Investment Policy of Governance of Economic Security of Agrarian Sector of Ukraine on the Basis of Theory of Fuzzy Logics

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ABSTRACT

In modern globalized world the issue of ensuring economic security is a priority task for the protection of the national interests of the state against all kinds of threats that are of particular importance to Ukraine. The different economic potential of the Ukrainian regions, the level of their development, the recent economic and financial problems in the country, the unresolved armed conflicts in the Eastern part, the large number of settlers from the occupied territories and other adverse conditions faced by the Ukrainian economy in early 2014 require a special approach to solving the problem ensuring economic security of the agrarian sector as a leading industry in Ukraine. The purpose of this article is to develop a system for investment managing the economic security of the agrarian sector of the region of Ukraine (Vinnytsia region) based on the innovative economic and mathematical model for estimating and forecasting the level of economic security of the agrarian sector built by the means of the theory of fuzzy logic. The subject of the research is a set of theoretical, methodological and practical aspects of investment managing of the economic security of the agrarian sector of Ukraine. The innovative mathematical model of estimation and prediction of economic security of agrarian sector of Ukraine in the region (namely, Vinnytsia region) was first developed based on the theory of fuzzy logic. The forecast of the level of economic security of the agrarian sector of the region of Ukraine up to 2022 was made. The structural diagram of the process of decision-making and support with the developed economic-mathematical model is proposed.

INTRODUCTION

The changing dynamics of modern life creates new problems, intensifies methodological quest research and creates new paradigms of economic processes. In their numerical list issues of investment management of economic security of agrarian sector of the region of Ukraine are highlighted. The issue of ensuring the country's economic security as a priority task of protecting the national interests of the state from all kinds of threats is of special urgency. One method of evaluating the current situation and ways to increase the level of economic security of the agrarian sector is the use of information technology that will improve the efficiency and quality of management decisions.

How world's experience shows, the agrarian sector can't develop effectively and be competitive without attracting investments. Accumulation of investment capital not only can provide economic security of the agrarian sector but also ensure the development of other sectors of the Ukrainian economy. In addition, investment is the tool of macroeconomic stabilization of the agrarian sector which also allows to solve other problems of the state development in general.

To address the issues it is needed to develop an economic and mathematical model of a new type, allowing a problem-oriented search, to analyze information, and to provide factual information to the user in an easily accessible form.

Resolving the problems of managing the economic security of the agrarian sector of Ukraine, attracting investment in this sector can be solved by developing an economic and mathematical model that will determine the level of economic security of the agrarian sector of Ukraine. On the basis of this model, it is possible to develop a decision support system that will allow managing effectively and determining the problems of the development of this industry. The use of such models and economic systems can provide accelerated economic growth of the leading - agrarian sector of Ukraine.

1. LITERATURE REVIEW

As is known, the problems of achieving economic security of the state, regions, separate branches of the economy, as well as research questions, investment management, are reflected in the scientific works of many foreign and Ukrainian scientists. According to the Law of Ukraine "About Investment Activity" (1991), an investment activity is a set of practical actions of citizens, legal entities and the state regarding the implementation of investments. The rational use of investment resources determines the effective implementation of investment activity in any industry, including in the agricultural sector. Formation of investment resources is an important component of the investment and general financial strategy of production structures, as well as the initial condition for the implementation of the investment process at all its stages.

According to F. Vajinskiy et al. (2016), without the states regulatory role investment activity in the agrarian sector cannot exist. State regulation of investment activity of the agricultural sector is based on three groups of methods: economic, organizational and legal. Economical methods consist of a combination of depreciation, tax, lending, innovation, pricing policies and policies in the field of human capital formation. According to I. Zlelko et al. (2016) - the development of innovation activity in the agrarian sector of the economy is restraining by the following factors: - the imperfection of the legislative framework and the lack of state incentives for innovation; the limited internal and external sources of funding for innovation and the impossibility of their rapid mobilization; the low level of investment attractiveness of the industry.

V. Kirilenko (2005) devoted his work to the issues of investment as a method of securing the economic security of the agrarian sector. He states that the investment component is sufficiently important in the system of economic security, in particular, investment security. Considering the concept of economic security in relation to the agrarian sector, its particular importance should be

taken into account, since the main purpose of the agrarian sector is to provide the population of the country with affordable food in the required volume and quality, as well as to create jobs for the inhabitants of the countryside. Therefore, as stressed by I. Ushachev (2006), the state of the agrarian sector determines not only food security but also social stability in society. However, despite the presence of a vast number of scientific developments, some issues of a comprehensive assessment of the state of the agrarian sector and its impact on ensuring the country's economic security requires clarification and further research.

O. Vlasuk (2008) and Kharlamova et al. (2016) considers the economic security of the agrarian sector has a complex structure that should be considered regarding the functional and structural aspect as a set of interconnected security systems that reflect the functioning of individual "blocks" or spheres of the state's economic system. B. Bisultanov (2008) offers the following interpretation: "*The Economic security of the agro-industrial complex is a state of economic, financial, social, legal and ecological conditions for functioning and achievement of competitiveness with providing the necessary level of protection of vital interests of enterprises of the complex from internal and external threats*".

N. Kulagina (2012) considers the economic security of the agrarian sector as a system of economic interests consists of finding mechanisms for a compromise between ensuring the national benefit of the country, food security and risks, as a result of which the stable functioning of the agroindustrial complex is ensured. Thus, V, Kurgan (2008) believes that "*the Economic security of the agrarian sector of the economy should be considered as an effective use of enterprise resources and existing market opportunities, which helps to prevent internal and external threats, ensures its long-term survival and sustainable development by the chosen mission*".

M. Lychik (2013) considers the Economic security of the agrarian sector is ultimately the food saturation and balanced nutrition of the Ukrainian population, the availability of resources for production and the ability to the dynamic economic development of rural areas. A. Svetlakov (2010) believes that "*the Economic security of the agro-industrial complex is a complex of economic, social, legal and environmental conditions and factors for the functioning, development and achievement of the competitiveness of the industry with the aim of self-sufficiency of high-quality food products of the population of the territory, stimulation of individual commodity producers*".

Analysis of the statements shows that the economic security of the agrarian sector has a complex structure. For example, O. Vlasuk (2008) proposes to consider economic security as a set of interconnected security systems that reflect the functioning of individual "blocks" or spheres of the economic system of the state and suggests to consider the following functional components of the economic security of the agrarian sector: political and legal; financial; production-technological; investment; innovative; ecological; marketing; intellectual-framing; social foreign economic activity.

Ensuring economic security of the agrarian sector of Ukraine can be achieved by applying modern methods of economic-mathematical modeling, namely, the theory of fuzzy logic. As emphasize K. Bilovsky and O. Matkovska (2013) in the report "*Application of fuzzy logic to solve economic problems*", exactly the uncertainty of information makes it necessary to replace the traditional mathematical methods of fuzzy logic simulation. Methods of fuzzy logic allow simulating any socioeconomic processes under conditions of insufficient information and quantitative uncertainty of input data. The advantages of models based on fuzzy sets are the possibility of using numerical and linguistic data, the possibility of obtaining a generalized assessment in the case of the use of non-interconnected input and output data, the possibility of taking into account the specifics of the object or process under study and the ability to adapt the model to dynamic conditions of the economy.

2. METHODOLOGY

Despite the urgency of the problem of granting the economic security of the agrarian sector, today there is no universally accepted, approved methodology for assessing the level of economic security. Economists directed their studies to study the issues of regional economic security and security of the economy using the methodology sponsored by the state and by comparing the values of macroeconomic statistical indicators with their threshold values determined the level of economic security of the country.

However, in our opinion, this approach is rather general and approximate, because it does not allow determining the real level of economic security of a particular region and its branches because of the failure to take into account the specifics of the territories, available resources, economic conditions, etc. Also, this approach does not take into account the dynamics factor. Thus, in order to assess the state and level of economic security of the agrarian sector of the region, it is necessary to form a system of indicators that fully characterize it, and based on the selected indicators, using one or another method of analysis, carry out an assessment of the state of economic security.

The ultimate goal of assessing the state and level of economic security of the agrarian sector is the development of measures to improve the functioning of the agrarian sector in order to ensure the food independence of the country as a whole and its regions on the basis of harmonization of goals and objectives of the agrarian policy of the state at all levels of management through the use and analysis of scientifically based quantitative and qualitative indicators that characterize the state of economic security. The initial stage in the assessment of the condition and level of economic security of the agrarian sector is the establishment of adverse factors that may be prerequisites for the emergence of internal and external threats to economic security.
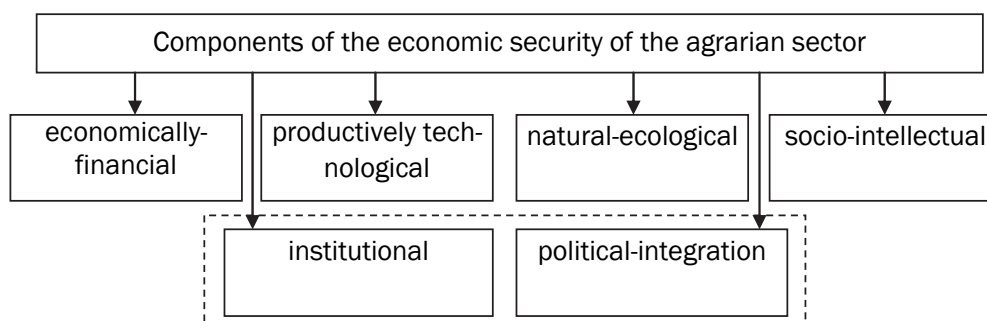
This can be done through the use of a systematic approach, which involves the separation of interrelated subsystems of economic security, the qualitative state of which directly affects the level and prospects for the development of agribusiness of the region and the country as a whole. We propose the following subsystems: the peculiarities of the agrofood business; level and quality of life of the population; the state of ecology and nature management; quality management of agroindustrial complex.

The methodology for assessing the level of economic security of the agrarian sector should take into account the interdependence of economic categories: *"economic security of the agrarian sector"* → *"food security of the country"* → *"national security as well as regional features of the territories"*. This is necessary for the case when it is necessary to adjust the indicators and criteria of economic security depending on changes in the natural and climatic conditions in which the agricultural sector operates.

In our opinion, the most well-known methods for assessing the state and level of economic security include the methodology by S. Yashin (2006). This methodology is based on the use of indicators published by state statistics authorities. The assessment of the level of regional economic security of the agrarian sector is carried out by comparing predefined indicators with their average values in the region.

Based on the results of the analysis, we believe that the indicator method with the use of threshold values may be the most optimal and effective for assessing the economic security of the agrarian sector at the regional level. In this regard, we propose to consider the economic security of the agrarian sector on the basis of the analysis of such components (see figure 1).

Figure 1. Components of the economic security of the agrarian sector

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│        Components of the economic security of the agrarian sector        │
└────────────────────────────────────────────────────────────────────────┘
     │              │                    │                    │
     ▼              ▼                    ▼                    ▼
┌──────────┐  ┌──────────────┐   ┌────────────────┐   ┌──────────────────┐
│economically-│ │productively tech-│ │natural-ecological│ │socio-intellectual│
│ financial │  │   nological   │   │                │   │                  │
└──────────┘  └──────────────┘   └────────────────┘   └──────────────────┘
          ┌─────────────────────────────────────────────────┐
          │  ┌─────────────┐       ┌──────────────────────┐  │
          │  │ institutional│       │ political-integration │  │
          │  └─────────────┘       └──────────────────────┘  │
          └─────────────────────────────────────────────────┘
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Source: compiled by the authors based on (Kozlovskyi and Jurakovskiy, 2016)

At the same time, it should be emphasized that the methods of economic modeling have recently become widely used. The advantages of these methods are following: shortening the timing of the analysis, the full coverage and taking into account the factors affecting the results of the object under study, the replacement of approximate or simplified calculations by exact calculations, the possibility of formulating and solving complex multidimensional problems.

However, classical methods of economic modeling are not quite suitable for analyzing and forecasting the development of systems operating in conditions of significant uncertainty. The traditional methods of economic modeling are based primarily on binary logic, which is not correct for dealing with inaccuracies and uncertainty occurring in financial and economic systems. For this purpose, the need to develop new methods that would be based on "soft" computing, mainly on fuzzy logic and neurocomputing occurred. It is the fuzzy logic that represents the system of calculations in which objects of calculations are objects with vague boundaries. In the areas of finance and economics, such modeling techniques are rather common than exceptional.

The advantages of the theory of fuzzy logic in comparison with other mathematical methods are given in (S. Kozlovskyi and V. Kozlovskyi, 2005), which one more time confirms the effectiveness of the use of the theory of fuzzy logic to solve the research problem – Table 1.

Table 1. Methodological analysis of the choice of mathematical apparatus for solving the research problem

Characteristics considered	Approaches to considering factors of uncertainty					
	multitasking logic	probability theory	the theory of errors	the theory of interval mean	theory of subjective probabilities	the theory of fuzzy logic
1. Considering the physical numerical 2. uncertainty	-	+	+	+	+	+
2. Considering the physical non-numerical uncertainty	+	+	-	+	+	+
3. Considering non-numeric linguistic 4. uncertainty	+	-	-	-	+	+
4. Dependence of the error of the final result on the accuracy of the input data	unac-ceptable	Increases rapidly		increases		does not surpass
5. Ability to take into account the semantic modality of information	+	+	-	-	+	+

6. Ability to take into account the level (quantification) of uncertainty	-	+	-	-	+	+
7. Taking into account expert qualifications (more than, significantly, very, etc.)	+	-	-	-	-	+
8. Ability to take into account the contradiction between accuracy and uncertainty	+	-	-	+	+	+
9. Efficiency of formalization of complete ignorance	+	-	+	+	+	+
10. Absence of a requirement for a clear task of a complete list of events	+	-	+	+	-	+
11. Possibility of effective consideration of the mutual influence of uncertainties in the processing of information	+	-	-	-	-	+
12. Possibility of simultaneous reception of pessimistic and optimistic assessments and the level of trust in them	-	+	-	+	+	+
13. Unified approach to presenting accurate, uncertain, incomplete, fuzzy parameter values	-	-	-	-	-	+
14. Ability to implement algorithms for processing information	+	+	+	+	+	+
15. Ability to work in the professional language of the user	+	-	-	-	-	+
16. Simplicity of obtaining expert opinions (statements)	+	-	+	+	-	+
17. Ability to work with uncertain information based on small statistical samples	+	-	+	+	-	+
18. Visibility of the results obtained for the calculation and risk assessment	-	-	-	-	-	+
19. Effective and rapid adjustment of the model	-	-	+	+	-	+

Source: compiled by the authors based on (S. Kozlovskyi and V. Kozlovskyi, 2005)

The theory of fuzzy logic allows to consider and analyze both qualitative and quantitative indicators. The use of this mathematical apparatus has been successfully tested in solving similar economic problems (S. Kozlovskyi et al., 2018; Shvedovsky et al., 2016) and can be applied to achieve the purpose of this work. In the process of research, the following methods were used:

− expert assessments – in assessing the factors affecting the economic security of the agrarian sector;
− systemic – in studying the principles of assessing economic security;
− synthesis, analysis, grouping – in determining the factors of influence and justifying the choice of factors that affect the economic security of the agrarian sector;
− modeling – in studying the processes of development of the agrarian sector;
− abstraction – in developing a model for assessing the economic security of the agrarian sector;
− generalization – when constructing analytic dependencies for choosing the method of constructing membership functions in models of management of economic security.

The purpose of this article is to develop a system for investment managing the economic security of the agrarian sector of the region of Ukraine (Vinnytsia region) based on the innovative economic and mathematical model for estimating and forecasting the level of economic security of the agrarian sector built by the means of the theory of fuzzy logic.

3. RESULTS

Considering the classification mentioned above of signs of "economic security of the agrarian sector", we will develop an economic-mathematical model for estimating and forecasting the level of economic security of the agrarian sector of the region of Ukraine with the theory of fuzzy logic.

The classical approach to modeling based on the theory of fuzzy logic involves a step-by-step solution to the following problems (Kozlovskyi, 2005): the isolation of the main factors of influence on the level of economic security of the agrarian sector; formalization of the interconnections between the factors of influence in a generalized form; definition and formalization of linguistic assessments of the factors of influence; construction of a fuzzy knowledge base on the interconnections between the factors of influence; the output of fuzzy logic equations based on linguistic estimates and fuzzy knowledge base; optimization of fuzzy model parameters.

Considering the necessity of observing the basic principles of simulation (Jurakovskiy et al, 2016) of the level of economic security of the agrarian sector of the region and the current conceptual apparatus of the theory of fuzzy logic the input factors of the model for assessing the level of economic security of the agrarian sector of the region are given in table 2.

Table 2. Input factors (variables) of the model and their linguistic estimation

Input factor (variable)	Name of the input parameter (variable)	Input parameter range	Linguistic evaluation of input parameters (terms)
Classification of economic and financial factors (e)			
x_1	Average prices of grain and leguminous crops in the region	1-5 thousand UAH / tonne	Low, 1-2, (H) Average, 2-3, (C) High, 3-5, (B)
x_2	Average prices of animal production in the region	2-10 thousand UAH / tonne	Low, 2-3 thousand UAH / tonne, (N) Average, 3-6 thousand UAH / tonne, (C) High, 6-10 thousand UAH / tonne, (B)
x_3	Net profit enterprises of the agrarian branch of the region	10-50 billion UAH.	Low, 0-10 billion UAH (H) Average, 10-20 billion UAH (C) High, 20-50 billion UAH (B)
x_4	The balance of the foreign trade of Vinnitsa region	-30-50 million dollars USA	Negative -30-0 million dollars USA, (HH) Low, 0-10 million dollars USA, (H) Average 10-30 million dollars USA, (C) High, 30- million dollars USA, (B)
x_5	The number of subsidies to agriculture from the state budget	50-500 million UAH.	Low, 50-100 million UAH, (H) Average 100-300 million UAH, (C) High, 300-500 million UAH (B)
x_6	The level of profitability of all activity of enterprises of the agrarian sector of the region	3-50 %	Low, 3-5%, (H) Average, 5-20%, (C) High, 20-50%, (B)
x_7	Inflation rate in Ukraine	0-100 %	Low, 0-8 %, (H) Average, 9-15 %, (C) High, 15-100 %, (B)
Classification of production and technological factors (v)			
x_8	Gross output of agriculture of the region	10-40 billion UAH.	Low, 10-15 billion UAH (H) Average, 15-30 billion UAH, (C) High, more than 30 billion UAH., (B)
x_9	Number of agrarian enterprises in the region	1-3 thousand pcs/year	Low, 1-1,5 thousand pcs/year, (H) Average, 1,5-2 thousand pcs/year, (C) High, 2-3 thousand pcs/year, (B)
x_{10}	Number of agrarian machinery in the region	5-80 thousand pcs.	Low, 1-20 thousand pcs., (H) Average, 20-40 thousand pcs., (C) High, 40-80 thousand pcs., (B)
Classification of natural and ecological factors (p)			
x_{11}	The volume of sown areas of the	1-2	Low, 1-1,2 million hectares, (H)

	main crops in the region	million hectares	Average, 1,2-1,7 million hectares, (C) High, 1,7-2 million hectares, (B)
x_{12}	Grain and legume yield cultures in the region	30-70 quintal per hectare	Low, 30-40 quintal per hectare, (H) Average, 40-50 quintal per hectare, (C) High, 50-70 quintal per hectare, (B)
x_{13}	Rape yield in the region	10-40 quintal per hectare	Low, 10-15 quintal per hectare, (H) Average, 15-30 quintal per hectare, (C) High, 30-40 quintal per hectare, (B)
x_{14}	Emission volume pollutants in the atmosphere of the region	30-200 thousand tonnes	Low, 30-80 thousand tonnes, (H) Average, 80-120 thousand tonnes, (C) High, 120-200 thousand tonnes, (B)
x_{15}	Natural disasters in the region	0-100 points	Low level, 0-25, (H) Average level, 25-50, (C) High level, 50-100, (B)
Classification of social and intellectual factors (s)			
x_{16}	Average number of employed workers in the agrarian production of the region	25-50 thousand persons/year	Low, 20-30 thousand persons/year, (H) Average, 30-40 thousand persons/year, (C) High, 40-50 thousand persons/year, (B)
x_{17}	Average salary in the region	1-7 thousand UAH/ month	Low, 1-3 thousand UAH/ month, (H) Average, 3-4 thousand UAH/ month, (C) High, 4-7 thousand UAH/ month, (B)
x_{18}	Intellectual potential (index of human development) of the country	0-1 unit.	Low, 0-0,5 (H) Average, 0,5-0,7 (C) High, 0,7-1 (B)
x_{19}	Innovative potential of the region	0-100 points	Low, 0-30, (H) Average, 30-60, (C) High, 60-100, (B)
Classification of institutional-political-integration factors (i)			
x_{20}	Institutional potential of the region	0-100 points	Low, 0-30, (H) Average, 30-60, (C) High, 60-100, (B)
x_{21}	The level of political stability in the country	0-100 points	Low, 0-30, (H) Average, 30-60, (C) High 60-100, (B)
x_{22}	International integration status of the country	0-100 points	Low, 0-30, (H) Average, 30-60, (C) High 60-100, (B)

Source: developed by the authors

Denote the linguistic variables of factors e, v, p, s, and by the following relationships:

$$e = f_e(x_1, x_2, x_3, x_4, x_5, x_6, x_7), \qquad (1)$$
$$v = f_v(x_8, x_9, x_{10}), \qquad (2)$$
$$p = f_p(x_{11}, x_{12}, x_{13}, x_{14}, x_{15}), \qquad (3)$$
$$s = f_s(x_{16}, x_{17}, x_{18}, x_{19}), \qquad (4)$$
$$i = f_i(x_{20}, x_{21}, x_{22}). \qquad (5)$$

where

$x_1...x_7$ – economic and financial factors;
$x_8...x_{10}$ – production-technological factors;
$x_{11}...x_{15}$ – natural and environmental factors;
$x_{16}...x_{19}$ – social and intellectual factors;
$x_{20}...x_{22}$ – institutional-political-integration factors.

The output value, that is, the level of economic security of the agrarian sector of the Vinnytsia region Z, can be determined by the formula (6):

$$Z = f_z(e, v, p, s, I, t), \qquad (6)$$

where e, v, p, s, i are linguistic variables that describe economically-financial, industrial-technological, natural-ecological, socio-intellectual, institutional-political-integration factors of influence and period of forecasting accordingly. The prediction period t will be encoded in two characters in the future: (6M, 1P, 2P, 3R, where the letters M and P are designated month and year).

Using the recommendations of experts (Official website of the World Food and Agriculture Organization of the United Nations) and according to the particular economic situation in the agrarian sector, the level of economic security of the region of Ukraine (namely, Vinnytsia region) can be characterized by the following levels (on a scale from 0 to 100):

- Z_1 (85-100) – excellent economic security   (class A or 1);
- Z_2 (66-84) – good economic security   (class B or 2);
- Z_3 (51-65) – satisfactory economic security   (class C or 3);
- Z_4 (31-50) – unsatisfactory economic security   (class D or 4);
- Z_5 (0-30) – absolute economic danger   (class E or 5).

The structure of the economic model for estimating and forecasting the level of economic security of the agrarian sector of the region of Ukraine (namely, the Vinnytsia region) will be presented in the form of the so-called "tree of logical conclusion". A logical conclusion tree is a graph that shows the logical connections between the predictive index Z and the factors $\{x_1 \ldots x_{22}\}$ that affect this predictive Z in compliance with the relationships given in formulas (1) to (5). Structural models of estimation and forecasting of the level of economic security of the agrarian sector of the region of Ukraine (namely: Vinnitsa region) will have the form shown in figure 2.

Presented structural analysis of the model of estimation and forecasting of the level of economic security of the agrarian sector of the Vinnytsia region shows that this model actually consists of five other interrelated models:

- the model of economic and financial factors providing economic security of the agrarian sector of the region;

- models of production-technological factors providing economic security of the agrarian sector of the region;

- models of natural and ecological factors ensuring economic security of the agrarian sector of the region;

- models of social and intellectual factors ensuring economic security of the agrarian sector of the region;

- models of institutional and political-integration factors ensuring economic security of the agrarian sector of the region.

Figure 2. Structural models of estimation and forecasting of level economic security of the agrarian sector of the region of Ukraine
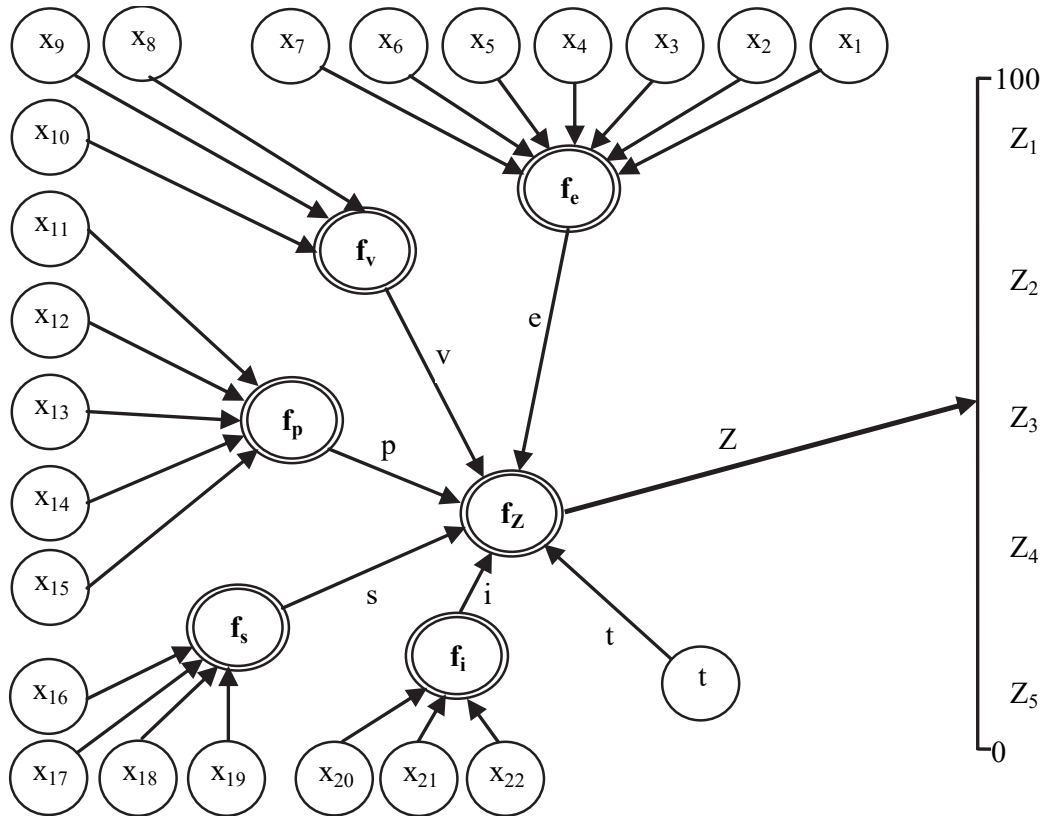
Source: compiled by the authors based on (Jurakovskiy et al, 2016)

It should be noted that when constructing the model, we operated with incoming quantitative and input qualitative parameters at the same time. Input parameters $\{x_1 \dots x_{14}, x_{16} \dots x_{18}\}$ are quantitative, and we used statistical data for their description. The parameters $\{x_{15}, x_{19} \dots x_{22}\}$ are qualitative, therefore for their description we used a scale of grades from 0 to 100 points.

The theory of fuzzy sets involves determining the levels (terms) of changes in the original index (Kozlovskyi et al, 2018). Each term is given by a fuzzy set with the corresponding membership function.

To describe the terms, we use the method shown in (S. Kozlovskyi and V. Kozlovskyi, 2005). In this case, the terms will be presented in the form of fuzzy sets, using the model of the membership function (MF):

$$\mu^T(x) = \frac{1}{1+\left[\frac{x-b}{c}\right]^2}, \tag{7}$$

where

b and c – membership function parameters (MF);
b – coordinate of the maximum of function;
c – coefficient of the concentration of stretching.

The values of the coefficients b and c for the variables x_1 are presented in table 3 (as an example).

Table 3. The values of the parameters b and the functions of the membership variables x_1

Input variables (parameter)	The name of the input variable (parameter)	Linguistic estimation of input variables (terms)	b	c
x_1	Average prices for grain and leguminous crops in the region	H	1	1
		C	2,5	1,5
		B	4	1,5

Source: developed by the authors

The choice of the membership function of this type (see formula 7) is explained by the fact that this feature is sufficiently flexible and simple, since it is given only by two parameters, and is more convenient for further adjustment of the model. The next step in modeling the level of economic security in the agrarian sector of Vinnytsia region is the compilation of a hierarchical knowledge base. To build the knowledge base, we used information from experts from the Department of Agrarian Development and the Department of Regional Economic Development of Vinnytsia Regional State Administration and the Main Department of Statistics in Vinnytsia region, factual information of central executive authorities of Ukraine and information from specialists in this field (Kaletnik et al., 2011).

Let's consider the relation (6). To estimate the value of linguistic variables that show the causal link between the level of economic security of the agrarian sector of the Vinnytsia region Z and economically-financial, industrial-technological, natural-ecological, social-intellectual, institutional and political-integration factors of influence we use the system of term-sets, which is proposed above. Then the knowledge base for the variable Z, which characterizes the level of economic security of the agrarian sector of the region of Ukraine (namely, the Vinnytsia region), will look like on table 4.

Table 4. Knowledge base of the variable Z

e	v	p	s	i	t	Z	w
H	H	H	H	H	t_1	Z_5	w_1
H	C	C	H	H	t_2	Z_5	w_2
C	H	C	H	H	t_4	Z_5	w_3
H	C	H	C	C	t_2	Z_4	w_4
C	C	H	H	C	t_3	Z_4	w_5
C	H	C	C	H	t_1	Z_4	w_6
C	C	C	C	C	t_4	Z_3	w_7
BC	H	C	BC	BC	t_1	Z_3	w_8
B	H	B	H	H	t_2	Z_3	w_9
C	BC	BC	BC	H	t_3	Z_2	w_{10}
BC	C	BC	C	C	t_2	Z_2	w_{11}
B	B	B	H	C	t_1	Z_2	w_{12}
B	B	B	B	B	t_3	Z_1	w_{13}
B	BC	BC	BC	C	t_4	Z_1	w_{14}
BC	B	B	BC	B	t_2	Z_1	w_{15}

Source: developed by the authors

Each knowledge base rule is an "IF-THEN" statement. Rules that have the same output parameter are merged in the table rows with the "OR" logical statement. The weight of the w rule expresses the personal confidence of the expert in this rule. At the stage of formation of the structure of the fuzzy model, we take the weight of all rules of the knowledge base equal to unity (Kozlovskyi and Grynyk, et al, 2017).

To implement a fuzzy logical conclusion, it is necessary to make a transition from logical statements to fuzzy logic equations (Zadeh, 1976). Such equations can be obtained by replacing linguistic values $\wedge$ with the values $\vee$ of membership functions, and the operations "YES" and "OR" are fuzzy logic operations of intersection and union. The weight of rules in the knowledge base is considered by multiplying the fuzzy expression corresponding to each line of the base to the corresponding value of weight (Rotshtein, et al, 1998).

Then listed in the table 4 linguistic statements will correspond to the following fuzzy logic equations (see formulas 8-12):

$$
\mu^{Z_5}(Z) = w_1 \cdot [\mu^H(a) \cdot \mu^H(e) \cdot \mu^H(s) \cdot \mu^H(p) \cdot \mu^H(i) \cdot \mu^{t_1}(t)] \vee
$$
$$
w_2 \cdot [\mu^H(a) \cdot \mu^C(e) \cdot \mu^C(s) \cdot \mu^H(p) \cdot \mu^H(i) \cdot \mu^{t_2}(t)] \vee
$$
$$
w_3 \cdot [\mu^C(a) \cdot \mu^H(e) \cdot \mu^C(s) \cdot \mu^H(p) \cdot \mu^H(i) \cdot \mu^{t_4}(t)];
$$
$$
(8)
$$

$$
\mu^{Z_4}(Z) = w_4 \cdot [\mu^H(a) \cdot \mu^C(e) \cdot \mu^H(s) \cdot \mu^C(p) \cdot \mu^C(i) \cdot \mu^{t_2}(t)] \vee
$$
$$
w_5 \cdot [\mu^C(a) \cdot \mu^C(e) \cdot \mu^H(s) \cdot \mu^H(p) \cdot \mu^C(i) \cdot \mu^{t_3}(t)] \vee
$$
$$
w_6 \cdot [\mu^C(a) \cdot \mu^H(e) \cdot \mu^C(s) \cdot \mu^C(p) \cdot \mu^H(i) \cdot \mu^{t_1}(t)];
$$
$$
(9)
$$

$$
\mu^{Z_3}(Z) = w_7 \cdot [\mu^C(a) \cdot \mu^C(e) \cdot \mu^C(s) \cdot \mu^C(p) \cdot \mu^C(i) \cdot \mu^{t_4}(t)] \vee
$$
$$
w_8 \cdot [\mu^{BC}(a) \cdot \mu^H(e) \cdot \mu^C(s) \cdot \mu^{BC}(p) \cdot \mu^{BC}(i) \cdot \mu^{t_1}(t)] \vee
$$
$$
w_9 \cdot [\mu^B(a) \cdot \mu^H(e) \cdot \mu^B(s) \cdot \mu^H(p) \cdot \mu^H(i) \cdot \mu^{t_2}(t)];
$$
$$
(10)
$$

$$
\mu^{Z_2}(Z) = w_{10} \cdot [\mu^C(a) \cdot \mu^{BC}(e) \cdot \mu^{BC}(s) \cdot \mu^{BC}(p) \cdot \mu^H(i) \cdot \mu^{t_3}(t)] \vee
$$
$$
w_{11} \cdot [\mu^{BC}(a) \cdot \mu^C(e) \cdot \mu^{BC}(s) \cdot \mu^C(p) \cdot \mu^C(i) \cdot \mu^{t_2}(t)] \vee
$$
$$
w_{12} \cdot [\mu^B(a) \cdot \mu^B(e) \cdot \mu^B(s) \cdot \mu^H(p) \cdot \mu^C(i) \cdot \mu^{t_1}(t)];
$$
$$
(11)
$$

$$
\mu^{Z_1}(Z) = w_{13} \cdot [\mu^B(a) \cdot \mu^B(e) \cdot \mu^B(s) \cdot \mu^B(p) \cdot \mu^B(i) \cdot \mu^{t_3}(t)] \vee
$$
$$
w_{14} \cdot [\mu^B(a) \cdot \mu^{BC}(e) \cdot \mu^{BC}(s) \cdot \mu^{BC}(p) \cdot \mu^C(i) \cdot \mu^{t_4}(t)] \vee
$$
$$
w_{15} \cdot [\mu^{BC}(a) \cdot \mu^B(e) \cdot \mu^B(s) \cdot \mu^{BC}(p) \cdot \mu^B(i) \cdot \mu^{t_2}(t)].
$$
$$
(12)
$$

The significance of the degrees of membership functions in equations (8) - (12) is determined by fuzzy knowledge bases that characterize economic-financial, production-technological, natural-ecological, social-intellectual, institutional-political-integration factors of influence.

Fuzzy logic equations (8) - (12) are a mathematical implementation of the model of estimation and forecasting of the level of economic security of the agrarian sector of the Vinnytsia region.

Defuzzification is the last stage of the simulation and represents a reverse transformation of the fuzzy logical statement (conclusion) found in the output estimating or predictive parameter (variable), which is subject to modeling and prediction. There are various methods of defuzzification, the choice and application of which depends on the object of modelling (Rotshtein, 1999).

Proceeding from the characteristics of the modelling purpose and the nature of the initial parameter (variable) to solve the logical equations we select the method of defuzzification, which is called "method of the center of gravity extended" (S. Kozlovskyi and V. Kozlovskyi, 2005). In our case, when the output parameter (variable) has "n" terms, the calculation of the center of gravity is reduced to the solution of equation (13):

$$Z = \frac{\sum_{i=1}^{n}\left[Z_E + (i-1)\cdot \frac{Z_A - Z_E}{n-1}\right]\cdot \mu^{Zi}}{\sum_{i=1}^{n} \mu^{Zi}}, \qquad (13)$$

where n – is the number of (discrete values) of the terms of the variable «Z»; $Z_E(Z_A)$ – lower (upper) limit of the range of variable "Z"; μ^{Zi} – function of the variable "Z" belonging to the fuzzy term "Z_i".

In the mathematical package Matlab (Pratar, 1999) an experiment was conducted using the above-mentioned method. The figure 3 shows the results of the estimation and forecasting of the level of economic security of the agrarian sector of the Vinnytsia region up to 2022.

Figure 3. Results of estimation and forecasting of the level of economic security of the agrarian sector of the region of Ukraine (namely: Vinnytsia region)
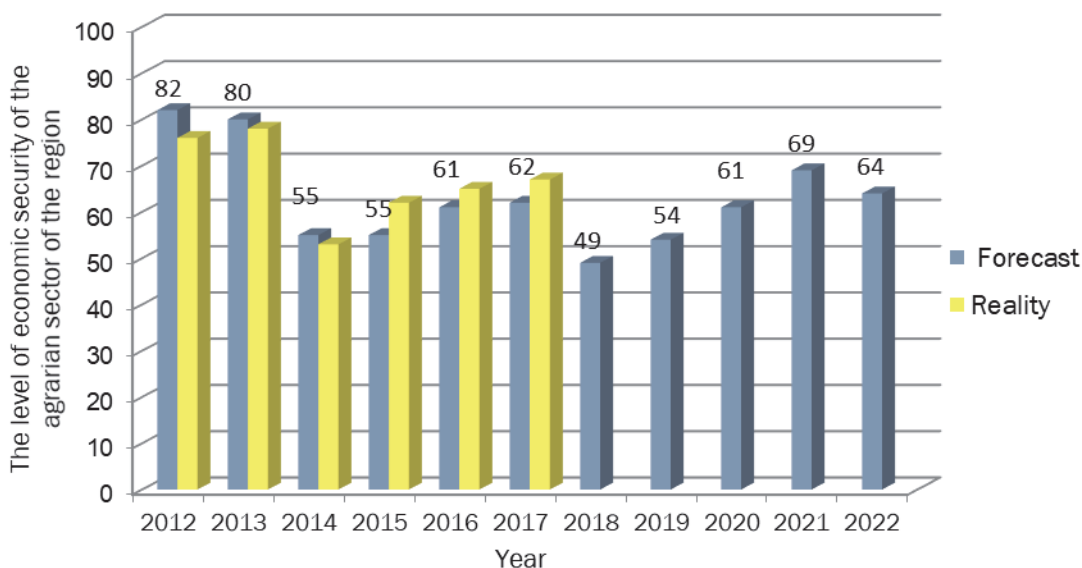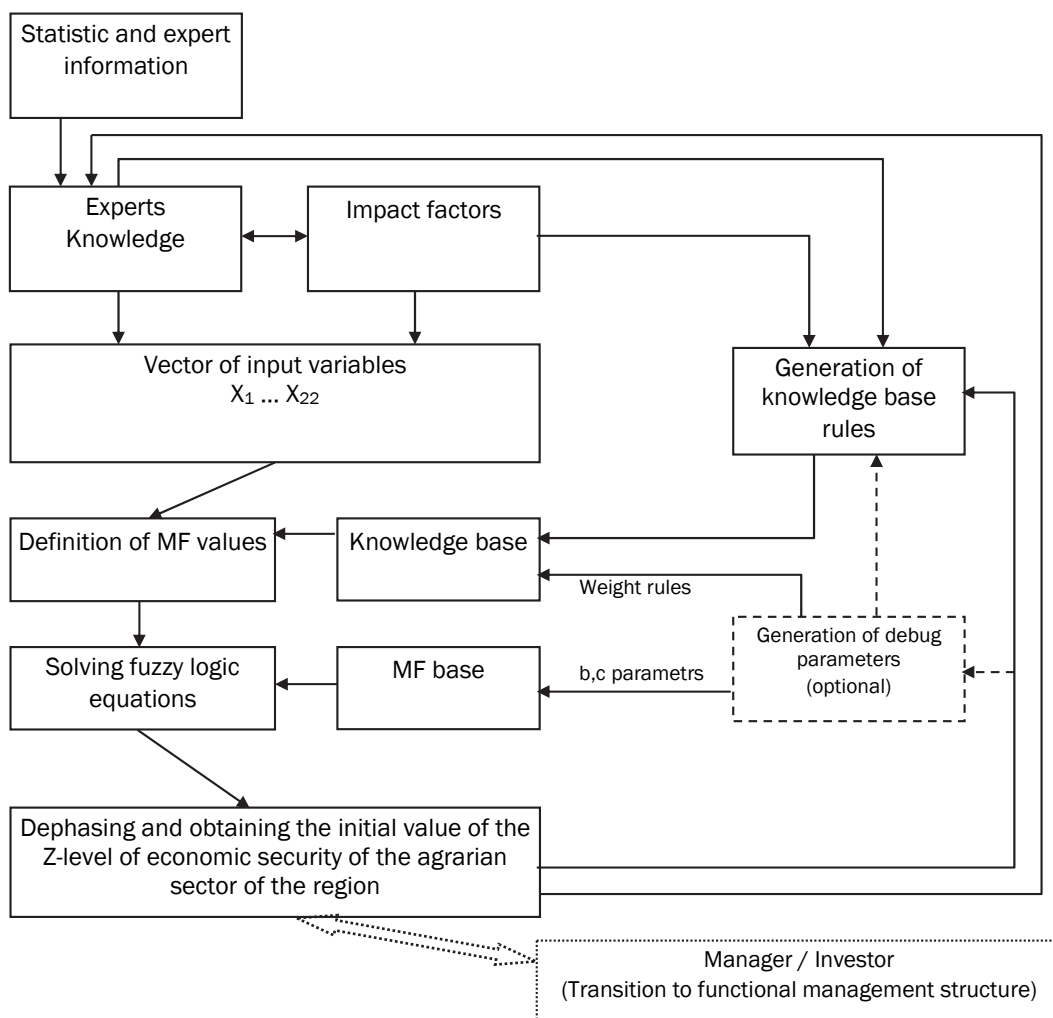

Source: developed by the authors

Analyzing the results of modeling the level of economic security of the agrarian sector of the Vinnytsia region for the period 2018-2022, one can draw the following conclusion: in 2018, the level of economic security of the agrarian sector of the region can be classified in class D – "*unsatisfactory economic security*". In 2019-2022, the predicted level of economic security of the agrarian sector will improve to class C – "*satisfactory economic security*". To improve the reliability of the forecast of the level of economic security of the agrarian sector of the region it is possible to optimize (adjust) this model.

The advantage of economic and mathematical models built with the use of fuzzy logic is the ability, when constructing a model, to take into account the input variables given by the linguistic conclusions of the experts, which largely compensates the lack of analytic relationships between the input and output variables of the prediction object.

However, the use of fuzzy logic makes it possible to realize another advantage of this method, namely – it gives an opportunity to influence the process of forming linguistic statements (conclu-

sions) of experts that they make on certain issues during the expertise. That is, models built with the use of a fuzzy logic have the ability to self-study. That is, the ability to flexible adjustment to reflect changes in the structure of causality between input and output parameters (variables) or according to changes in external factors. That provides an opportunity to build an interactive decision support system for managing the economic security of the agrarian sector of the Vinnytsia region. Considering the above-mentioned facts, the process of making and supporting investment decisions with the help of the developed model can be presented in form of the diagram shown in figure 4.

Figure 4. The block diagram of the process of acceptance and support of investment decisions with the help of the developed economic-mathematical model

Source: developed by the authors

We agree with the expert's opinion that the process of "decision-making2 by complexity and character is comparable directly with the thinking process. By making decisions, we understand the one-off act of choosing a certain alternative of managerial influence from their plurality. Among the input parameters of our economic and mathematical model of estimation and forecasting of the level of economic security of the agrarian sector of the region of Ukraine are parameters that take into account the process of human thinking. There are reflexive parameters x_{19}-x_{22}, which reflect the result of human thinking.

CONCLUSION

The situations in which decisions regarding the economic security of the agrarian sector of the Ukrainian regions are made aren't always clearly defined. The main difficulties in making decisions in uncertain situations are the impossibility of obtaining a completely reliable forecast or estimation of the probability of occurrence of specific events in one or another economic situation. The choice of an alternative solution is done with the help of the reflexive (intellectual) processes that we have taken into account in the developed model of estimation and prediction of the level of economic security of the agrarian sector of the region of Ukraine.

The developed economic-mathematical model of estimation and forecasting of economic security of the agrarian sector of the region of Ukraine can be considered as typical for this class of objects, and the modeling methodology developed on its basis can be used for modeling of any economic processes characterized by a fuzzy connection between the input and output parameters, the ability to draw linguistic conclusions of experts for the construction of models, etc.

The reported system allows predicting the level of economic security of the agrarian sector of the region of Ukraine and determining its state (class) based on analysis of expert statements. The developed system of support and decision-making will enable the management of central and regional authorities to make optimal decisions on the development and implementation of a program for the development of the agrarian sector, both for individual regions and for the country as a whole.

The developed economic-mathematical model allows an investor to determine the level of economic security of Ukrainian agrarian sector and make decisions based on the received information about the possibility of implementing investment policy in this sector of the economy. Also, an investor can monitor the level of economic security of the agrarian sector and find ways to improve it.

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