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RECURRENT METHOD FOR CONSTRUCTING FUZZY COGNITIVE MAPS FOR FOOD SECURITY ASSESSMENT

Abstract: *Assessing and ensuring food security (FS) taking into account the quality of life (QL) of the population is one of the most important problems of economic security. The problem of integral estimation of the FS level can be solved by developing a family of fuzzy cognitive maps (FCM). The purpose of the article is to build such models. The FCM algorithmic core is consistently supplemented with new concepts, such as generalized QL. At each iteration, the values of the weights corresponding to the new configuration of the modified FCM graph are revised. The conceptual model of cognitive modeling FS is constructed in accordance with the identified criteria of food security, including production; consumption, QL, level of infrastructure provision and import. The constructed model allows us to evaluate the impact of additional concepts, including QL, on the evolution of the integral FS level.*

Keywords: *Food Security; Quality of Life; Fuzzy Cognitive Systems; Forecasting; Matrix Cognitive Models; Import Substitution.*

1. Introduction

One of the trends in the development of the modern world economy is a high level of regionalization, which leads to the formation of regional subsystems as elements of global socio-economic systems (SES). Regional SES have greater flexibility and mobility than national ones, which contributes to their effectiveness in the context of the globalization of the world market economy and allows them to successfully address issues of ensuring economic and food security (Antamoshkina & Rogachev (2020a), Rogachev et al., 2018; Rogachev & Mazaeva, 2015), including QL (Fassio et al., 2013, Popkova et al., 2015a). Under the influence of global SES integration processes, the level of mutual dependence of individual regions increases. On the one hand, it promotes specialization and division of labor. On the other hand, this poses a threat to economic security, as excessive dependence on imports can lead to the loss of the region's sovereignty (Rogachev & Shokhneh, 2015).

An important part of the national security of the state is to ensure the food security of the country, which guarantees regular access of the population to high-quality and safe food for the consumer. Consumption is a basic indicator of the quality of life of the population. If there is an insufficient amount of food and its poor quality, negative consequences can occur, since a full and balanced diet largely determines the level of health of the population and its life expectancy. The food supply of the population and the FS and regions should be sufficiently sustainable. This makes it possible, among other things, to formulate conditions for planning import substitution of certain types of food with products of

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domestic producers in order to provide the population with high-quality and safe food products (Golubev, 2016; Antamoshkina & Rogachev, 2020b). Therefore, the problem of PB is one of the most important problems of economic security, which, along with QL, is strategic (Rogachev & Fedorova, 2014) and should be considered as one of the key priorities for the development of modern economic systems. The theoretical basis for the study and modeling of FS problems are the works of such scientists as (Garthwaite et al., 2015), (He, 2015), (Jacknowit et al., 2015), (Maitra & Rao, 2015), (Bannikova et al., 2015), etc. The analysis of these studies has shown that at present, despite a large number of theoretical and methodological studies in the field of food security, there is no unified methodology for assessing the level of FS in the region (Rogachev, 2013).

Various aspects of the "standard of living" category and assessment are considered in articles by Russian and foreign scientists (Revich, 2018), (Khasaev et al., 2019), (Piskun et al., 2019), (Vorobyova et al., 2019), (Musieva, 2019). Researchers of QL problems note (Kusi-Sarpong et al., 2018) that the application of fuzzy mathematics methods is effective in conditions of incomplete or fuzzy information.

In this article, we analyze the hypothesis that the problem of integral estimation of the FS level, taking into account the QL factor, associated with the presence of a set of partial indicators, as well as their incomplete and fuzzy nature, can be solved by developing a fuzzy cognitive model (Ginis et al., 2016), containing a limited number of concepts that are recursively introduced in a fuzzy cognitive FCM with an expert re-evaluation of the parameters of their relationship. The purpose of the article is to test the proposed hypothesis, build a cognitive model containing a limited number of concepts, and methods for supplementing FCM concepts.

Achieving this goal involves solving the following tasks:

- determination of the problems of cognitive modeling of FS by constructing and FCM adjusting the composition of concepts;
- analysis of qualitative and quantitative mismatches of actual and model processes of evolution of FS indicators with different combinations of key and additional concepts;
- development and research of a method of recurrent addition of concepts, in particular describing QL, which allows to complement FCM when parameterizing them.

2. Materials and methods

During the cognitive modeling of FS implemented the following stages: pre-structural-parametric analysis of statistical indicators of socio-economic system defining its BOP; the study of the composition of key groups of factors determining FS; the Construction of a FCM, which is a weighted directed graph, whose vertices correspond to selected concepts; identify the most important concepts that form the algorithmic core of the FCM, graphic-analytical study of the processes of interaction concepts and their recursive addition.

Cognitive modeling of the evolution of PB indicators was performed according to the matrix dependence:

$$x(t) = (I + A + A2 + \ldots + At)x(0), \quad (1)$$

where $A = \|a_{ij}\|$ – adjacency (incidence) matrix, size n x n,

t - is the number of the modeling pulse.

A recurrent algorithm defines a method for calculating the terms of a sequence describing a function using recurrent formulas, in which the subsequent member of the sequence is calculated as a function of the previous one. In a more general case, the next term of a recurrent sequence depends not on one, but on several, for example, the previous two:

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$$Xk = f(Xk\text{-}1, Xk\text{-}2) \qquad (2)$$

where X0 = a, X1 = b, a, b - are constants.

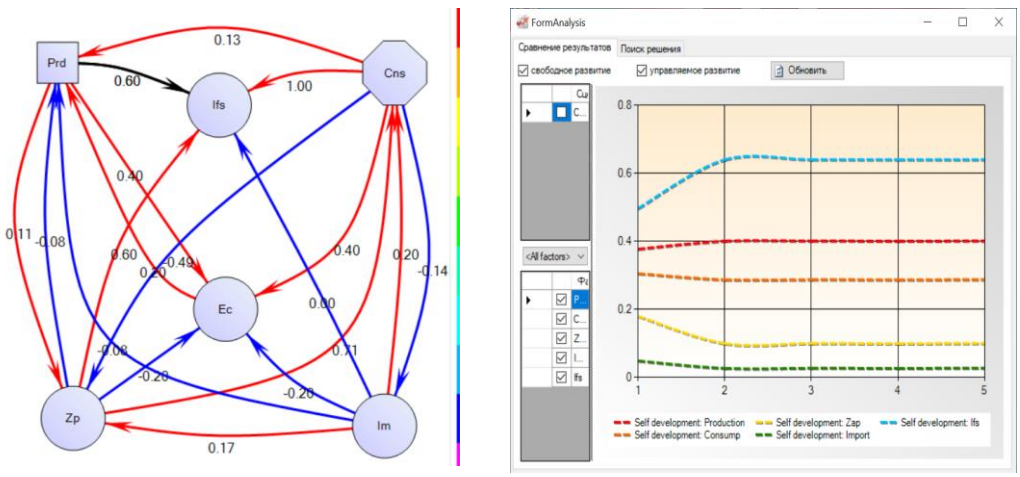
3. Results

You must first build a minimal cognitive structure – algorithmic kernel FCM, which a priori, according to experts, should be based on the recurrent Supplement when building a FCM fuzzy cognitive maps (Figure 1-a.).

3.1 Building the FCM Algorithmic core

Basic fuzzy cognitive map, the algorithmic core of which was formed on the basis of the food security Doctrine of the Russian Federation, included 4 consolidated groups: agricultural production; food consumption, manage their stocks and food imports.

Charts the evolution of the basic system with the addition of its concept of the integral indicator of the level of FS is shown in Figure 1, where the variant a) corresponds to FCM with four groups of the basic concepts of system security FS; additionally take into account the added concept of the integral indicator of the level of PB; b) diagram of the evolution of the indicators FCM, including an integral indicator FS.



a b

Figure 1. Algorithmic core and integral indicator FS:
a - algorithmic core; b - diagram of the evolution of the integral indicator of the FS level

3.2 Method of recurrent addition of concepts

We will consistently add additional concepts from the a priori constructed ranked list to the FCM algorithmic core (Rogachev & Melikhova, 2020).

The recurrent approach can be extended to n terms of the defined sequence. Then the expression (2) takes the form

$$Xк = f(X_{к\text{-}1}, X_{к\text{-}2}, \ldots, X_{к\text{-}n}) \qquad (3)$$

where $X_0 = a, \ldots X_n = z$.

Consider the authors' proposed use of a recurrent approach to the construction of FCM for assessing food security.

At each iteration, the values of the weights corresponding to the new configuration of the modified graph formed by FCM are reviewed by experts (Figure 2). Initialization of the process is implemented in block 1, in block 2, the condition for completing the procedure for recurrent addition of concepts is checked, in block 3, the addition of a new concept and expert evaluation of the weights of all interactions are provided.

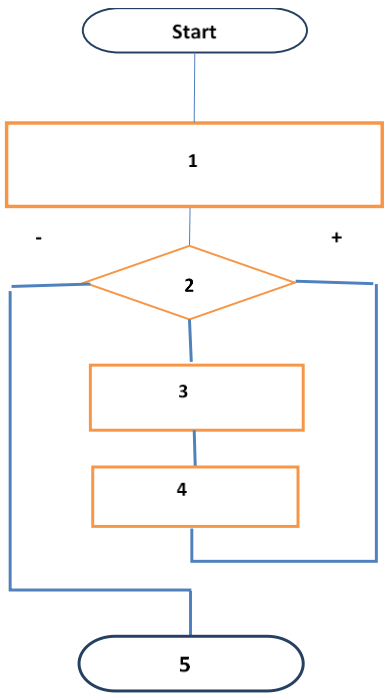


Figure 2. Generalized algorithm for recurrent addition of FCM concepts
(Compiled by the authors)

Analysis of the results of modeling the evolution of indicators after adding a new concept is provided in block 4. The recurrent procedure for adding concepts in FCM is completed (block 5) when the condition specified in block 2 is met, after which a detailed scenario analysis can be performed.

Let's consider the proposed method of recurrent addition of FCM on the example of introducing new concepts and / or decomposing the FS that change during modeling, taking into account imports.

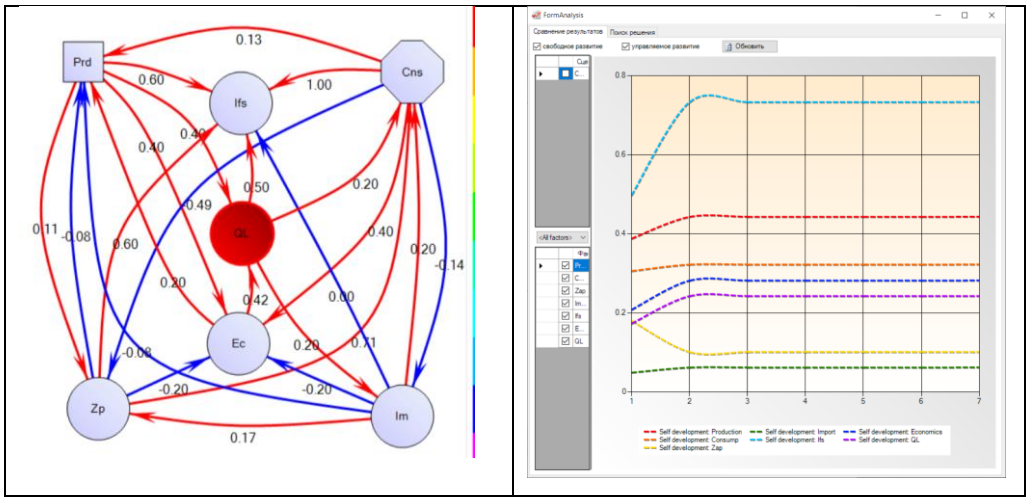
3.3 FCM supplement on the example of the concept «quality of life»

When FCM is supplemented with the new concept "quality of life", which generically characterizes the aggregate economic indicators that characterize the quality of life of the population, the nature of the evolution of the curves changes somewhat (Fig. 3-b).
As the results of the analysis, the addition of FCM concept "quality of life" and the introduction of additional ties its influence on the concepts of "food consumption", "food security" and "import", and consideration of the impact of "production" and "economic infrastructure" leads to another adjustment to the curves of the evolutionary dynamics that take the form shown in Figure 3-b.

Thus, by consistently building the FS support systems developed by FCM using the recurrent complement method, and enriching them with additional concepts, it becomes possible not only to track the impact of new concepts, but also to adjust the parameters of their interaction at each step.

The scientific significance of the results lies in the development of the methodology of cognitive assessment of the level of FS generated by the socio-economic system with the expert incomplete and fuzzy data is determined by the recursive methodology of fuzzy cognitive modeling and obtaining integral evaluation with justification of the methodology complement the concepts of the FCM.

It should be noted that there are many different threats to the production of sufficient volumes of food, among which the risks associated with crop failure, epidemics of farm animals, rising prices for feed, fertilizers, plant protection products, etc. require detailed study.



a b

Figure 3. Diagrams of the evolution of the system taking into account QL and economic infrastructure: a - the algorithmic core, supplemented by the concept of QL; b - the evolution of the indicators of the simulated system taking into account QL

It is important to use mathematical modeling to select the type and volume of import substitution, to encourage the state through tax conditions, concessional lending and subsidies (Popkova et al., 2015b).

3. Conclusion

In the result of the study confirmed the hypothesis formulated and proposed a conceptual model of cognitive modeling of PB, such as the socio-economic system, based on the description of interaction together key groups (blocks) of concepts in accordance with the identified criteria of food security - production and processing; consumption and the level of infrastructure support and services.

The developed model of cognitive assessment of the FS level allows us to evaluate the implementation of import substitution mechanisms. The developed model, which takes into account the concept of "import" and its decomposition, allows us to assess their impact on the evolution of other concepts and the integral level of FS, in particular, QL, which allows us to consistently assess the feasibility of import substitution scenarios and choose its optimal option.

The development of new FCM, taking into account additional factors to ensure and increase FS at the level of regions and states, is a promising direction for further research based on a fuzzy cognitive approach.

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References:

Antamoshkina, E., & Rogachev, A. (2020a). The Model of Statistical Assessment of Food Security Complex Systems (Innovation and Sustainability in the Digital Age. Vol 1 Studies in Systems, Decision and Control. Ed. Bogoviz A) 282 pp 471-481. doi: 10.1007/978-3-030-44703-8

Antamoshkina, E., & Rogachev, A. (2020b) The methodological approach to analyzing the food security sustainability in the context of import substitution. *E3S Web of Conferences 208*, 03004. Retrieved from https://doi.org/10.1051/e3sconf/202020803004

Bannikova, N. V., Baydakov, A. N., & Vaytsekhovskaya, S. S. (2015). Identification of Strategic Alternatives in Agribusiness. *Modern Applied Science*, *9*(4), 344-353.

Fassio, O., Rollero, C., & De Piccoli, N. (2013) Health, quality of life and population density: a preliminary study on "contextualized" quality of life. *Social Indicators Research*, *110*(2), 479-488.

Garthwaite, K. A., Collins, P. J., & Bambra, C. (2015). Food for thought: An ethnographic study of negotiating ill health and food insecurity in a UK foodbank. *Social Science and Medicine*, *132*(1), 38-44

Ginis, L. A.., Gorelova, G. V., & Kolodenkova, A. E. (2016) *International Journal of Economics and Financial*, *6*(5).

Golubev, A. V. (2016) *Import substitution and efficiency of the agro-industrial complex: Monograph. Moscow*: Publishing House RGAU-MSHA, 167 p.

He, J. (2015). Chinese public policy on fisheries subsidies: Reconciling trade, environmental and food security stakes. *Marine Policy*, *56*(1), 106-116.

Jacknowitz, A., Morrissey, T., & Brannegan, A. (2015). Food insecurity across the first five years: Triggers of onset and exit. *Children and Youth Services Review*, *53*(1), 24-33.

Khasaev, G. R., Lazareva, N. V., Rozenberg, G. S., Kudinova, G. E., & Kuznetsova R. S. (2019). Ecology, innovation, and quality of life: ab ovo usque ad mala. *Contributions to Economics*, 121-134

Kusi-Sarpong, S., Varela, M. L., Putnik, G., Avila, P., & Agyemang, J. (2018). Supplier evaluation and selection: a fuzzy novel multi-criteria group decision-making approach. *International Journal for Quality Research*, *12*(2), 459-486. doi: 10.18421/IJQR12.02-10

Maitra, C., & D.S.P. Rao, (2015). Poverty-Food Security Nexus: Evidence from a Survey of Urban Slum Dwellers in Kolkata. *Source of the World Develop*ment, *72*(1), 308-325.

Musieva, D. M. (2019) The concept of "Quality of life" and approaches to its definition. *Information wars 3* **(**51), 16-20

Piskun, E., Khokhlov, V., Simchenko, N. (2019) Economic development of Sevastopol and its influence on the population's life quality. *International Journal for Quality Research*, *13*(2), 485-500.

Popkova, E. G., Chechina, O. S., & Abramov, S. A. (2015a). Problem of the Human Capital Quality Reducing in Conditions of Educational Unification. *Mediterranean Journal of Social Sciences*, *6*(3), 95-100.

Popkova, E. G., Abramov, S. A., Ermolina, L. V., & Gandin, E. V. (2015b). Strategic Effectiveness Evaluation as Integral Part of the Modern Enterprise Management. *Asian social science*, *11*(20), 16-21.

Revich, B. A. (2018). Priority factors in urban environments that affect the quality of life for metropolitan populations. *Studies on Russian Economic Development*, *29*(3), 267-273.

Rogachev, A. (2015). Economic and Mathematical Modeling of Food Security Level in View of Import Substitution. *Asian Social Science*, *11*(20), 178-184.

Rogachev, A., & Melikhova, E. (2020). Recurrent method for constructing fuzzy cognitive maps for food security assessment *E3S Web of Conferences 217*, 09005 https://doi.org/10.1051/e3sconf/202021709005

Rogachev, A. F., Mizyakina, O. B., & Myagkova, T. L. (2018). Food security of region as component of economic security. *Espacios, 39*(3), 23.

Rogachev, A. F. (2013). Methodological approaches to modeling ecological & economic security. *Economics and business, 12-4* (41-4), 107-109.

Rogachev, A. F., & Fedorova, Y.V. (2014). Unclear modeling of ecological & economic systems. *Modern problems of science and education, 5*(1), 317.

Rogachev, A. F., & Mazaeva, T. I. (2015). Methodological approaches to systemic modeling of provision of regional food security. *Economics and business, 9*(4-1), 5-8.

Rogachev, A. F., & Shokhnekh, A. V., (2015). Genesis of mathematical modes of econophysics as a way to food security. *Audit and financial analysis, 1*(1), 410-413.

Vorobyova, V. V., Vorobyov, S. P., & Shlegel, S. V. (2019). Assessing the quality of life of the population in rural areas of the Altai region. *Advances in social science, education and humanities research*. *Proceedings of the International Conference on Sustainable Development of Cross-Border Regions: Economic, Social and Security Challenges* (ICSDCBR 2019). Altai State University. Pp. 223-227.

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