

# Methodical Approach to Food Security Assessment and Forecasting

Elena N. Antamoshkina  
Volgograd State Agrarian University  
Economic faculty  
Volgograd, Russia  
[antamoshkina@mail.ru](mailto:antamoshkina@mail.ru)

Alexey F. Rogachev  
Volgograd State Agrarian University  
Electric Power and Energy Faculty  
Volgograd, Russia  
[rafr@mail.ru](mailto:rafr@mail.ru)

**Abstract** — The article presents a methodical approach to food security assessment based on the determination of a comprehensive indicator – efficiency index obtained by aggregation of economic ( $i_e$ ), financial ( $i_f$ ) and social indicators.

The authors set evaluation criteria for each indicator of agri-food policy effectiveness and thresholds for indicators in the field of food security. This article assesses the effectiveness of agricultural policy for food security based on statistical data on the regions of the Southern Federal District. The research revealed that in 2017 the efficiency index of agri-food policy was equal to 0.8 points, which corresponded to the acceptable level.

Practical significance of the presented approach to assessment of agricultural policy effectiveness for food security involves the possibility of using data obtained in the planning and development of economic policy, in order to improve its socio-economic and financial efficiency in the field of food security.

The paper substantiates the necessity of integrated accounting and optimization of the ratio of food products manufacturing and consumption in accordance with the specified structure and consumption rates. Problem solution requires the use of cognitive economic and mathematical modeling based on fuzzy production cognitive maps, as well as creation and improvement of methods of intellectual analysis to predict the level of food security.

**Keywords:** food security, fuzzy cognitive systems, forecasting, economic and mathematical methods, modeling of controlled development

## I. INTRODUCTION

As the strategy of scientific and technological development of the Russian Federation notes, ensuring food security and food independence of the country, achieving competitiveness of domestic products in the world food markets are among the big challenges facing the Russian economy and society, according to them regions of the country should determine priorities for their development [1]. "Doctrine of food security of the Russian Federation" is the normative basis for ensuring food security of the Russian Federation.

A.V. Ulezko [1] and T.M. Yarkova [2] highlight some aspects of food availability and food security in context of the theory and practice of sustainable development of the regions of Russia. A.I. Altukhov [3] and V.I. Nazarenko [4] analyse problems and directions of agrarian policy of the state.

Definition and evaluation of the system of food security factors are of current importance.

M. Gill, A. Herforth [5] D. Grace, G. Mahuku, V. Hoffmann [6], H. Weikard [7], R. Capone, H. Bilali, F. Debs [8] in their works present characteristics of the system organization of food security and control of food safety and quality in Europe, the United States, Canada, as well as analyze in detail measures of regulation and support for agri-food sector of the economy.

Large-scale interest in the problems of assessment and forecasting of the level of food security has led to a significant number of different approaches, methods and models. Despite their diversity, most of them are focused on the description of individual, certain aspects of food security. The lack of objectivity in the analysis results is due to the fact that most of them are insufficiently formalized, often based on expert assessments.

It is important to emphasize that there are almost no approaches for the construction of cognitive dynamic models of food security, based on fuzzy cognitive approach and their use for solving multi-criteria optimization problems, including large-scale ones. Methods of in-depth research and forecasting of the situation development are required, including a scenario approach to the formation of agricultural and food market saturation and availability; assessment of the level of threats to the stability of food security of regions in Russia; planning of measures to counteract and mitigate negative consequences, as well as optimization of strategic food stocks [9].

## II. MATERIALS AND METHODS (MODEL)

There are good reasons to use the following methods, approaches and specific methods of analysis in the methodology of food security assessment. To substantiate the groups of factors and the system of indicators of food security, an expert method of analysis of hierarchies should be used. The obtained system of indicators forms the structure, connections and membership functions of fuzzy cognitive maps. Infological and information models are constructed to parameterize cognitive maps; they provide justification for the relational database structure on analyzed statistical indicators.

Specific indicators for food groups enable construction and verification of a family of predictive econometric models. Methods of integration of the obtained econometric models into the cognitive map can be developed based on membership functions and fuzzy logic. In the future, there are plans to construct, test and debug a specialized software package that implements impulse modeling of analyzed systems based on incident matrices corresponding to cognitive maps. As a result, scenario analysis of the food security level will be carried out using fuzzy cognitive maps.

To support numerical research and scenario analysis using developed cognitive maps a software package is needed. Such package of programs should include a computer program, a knowledge base in order to construct functions of factor membership and a statistical database for the research, using an intelligent system to assess and predict the integral level of food security.

The analysis of available publications on modeling and evaluation of food security has revealed the need to improve

both theoretical and methodological framework and computer support for monitoring, assessment and forecasting of food security level in modern conditions.

There was developed a methodological approach to integrated assessment of the effectiveness of agri-food policy in the field of food security based on the determination of efficiency index ( $I_{eap}$  – Effectiveness Index of Agrarian and Food Policy), obtained by the aggregation of economic ( $i_e$ ), financial ( $i_f$ ) and social indicators ( $i_s$ ) [10]:

$$I_{eap} = \sum (i_e + i_s + i_f), \quad (1)$$

Table I presents values that determine indicators of the agricultural policy efficiency, as well relations between the values of calculated indicators and the values of corresponding indicators.

**TABLE I. INDICATORS AND CRITERIA OF AGRICULTURAL POLICY EFFICIENCY FOR FOOD SECURITY [11]**

Name of indicators, assessment values	Analyzed parameters	Established ratios of levels of efficiency indicators	
$i_e$ – indicator of economic efficiency, $i_e = f(K_{fc}) = \frac{q_{fact}}{q_{rate}} \quad (2)$	– is determined based on actual coefficient of food consumption in the region ( $C_{fc}$ ) and it shows the factual quantity of food consumption ( $q_{fact}$ ) in comparison with the rational consumption rate ( $q_{rate}$ )	$C_{fc} \leq 0.5$ – low;	$i_e = 0$
		$0.5 < C_{fc} \leq 0.95$ – permissible;	$i_e = 0.1$
		$0.95 < C_{fc}$ – optimal;	$i_e = 0.2$
$i_s$ – indicator of social efficiency, $i_s = f(C_p; C_c; C_G) \quad (3)$	- share of population with incomes below the subsistence minimum ( $C_p$ ); - share of expenditure on food in the structure of expenditures of households on final consumption ( $C_p$ ); - degree of inequality in the distribution of population by income level ( $C_G$ )	high: $C_p > 0.4$ ; $C_c > 0.5$ ; $C_G > 0.5$ ;	$i_s = 0$
		permissible: $0.2 < C_p \leq 0.4$ ; $0.25 < C_c \leq 0.5$ ; $0.3 \leq C_G < 0.5$ ;	$i_s = 0.1$
		optimal: $C_p \leq 0.2$ ; $C_p < 0.25$ ; $C_G < 0.3$	$i_s = 0.2$
$i_f$ - financial efficiency indicator, $i_f = f(C_s) = \frac{q}{n * q_p} \quad (4)$	- level of food self-sufficiency ( $C_s$ ), characterizes how completely the region meets the population needs in food products through local production where: $q$ – factual quantity of food production in the region; $n$ – number of population in the region; $q_p$ – sustainable rates of consumption.	$C_s \leq 0.5$ – low;	$i_f = 0$
		$0.5 < C_s \leq 0.9$ – permissible;	$i_f = 0.1$
		$0.9 < C_s$ – optimal	$i_f = 0.2$

Table II offers a list of values of efficiency index of agrarian policy (table II).

**TABLE II. VALUES OF EFFICIENCY INDEX OF AGRICULTURAL POLICY [10]**

Range of values ( $I_{eap}$ )	Achieved level of efficiency
$0 < I_{eap} \leq 0.2$	agricultural policy is not effective
$0.3 \leq I_{eap} \leq 0.5$	low level
$0.6 \leq I_{eap} \leq 0.8$	permissible level
$0.9 \leq I_{eap} \leq 1$	optimal level

We use the proposed approach to assess the effectiveness of agri-food policy in the field of food security in the Southern Federal District.

### III. RESULTS AND DISCUSSION

Regions of Russia actively developing agricultural production, potentially have advantages in providing the population living in these regions with food products in comparison with other regions of the country. The Southern Federal District traditionally belongs to the regions focusing on agriculture and occupies a leading position in the production of grain and crops, sunflower, and vegetables. Data on the branches of agriculture in the Southern Federal District show higher growth rates in the field of crop production, compared with the results achieved in the production of livestock products [12].

With the analysis of the volume of basic food consumption in subjects of the Southern Federal District in 2017, we can conclude about the structure of consumer diet for the population and its lack of balance. So, on average, in the Southern Federal District, the volume of consumption of

bread products (flour, cereals, rice, pasta and legumes belong to this category) exceeded the rational consumption rate by 23.9%.

In 2017, in the Southern Federal District the volume of consumption of meat and meat products on average exceeded specified rational consumption rate (73 kg/year) by 2 kg. At the same time, in 2017, the situation was heterogeneous with the consumption of meat (beef, lamb, pork, poultry) in the subjects of the Southern Federal District. In some regions, in particular in the Republic of Adygea, the Republic of Crimea, the city of Sevastopol, Rostov region, the volume of consumption was below established rational rates. [13, p. 248 – 252].

The situation with milk and dairy products consumption is still quite complicated. With the specified rational consumption rate of 325 kg per year, in 2017, in the Southern Federal District the volume of consumption on average amounted to 216 kg, which is only 66.5% of the recommended rational consumption rate. The volume of milk and dairy products consumption in the Southern Federal District was below the average consumption in Russia as a whole by 15 kg per year. In 2017, in the Southern Federal District the factual volume of consumption of eggs amounted to an average of 306 pieces, by this indicator the region exceeded the average consumption in Russia by 9.7%.

In 2017, the population of the Southern Federal District (the SFD) exceeded almost 2 times the established rational rate of sugar consumption of 24 kg per year, the average consumption was 42 kg, which exceeded the average for Russia – 39 kg (table III).

**TABLE III. FOOD CONSUMPTION IN THE SOUTHERN FEDERAL DISTRICT (per capita, kg per year)**

Subject of the Russian Federation, rates and level of consumption	Bread products	Meat products	Dairy produce	Eggs, pcs	Sugar	Vegetable oil
The Russian Federation	117	75	231	279	39	13.9
The SFD	119	75	216	306	42	14.6
Sustainable rates of consumption [14]	96	73	325	260	24	12
$C_{fc}$	1.23	1.02	0.66	1.18	1.75	1.21

Such a significant excess of sugar consumption in comparison with the specified sustainable rates of consumption also indicates an imbalance in food diet of the population of the Southern Federal District. In 2017, the volume of vegetable oil consumption by the population of the Southern Federal District amounted to 14.6 kg, which slightly exceeded specified sustainable level of consumption – 12 kg. With the help of the obtained values ( $C_{fp}$ ), the average value was determined and the indicator of economic efficiency of agricultural policy ( $i_e$ ) was calculated, with the value of 0.2.

Determination of the indicator ( $i_s$ ) showed that in 2017 the population with incomes below the subsistence minimum in the Southern Federal District amounted to 16.1% [13, p. 228]. The value ( $i_s$ ) depending on the analyzed parameter is 0.2.

In 2017, the share of food expenditures in the structure of household expenditures of the Southern Federal District amounted to 37.9%, the figure for Russia as a whole is lower – 34.3%. In some regions of the Southern Federal District there is a rather unfavorable situation in terms of consumer spending structure. In the Republic of Crimea and the city of Sevastopol, about half of household expenditure is spent on food. Thus, in 2017, in the Republic of Crimea the share of food expenditure decreased by 5.4% compared to the level of spending in 2016 and amounted to 46.2%, in the city of Sevastopol food expenditure amounted to 52.7% of the total consumer spending [13, c. 236]. The value ( $i_s$ ) was 0.1. In 2017, Gini coefficient was equal to 0.362 [13, p. 220]. The value ( $i_s$ ) depending on  $C_G$  is 0.1.

We will calculate the food self-sufficiency of the Southern Federal District in 2017 (table IV).

**TABLE IV. LEVEL OF FOOD SELF-SUFFICIENCY OF THE SFD IN 2017**

Food supply	Actual production, thousand tons	Required volumes of food production in accordance with rational rates	$C_s$
Potato	2109.3	1478.5	1.42
Vegetables	3892.5	2299.9	1.69
Milk	3578.2	5339.2	0.67
Meat	993.8	1199.3	0.82
Eggs, million pcs.	5573.1	4271.4	1.30

The value of self-sufficiency coefficient ( $C_s$ ) was 1.18, therefore, the indicator ( $i_f$ )=0.2. Let us define  $I_{eap}$  for the SFD in 2017:

$$I_{eap} = \sum (i_e + i_s + i_f) = 0.8$$

According to the results of calculations, the agricultural policy effectiveness of the Southern Federal District in the food security was at permissible level. Results of the analysis allow us to substantiate the directions of agricultural policy improving in the Southern Federal District: it is necessary to increase the level of self-sufficiency in dairy, meat products; the priority is to ensure the economic availability of food for the population, which requires to form a set of measures to ensure the growth of the population income level of the Southern Federal District.

#### IV. CONCLUSION

In order to optimize the processes of assessment and forecasting of food security, it is worthwhile using cognitive maps, as they provide modeling of main areas of the food security level formation to obtain an integral indicator. The cognitive maps construction involves analysis results for the system of groups of factors and indicators that form the level of food security.

The study substantiates the concept of creating an intelligent system for multi-criteria assessment and forecasting of food security level of the state and certain regions, in the conditions of import substitution on the basis of fuzzy cognitive approach.

The construction requires:

- specifying theoretical and methodological basis of the integrated assessment of the level of food security in the conditions of import substitution;
- developing a system of indicators and methodology for the construction of fuzzy production cognitive maps to assess the forecast of food security, taking into account the sphere of production, consumption, reservation and import;
- elaborating methodology and building membership functions for the factors of food security relevant for production cognitive maps;
- building a system of fuzzy cognitive maps to assess the level of food security of subjects of different levels;
- modeling of self-development and controlled development of food security system with the help of cognitive maps for subjects at different levels;
- development of a software package for monitoring, assessing the level of food security and forecasting its dynamics.

The implementation of these subtasks will solve the problem of objective integrated assessment of food security level based on intellectual cognitive system, as well as will assess the dynamics of its change, taking into account the public authorities management.

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### **References**

- [1] Ulez'ko A.V. Rynok prodovol'stvennyh resursov v sisteme obespechenija prodovol'stvennoj bezopasnosti Dal'nego Vostoka [The market of food resources in the system of ensuring food security of the Far East]. Voronezh: Voronezhskij GAU, 2014. 291 p.
- [2] Jarkova T.M. Opredelenie gosudarstvennoj podderzhki generirovanija prodovol'stvennyh zasposov regiona v formate VTO [Determination of state support for the generation of food stocks in the region in the format of the WTO]. Jekonomika regiona [Economy of the region], 2013, no. 4 (36), pp. 157-166.
- [3] Altuhov A.I. Region v sisteme obespechenija prodovol'stvennoj bezopasnosti strany: metodologicheskij aspekt [Region in the system of ensuring food security of the country: a methodological aspect]. Agroprodovol'stvennaja politika Rossii [Agrofood policy of Russia], 2016, no. 5, pp. 5-12.
- [4] Nazarenko V.I. Prodovol'stvennaja bezopasnost' (v mire i v Rossii) [Food security (in the world and in Russia)]. Moscow: Monuments of historical thought, 2011, 286 p.
- [5] Herforth A., Gill M.. Strengthening the links between nutrition and health outcomes and agricultural research. Food Security. June 2015. volume 7. Issue 3, pp.457–461.
- [6] Grace D., Mahuku G., Hoffmann V. International agricultural research to reduce food risks: case studies on aflatoxins. Food Security, June 2015. Volume 7. Issue 3, pp. 569–582.
- [7] Weikard H. Phosphorus recycling and food security in the long run: a conceptual modelling approach. Food Security, April 2016. Volume 8. Issue 2, pp. 405-414
- [8] Capone R., Bilali H., Debs Ph., Cardone G., and Driouech N. Food System Sustainability and Food Security: Connecting the Dots. Journal of Food Security, 2014, vol. 2, No. 1. pp. 13-22;
- [9] Nizhegorodtsev R.M. Importozameshhenie institutov: ključevaja zadacha obespechenija nacional'noj bezopasnosti [Import substitution of institutions: the key task of ensuring national security]. Izvestija Ural'skogo gosudarstvennogo jekonomičeskogo universiteta [News of the Ural State University of Economics]. 2016, no. 4 (66), pp. 1-18.
- [10] Antamoshkina E.N. Ocenka jeffektivnosti agroprodovol'stvennoj politiki regiona [Evaluating the effectiveness of the agri-food policy of the region]. Izvestija Nizhnevolzhskogo agrouniversitetskogo kompleksa: nauka i vysshee professional'noe obrazovanie [Proceedings of Nizhnevolzhskiy agrouniversity complex: science and higher vocational education], 2016, no. 1(41), pp. 275-282.
- [11] Antamoshkina E.N. Agrarnaja politika: mehanizm i kriterii optimizacii [Agrarian Policy: Mechanism and Optimization Criteria]. Vestnik Severo-Osetinskogo gosudarstvennogo universiteta imeni K.L. Khetagurova. [Bulletin of North-Ossetian State University named after K.L. Khetagurov], 2018, no. 2. pp. 111-118.
- [12] Buyanova M.E., Antamoshkina E.N., Shlevkova T.V. Indicators of Food Security in the System of Socio-Economic Diagnostics of the Region. Proceedings of the International Scientific Conference "Far East Con" (ISCFEC 2018). Series: Advances in Economics, Business and Management Research, volume: 47. Atlantis Press, 2019. pp. 1210-1213. Available at: <https://www.atlantis-press.com/proceedings/iscfec-18/55912594>. Reference date: 15.02.2019.
- [13] Regiony Rossii. Social'no-jekonomičeskie pokazateli [Regions of Russia. Socio-economic indicators] 2018 stat. sbornik. Moscow: Rosstat Publ, 2018. 1162 p.
- [14] Prikaz Ministerstva zdravoohraneniya i social'nogo razvitiya Rossijskoj Federacii ot 19 avgusta 2016 g. N 614 "Ob utverzhenii rekomendacij po racional'nym normam potrebleniya pishhevnyh produktov, otvechajushhim sovremennym trebovanijam zdorovogo pitaniya" [The order of Ministry of Health and Social Development of the Russian Federation from August 19, 2016 N 614 "On approval of recommendations for rational consumption rates of foods corresponding to modern requirements of a healthy diet"]. Available at: [http://base.garant.ru/71485784/#block\\_1000](http://base.garant.ru/71485784/#block_1000). Reference date: 15.02.2019.