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Review Article

Information Technology for Fuzzy Modeling of the Food Security Level

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Abstract

Modeling the level of food security (FS) in the context of globalization is an urgent task to ensure economic and national security. The solution to this problem is important, both for states with developed agricultural production and for developing countries with a shortage of food production. Statistical approaches to assessing the level of FS on the basis of mathematically calculated indicators are limited by the need to obtain reliable statistical information of high dimension, including hundreds and thousands of different indicators. A separate task is the need to assess the impact on the simulated FS level of the dynamics of the forecast change in indicators, taking into account the trend of their change. The aim of the study is to build a model for the numerical assessment of the level of food security on the basis of a fuzzy logical conclusion, which allows to aggregate quantitative and qualitative information. The main tasks solved within the framework of the study are the substantiation of the system of basic economic indicators, the construction of membership functions and the rule base for fuzzy inference, as well as the development of information technology and a program ensuring the implementation of the developed model.

Keywords: Information Technology; Food Security; Modeling; Fuzzy Output; Membership Functions

Introduction

Researchers of economic and food security note that the global world problem of food security is compounded by our increasing tendency to depend on a narrow mix of food crops [15,16].

The basis of the state policy in the field of food security is a sustainable supply of the population with food, and processing enterprises with raw materials, regardless of external and internal impacts. It should not be dependent on price increases, currency rates, any sanctions from any states [1,2,9]. Russia's accession to the World Trade Organisation (WTO) (2012) actually increased the threats to the country's food security, primarily due to the required limitation of state support for the industry from $ 9 billions in 2012 to $ 4.4 billions in 2018, as well as a reduction of import duty rates by 30% all food products produced in Russia [2]. The temporary food embargo imposed by the Russian government led to an increase in food prices, a reduction in their range, a decline in quality, and, ultimately, a decrease in the level and quality of life [5,8].

The fundamental legislative document in the study area is the Doctrine of Food Security of the Russian Federation, approved by the Decree of the President of the Russian Federation dated January 30, 2010. No. 120, which interprets food security (PB) as "... the state of the country's economy, which ensures food independence, guaranteeing for every citizen the physical and economic accessibility of food that meets the requirements of the Russian legislation on technical regulation, in amounts not less than rational norms consumption of food products necessary for an active and healthy lifestyle" [4].

Studies of food security problems based on statistical and economic-mathematical modeling, including its provision for implementation in the framework of agrarian and socio-economic policies, were considered by A.I. Altukhov (2014), E.N. Antamoshkina (2016), V.G. Larionov, N.A. Kulaginoy, V.I. Nazarenko, L.N. Khounthavong, M., Krapchina, L. G. Kotova, E.G. Popkova (2017), Sander, B.O (2019), D.K. Sinha, I.A. Sergeeva (2015), A.Yu. Sergeev, G.V. Timofeyeva (2017), I.G. Ushachev., Villanueva, J., Vo, T.B.T., Wassmann, R. (2019) and the other economists.

The food security of our country is in an ambiguous situation, due to the low labor productivity in agricultural production and the problem of import substitution that is not completely solved [9,12-

14]. In addition, the consequences associated with the introduction of economic and political sanctions against Russian organizations and citizens by the European Union, the United States and Canada remain. To ensure PB, the Government of the Russian Federation adopted a decree providing for the imposition of an embargo on the import of a number of product categories from countries that supported economic pressure (Government Decree "On measures to implement the Decree of the President of the Russian Federation No. 560 of August 6, 2014 special economic measures to ensure the security of the Russian Federation").

Methodology

Methods of fuzzy mathematical modeling were used to build information technologies. To complete the model, all factors are pregrouped by significance and functional characteristics for economic entities of different levels. For the selected groups and factors that determine the level of food security, nonlinear membership functions were constructed and their forms and parameters were justified. Based on a number of theoretical assumptions that interpret the level of FS as a function of interrelated endogenous and exogenous factors, it is possible to estimate the degree of threats using the mathematical apparatus of fuzzy logic, widely used in systems based on artificial intelligence [15]. Based on expert judgment was formed of the database, including logical rules for making decisions about ratifitsirovala variables. Information technology to conduct simulations and scenario analysis demanded multicriteria selection of software on the basis of FisPro. The computer program provides fuzzy modeling and visualization of the response function of the integral indicator depending on the relevant groups of factors. The proposed approach allows us to more adequately assess the causes and extent of crisis situations, as well as to obtain indicative tools to increase the level of FS.

The mathematical apparatus of fuzzy logic is used when the available information (quantitative and qualitative) is either insufficient or insufficient to obtain statistically significant conclusions with the necessary degree of reliability. This approach allows to create a set of design alternatives based on fuzzy estimates of their technical and economic indicators by expert ranking or solving the problem of economic and mathematical optimization, formulated on the basis of selected criteria [6,7]. Flexibility and universality of fuzzy mathematics approaches allow to use them as an effective tool for solving various problems of analysis and long-term forecasting of the development of complex socio-economic systems.

Results and Discussion

To build, study the quality and assess the sensitivity of the fuzzy model, the authors developed an information technology based on open source software FisPro. The built fuzzy model of the FS indicator includes two levels - the lower and the upper. On the first of them, after fuzzification using the obtained membership functions, a numerical assessment of the generalizing indicators for each of the selected groups (production, consumption, stocks) is made. At the top level of modeling on the basis of production rules the fuzzy integral estimation of FS level is formed. After the corresponding fuzzification, the fuzzy estimate is converted to numerical value using FisPro in automated mode. The basis for the fuzzy inference of the model is a system of logical production rules recorded in the table.

The level of food security of the Russian Federation is largely determined by the relevant regional indicators of its subjects.

The groups of indicators stipulated by the Doctrine of the FS in the relevant areas, in turn, include a set of particular indicators, for example, by types of food. A significant number of private indicators for these groups requires the use of modern approaches to their aggregation, which is proposed to be carried out using fuzzy-multiple methods.

Fuzzy Logic Toolbox (MATLAB systems), fuzzyTECH, FisPro, etc. [11] were analyzed to substantiate the fuzzy inference computer tool environment. Taking into account the combination of functionality, degree of mobility and availability, the freely distributed software tool "FisPro version 3.5" was chosen, which allows creating systems of fuzzy classification and fuzzy logic inference for various purposes.

The basic concept of a computerized fuzzy inference system is the FIS-structure (Fuzzy Interface System), which contains data for the functional mapping of the "inputs-outputs". The structure of the resulting fuzzy inference system is shown in Fig. one.

In order to build the FP of each of the particular indicators that determine the level of BOP in the simulated spheres, a preliminary analysis was made of the dynamics of their changes over an economically significant period [12,13]. For example, for such an important indicator as regional meat production, a graphical representation of logarithmic growth, as well as a short-term forecast, are presented in Figure 1.

Dynamics of changes in the values of MP - "meat production" and MC - "meat consumption, kg / year per capita was analyzed for the period since 2000.

The trend approximation of the change in the MP index using the logarithmic function was

$$MP = 6.112 \ln(Y) + 42.083, R^2 = 0.85, (1)$$

where Y is the year number.

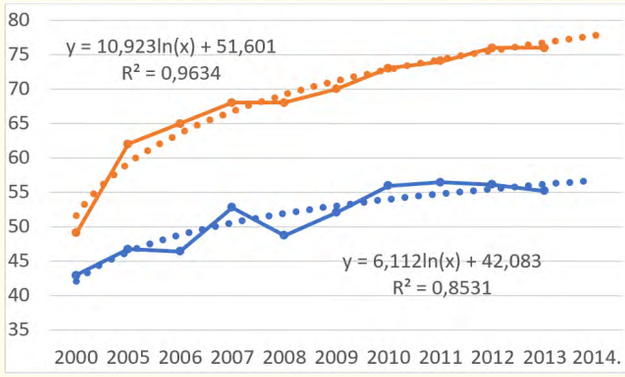


Figure 1: Dynamics of production and consumption of meat in the Volgograd region, kg/year per capita.

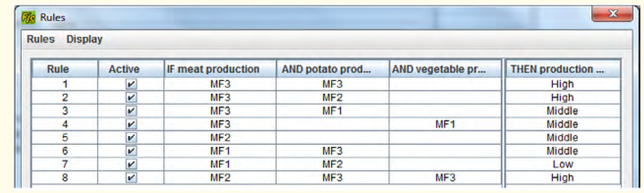
The structure and parameters of the triangular membership function of the variable "meat production" ("meat production"), the term set of which in the developed model is represented by three linguistic values ("low"; "medium"; "high").

In particular, the top of the triangle of the dependence "trimf" for the term "average" (MF2) corresponds to MF2 = 60 kg per year per capita, hence μA (60) = 1.0. For the terms "low"; "High" taken by the FP of the "semi trapezoidal" type with characteristic points of 45 and 72 kg/year per capita, respectively. The FS level for the remaining indicators was formed similarly based on the regression analysis of the trend models of their dynamics.

At the first level of the developed fuzzy-multiple model, on the basis of aggregation of particular indicators, dimensionless values of indicators of PB levels were obtained in the "Production", "Consumption" and "Management and Organization" areas with the range in the interval [1].

The formation of the FS was based on the position that for a number of key indicators in the sphere of consumption a deviation from the "optimal" in any direction is undesirable and indirectly characterizes the violation of the physiologically reasonable consumption structure. This was taken into account when forming the base of production rules in the "Rules" window. a fragment of which is shown in figure 2.

The numerical values of indicators by modeling spheres, calculated at the first level, were taken as input variables of the second level. The value of the integral indicator of food safety and security indicator was modeled, with the range of changes also in the interval [1].



Rule	Active	IF meat production	AND potato prod...	AND vegetable pr...	THEN production ...
1	✔	MF3	MF3		High
2	✔	MF3	MF2		High
3	✔	MF3	MF1		Middle
4	✔	MF3		MF1	Middle
5	✔	MF2			Middle
6	✔	MF1	MF3		Middle
7	✔	MF1	MF2		Low
8	✔	MF2	MF3	MF3	High

Figure 2: A fragment of the production rules database for fuzzy inference.

Discussion

In the FisPro preview window, 3-D visualization of the response surface of the FS level value is presented for various combinations of local and integral indicators for selectable axes of coordinates. The program provides the ability to scale and rotate the coordinate axes in space.

The 3-D visualization of the resulting response surface for the level of FS makes it possible to identify the zones that characterize its high (I_{FS} > 0.7), medium (0.5 <I_{FS} <0.7) and low values (I_{FS} <0.5). More rigorous graph-analytical study of its sensitivity to changes in input variables is more convenient to carry out in the "Inference" window.

The obtained values of the integral and particular indicators for the analyzed areas for the Volgograd region were respectively Ind FS = 0.53 with Sph_1 = 0.52; Sph_2 = 0.77; Sph_3 = 0.51 (Figure 3).

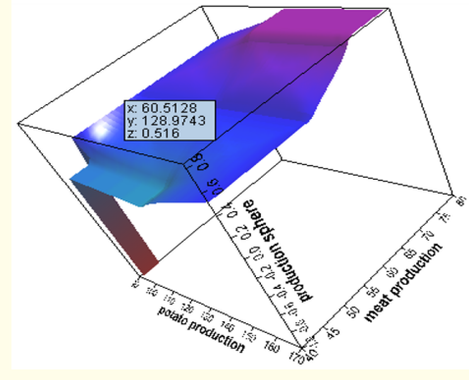


Figure 3: The response surface of the variable "Integral index of "Production sphere" in coordinates 'Potato production" and "Meat production".

According to authors, relatively low values of dimensionless food security levels in the production (0.52) and management and organization (0.51) are due both to an insufficient level of domestic

production, primarily livestock products. The remaining high share of imports of the relevant products, which determined the low level of the integral indicator food security (0.53). This allows you to identify the reserves of its increase in enlarged areas and private indicators [5,14].

The method of application of the developed model is illustrated on the numerical data of a typical agrarian region of Russia. The application of the developed information technology provides for the effects of various groups of economic factors that characterize the production, consumption, import-export and storage of food. The conducted scenario analysis allows us to predict various options for controlling the level of FS on the basis of a qualitatively formulated logic of their influence on the integral indicator.

Conclusion

The developed information technology and software provide input of initial data of the model, storage of membership functions for each of the factors, as well as production rules of fuzzy inference. The computer program provides visualization of simulation results in the form of 2D and 3D projections. When using the developed model to estimate and predict the level of FS, it is possible to change the values of the input variables corresponding to the current state of economic indicators. The model integrates three simulated areas - production, consumption and management, as well as a set of partial indicators characterizing each of them. The output data of the developed model of PB allow to determine in the conditions of incomplete information certainty the direction of improvement of the food supply system. This makes it possible to ensure not only the full supply of food to the population, but also the sustainable development of the agricultural sector, including the employment of the rural population, within the framework of the implementation of the agrarian policy of the region.

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