Abstract. In the national security system of the Russian Federation, food security (FS) is also one of the important tasks, since without a reliable food supply, it is impossible to avoid dependence on other States. The new FS Doctrine, approved by Presidential Decree No. 20 of January 21, 2020 "On the Approval of the Food Security Doctrine of the Russian Federation" approved a new FS Doctrine. The doctrine considers the FS as a multi-component system that includes, as components, the availability of food, its economic, social and physical availability, stability over a long period of time, as well as food issues. To provide cognitive modeling, we can represent the FS support system as a weighted directed graph, whose points correspond to the elements of the set, and whose arcs correspond to the non-zero elements of the W relation. The ratio W can be represented as a matrix of dimension $n \times n$, where $n$ is the number of factors, which can be considered as the adjacency matrix of the graph. The dynamics of the evolution of the simulated socio-economic system and the forecast of its development were obtained by summing increments. The components of the vector of predicted increments of the FCM calculated using the adjacency matrix are calculated at consecutive points in time. It is shown that the following concepts should be taken as key concepts in cognitive modeling of the level of FS: production, consumption, stocks and imports of food, as well as a number of additional ones that characterize the ecological and economic infrastructure for ensuring PB. Modeling has shown that the fluctuating nature of changes in the indicators of all concepts during the transition period forms 3 groups: increasing (FS level, Production, Crop production), stagnating (Consumption) and falling indicators (Import, Irrigation reclamation, Economy, Ecology). The identified trends in the evolution of the main concepts of the level of food security in the context of import substitution should be taken into account when developing programs to ensure FS by subjects of various levels.

1. Introduction

In the national security system of the Russian Federation, food security is also one of the most important tasks, since without a reliable food supply, it is impossible to avoid dependence on other States.

The new PB Doctrine, approved by Presidential Decree No. 20 of January 21, 2020 "On the Approval of the Food Security Doctrine of the Russian Federation", was adopted to replace the...
previous one of 2010. The doctrine considers the BOP as a multi-component system that includes, as components, the availability of food, its economic, social and physical availability, stability over a long period of time, as well as issues of food use.

To provide the population with such products, the agro-industrial complex of the Russian Federation must meet the world level and modern requirements, as well as effectively use technological innovations.

Various software systems are known to support cognitive modeling procedures—from the oldest foreign FCMappers to domestic developments "IGLA", "Strela", "Strategist", etc. With similar capabilities, they differ mainly in interfaces, as well as technologies for organizing interaction with users [9]. In the FCMappers system, you can set the initial weights of the concepts to be considered. The system allows you to visualize the FCM using the Pajek tool.

At the same time, mechanisms for effectively solving the problems of food security management at various levels of the hierarchy of socio-economic systems are not sufficiently developed, which require additional analysis and improvement of algorithms to justify the parameters of food independence and security.

2. Materials and methods

The FCM developed for estimating the FS level is a weighted directed graph whose points correspond to the elements of the set, and whose arcs correspond to the non-zero elements of the \( W \) relation. The ratio \( W \) can be represented as a matrix of dimension \( n \times n \) (where \( n \) is the number of factors), which can be considered as the adjacency matrix of the graph.

The method of obtaining a forecast with summing increments was first proposed by Roberts. The vector of predicted increments is calculated, its components are calculated by the formula:

\[
p_i(t + 1) = \sum_j w_{ij} \cdot p_j(t)
\]

(1)

The method for obtaining a forecast without summing increments is based on the max-product rule:

\[
p_i(t) = \max_j w_{ij} p_j(0)
\]

(2)

Using the consonance and the state vector of the system, we get a tuple

\[
< X(t), C(t) >
\]

(3)

allows you to evaluate the state of the system at a given time \( t \).

3. Results

Despite the existence of a national food security Doctrine, the provision of FS, as a typical socio-economic system, is poorly structured [9]. For such systems, it is characteristic that their parameters and laws of behavior are described mainly at the qualitative level, and changes in their parameters can lead to difficult-to-predict changes in behavior.

3.1. Building a graph cognitive model

Modeling and managing FS systems using traditional approaches based on analytical description or statistical observation is a known challenge. This forces us to resort to subjective approaches based on expert information, processed using the logic of "common sense", intuition and heuristic approaches. One of the most effective approaches is cognitive modeling based on special graph structures—cognitive maps. It allows you to help the decision-maker (PL) to activate intellectual processes and display the idea of the problem situation in the form of a formal model. Such a model is a cognitive map (CC), which is a set of factors on which a set of causal relationships is set. A further development of the CC was the fuzzy cognitive maps (FCM), which include the weights of the concepts taken into account and characterize their mutual influence [9].

To assess the state of the PB, consistent with the current Doctrine of the FS of the Russian Federation, the following consolidated system of indicators is used:

a) in the field of consumption;
b) in the field of production and national competitiveness, including the volume of production and import of agricultural and fish products, raw materials and food;

c) in the field of management organization, including the volume of food of the state material reserve, and stocks of agricultural and fish products, raw materials and food.

To assess the state of the BOP, the specific weight of domestic agricultural, fish products and food in the total volume of commodity resources (taking into account rolling stocks) of the domestic market of the corresponding products is determined as a criterion. The threshold values of the main types of products are also defined, which are tightened in comparison with the version of the Doctrine of 2010.

Table 1. Factors of the developed fuzzy cognitive model [14].

| The enlarged group | The Name of the concept | Note |
|--------------------|-------------------------|------|
| Production and processing of products | Production and processing of meat products | Including vegetables and fruits |
| Consumption | Production and processing of crop products | Including vegetables and fruits |
| Stocks | Consumption of food products | |
| Import | Import of food products | Including seeds |
| Export | The Export of food products, Particularly grain |
| Economic infrastructure | The state of the economy and budget support for rural producers |
| Ecology | Development of land reclamation and increase of fertility |
| FS Level | Ecological state of the environment and the products consumed | Including field productivity |

By Order of the Government of the Russian Federation No. 2138-r of November 18, 2013, in order to form the state automated information system, a more extensive list of indicators in the field of food security was approved. Some of the indicators of the system of information and statistical assessment of food security, recommended, are given in the article [1]. The scorecard includes three base unit: target indicators of the state of food security indicators for monitoring the state of food security and indicators of the state of food security (Table 1).

The first set of indicators includes 3 main subgroups: targets in the field of food consumption (Figure 2), in the field of physical availability of food for the population (Figure 1) and the independence of the Russian Federation (Figure 1).

The second set of indicators consists of monitoring indicators in the field of consumption (21 private indicators), in the field of commodity circulation of agricultural, fish products and food (27 private indicators), in the field of production of agricultural and fish products (31 private indicators), the state of stocks and reserves (4 private indicators) and the population and labor resources (9 private indicators).

The third block is represented by indicators that characterize the forecast scenario conditions for ensuring food security (18 private indicators), forecast sectoral macroeconomic indicators (3 private indicators) and forecast food balances (12 private indicators).

Note the presence of a large number of methods for aggregating statistical indicators (figure 2), as well as a significant number of indicators and the lack of reliable information on some of the above...
indicators. These circumstances force us to look for alternative methods, based on non-fuzzy or hybrid approaches, rather than strict statistical methods for their integral estimation. These sets of factors for ensuring FS, including import and import substitution indicators, should be taken into account in cognitive modeling.

Therefore, the cognitive model should qualitatively show a similar picture of the evolution of the agri-food system that provides the FS of the region [14]. Taking into account the above, the developed fuzzy cognitive model included the following factors (Table 1).

The relationship and weights of the 11 concepts listed in section 2, including the "Import" of food products. The FCM is shown in Figure 2. Note the presence of both one-sided relationships, for example, the negative impact of "Production and processing-Ecology", and bilateral "Economy-stocks (positive), Stocks-economy (negative)". Expert-defined weight values are also shown in Figure 2.

The software implementation of the preliminary cognitive modeling was provided using the Strategist computer system developed at the Volgograd State Technical University. The system has a user-friendly interface that provides interactive construction, visualization and research of a fuzzy cognitive model.

![](image)

**Figure 1.** Values of the relationship weights of the main FCM concepts.

### 3.2 Software implementation of FCM

A special software system was developed to simulate the influence of the time factor on the change in the relationships between concepts.

Diagrams of the evolution of the indicators of the agri-food system are shown in Figure 4.

The analysis of the diagrams in Figure 3 shows that the changes in the indicators of the concepts during the transition period are of an oscillatory nature. It is possible to distinguish groups of increasing (FS level, Production, crop production), stagnating (Consumption) and falling indicators (Import, Irrigation reclamation, Economy, Ecology).
Thus, the main concepts taken into account in the subsequent modeling of the level of BOP should be food production, consumption, stocks and imports, as well as concepts that characterize the ecological and economic infrastructure as a socio-economic system for ensuring FS level.

Figure 2. Mutual relations of the main FCM concepts and their weights.

Figure 3. Diagrams of the evolution of indicators of the regional agri-food system.

4. Conclusions
1. In cognitive modeling of the level of PB, the following concepts should be taken as key: production, consumption, stocks and imports of food. Additional concepts that characterize the ecological and economic infrastructure are, among other things, environmental factors that determine the socio-

economic infrastructure for ensuring FS.

2. The fluctuating nature of changes in the indicators of all concepts during the transition period evolves into the following groups: increasing (FS level, Production, Crop production), stagnating (Consumption) and falling indicators (Import, Irrigation reclamation, Economy, Ecology).

3. The identified trends in the evolution of the main concepts of the level of food security in the context of import substitution should be taken into account when developing programs for providing FS by subjects of various levels.

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