intensive segments of agriculture by 15%, a decrease in the differentiation between rural and urban population by 15% and an increase in the quality of life in rural areas by 28%. The simulated ratio of the strategy parameters will increase the growth rate of agricultural production by 18.5%, increase the gross value added per person employed in agriculture by 26%, and ensure the growth of profitability of agricultural organizations by 28%.

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