Modeling and Forecasting the Level of State Stimulation of Agricultural Production in Ukraine Based on the Theory of Fuzzy Logic

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ABSTRACT

Agricultural sector is a strategic sector for Ukraine; therefore, the task of developing effective incentive mechanisms for the development of agricultural production and increase of efficiency of activities of agricultural product manufacturers – economic entities of the agrarian market – is urgent. The conditions in which the agricultural sector of Ukraine is functioning, and research priorities of modern agricultural science provide an opportunity to deepen research in this direction and focus on justification of scientific and practical recommendations on creation of consolidated, adapted to domestic realities tools of stimulation of development of agricultural production in the country as a whole and its individual territories. The aim of this work is to develop economic and mathematical models of forecasting the level of economic and administrative stimulation of agricultural production in Ukraine based on the theory of fuzzy logic. The object of the study is the system of economic relations for stimulation of agricultural production in Ukraine. The subject of the study is principles of formation and development of economic and mathematical models of stimulation of agricultural production in Ukraine. The agricultural sector of Ukraine's economy with all the elements and components that provide the formation of the country's food security at the national level largely depends on the functionality of the mechanism of stimulation of development of agricultural production, which is one of the important and unsolved issues for Ukraine that requires a prompt solution. The study identifies the factors influencing the level of state stimulation of agricultural production in Ukraine. Factors influencing the level of agricultural production in Ukraine are classified. Economic and mathematical model of estimation and forecasting the level of economic and administrative stimulation of agricultural production in Ukraine is developed. The level of economic and administrative stimulation of agricultural production is forecast till 2020, which will allow forming the strategy of development of Ukraine's agricultural sector.

INTRODUCTION

Deep organizational and economic transformations in the agricultural sector of the national economy over the past 25 years have created an institutional framework for the development of domestic agricultural production, and its adaptation to the market competitive business environment has led to the restructuring of this production management by the state, including the restructuring of the system of stimulation and organization, as well as implementation mechanisms of managerial influence on the actors of the agricultural sector.

Ukraine, as one of the leading players on the world agricultural markets, is constantly making appropriate steps in the direction of regulation of economic relations in the agricultural sector of the economy. Prospects of development of agricultural production of Ukraine in the modern institutional environment require a higher level of competitiveness of domestic agricultural products and efficiency of activity of agricultural manufacturers. At the same time, the agro-industrial complex of Ukraine is still in a state of deep organizational and economic transformations which by their performance and functionality are not complete, which consequently makes relevant the issues of improving the incentive mechanism to promote the development of agricultural production.

Stimulation of agricultural production is an important component of the state policy of formation of the national food security guarantee, and for Ukraine, it is also a toolkit to facilitate global competitiveness; therefore, there is the need to search for approaches to make predictive estimates of possible and achievable results of both the stimulation and performance of the industry. The given problem statement on the need to develop economic and mathematical models of forecasting the level of stimulation of agricultural production is associated with the fact that this sector is strategic for Ukraine, so priority is given to ensuring its strategic competitiveness. This, in turn, actualizes the issue of stimulating agricultural production and, consequently, of making creative scenarios, models and forecasts, including with respect to the level of economic and administrative encouragement of economic market players. In methodological terms, the objective is not simple, but the ability to solve it is not considered something unattainable – this issue can be solved using the theory of fuzzy logic.

1. LITERATURE REVIEW

The experience of agricultural countries of the world shows that government support plays an important role in the development of agriculture. Recently, the Ministry of Agrarian Policy and Food of Ukraine has published the draft Law of Ukraine "On Stimulation of Development of Agro-industrial Complex of Ukraine" (2017), which provides for the regulation of relations connected with the implementation of the state policy on development of the agricultural sector of Ukraine, promotion of agricultural production, development of the agrarian market, creation of favorable conditions for economic entities in agriculture and food security.

Currently, as noted by Vakulenko V. (2016), the state support of the agro-industrial complex should be based on protecting national interests and taking into account the assumed international obligations under the WTO. Therefore, the Government of Ukraine (Official website of the Ministry of agrarian policy and food of Ukraine, 2018) is expected to promote the agro-industrial complex in the following directions: implementation of general measures (promotion of research and scientific-research activities, education and training of specialists, implementation of veterinary, sanitary and phyto-sanitary measures, implementation of information and consultancy work, implementation of advisory activities); activities for market development and production support (support of production of certain agricultural products, support of farmers' income, price stabilization in the agricultural market); incentives that are not related to production: regional benefits in depressed mountainous and disadvantaged regions, compensation to agricultural manufacturers of the cost of construction of social facilities in rural areas, etc.).

The process of promoting the growth of agricultural production may be considered through the process of state regulation. According to Y. Krupka (2006), state regulation of the agricultural sector is a form of the state influence on the agro-industrial complex of the country by establishing and enforcing by state authorities of rules aimed at the adjustment of economic activity of agricultural business entities for agriculture to achieve maximum efficiency to meet the needs of the population in food and the needs of industry in raw materials.

M. Latin (2005) considers the mechanism of state regulation of development of the agricultural sector of economy as the method of action of a regulated entity which is based on core principles and functions, providing the effective functioning of the system of state regulation to achieve the goal and to solve contradictions using certain forms, methods and means. I. Surai (2003) believes that the term "state regulation of the agricultural sector of economy" should be considered as part of the state management of the agricultural sector, which should manifest itself primarily through indirect economic incentives with regulatory support of economic processes in the agricultural sector of economy. H. Pavlova (2013) considers the state regulation as "a set of methods, forms and instruments of implementation of the state development strategy related to WTO requirements at different levels of management: joint ventures, related industries, regional and national with the priority of sustainable development of the agricultural sector".

Based on the above, it can be concluded that state regulation of the agricultural sector can be considered one of the most important components of the state stimulation of the agricultural sector of Ukraine. Analyzing the state and trends of development of the agricultural sector of Ukraine, it can be noted that the control of the industry has shifted to a market basis, because the agricultural sector in most of its manifestations has become a market segment with its inherent competition. Therefore, the agricultural sector requires the search for information appropriate to the requirements of business entities, analytical facts about the development of business structures, structuring of the state system of management of the agricultural industry and the like. At the same time, the management system of agricultural industry will only be functional under the condition when there is full and objective information on the state of the control object. This information may be obtained using modern economic and mathematical models, especially models those built by means of the theory of fuzzy logic.

For the development of economic and mathematical models for estimating and forecasting the level of economic and administrative stimulation of the agricultural production in Ukraine, we propose the use of a modern mathematical apparatus – the theory of fuzzy logic which is successfully used in other fields of human activities T. Saati (1991), A. Rotshtein (1998 . The theory of fuzzy logic in technical systems was investigated by L. Zadeh (1976), A. Rothstein (1999), S. Shtovba (2009), O. Kozachko (2010) and others. In economic systems, the theory of fuzzy logic was used by A. Matviychuk (2007), V. Kozlovskyi (2005), O. Burlaka (2016) and others.

As emphasized by K. Biliovskyi and O. Matkovska (2013) in the report "Application of fuzzy logic for the solution of economic problems," it is the uncertainty of information that makes to replace the traditional mathematical modeling methods with fuzzy logic methods. Methods of fuzzy logic allow the modeling of any socio-economic processes in the conditions of insufficient information and quantitative uncertainties of the input data. Advantages of the models based on fuzzy sets is the ability to use numerical and linguistic data, the possibility of obtaining generalized estimates in case of using mathematically unrelated input and output data, the possibility of taking into account the specifics of the studied object or process and the possibility of adjusting the model to the dynamic conditions of the economy. Therefore, for modeling and forecasting the level of economic and administrative stimulation of the agricultural production in Ukraine, it is appropriate to use a modeling method based on the theory of fuzzy logic.

Exploring the theory of stimulation of agricultural production, one should note the importance of development at the state level of the agricultural policy concept, as well as the state's position on this issue, which is formalized by economic incentive institutions and implemented by the rele-

vant state institutions. At present, the positive is the fact that the results of scientific practices developed by local experts and researchers are gradually embodied in the strategic and tactical plans, legal acts, which determine the set of incentives offered by the state to encourage the development of agricultural production.

Thus, institutionalization of the agricultural production support mechanisms in Ukraine is primarily implemented in the Constitution (1996), Laws of Ukraine: "On Principles of the State Policy for the Period until 2015" (2015), "On the State Support of Agriculture of Ukraine" (2004), which define the model, schemes and procedure for the stimulation of agricultural production. Conceptual scientific theoretical positions and definition of the components of the agricultural production support mechanisms that have been proposed by several researchers are systematized and presented in Table. 1.

Table 1. Conceptual definitions of the components of stimulation of agricultural production

Concept	Author/Informal definition of the content	Relation to the codification of stimulation
State regulation of the economy	I. Myhasuk (2006), Set of measures of the state influence on the subjects of market exchange for the need of directing their actions towards achieving the national goals	Macroeconomic and general political definition of stimulated occasions
	O. Kovtun (2006), Decision-making system for providing a framework regime in the economy development	
	V. Novichkov (2001), Actions of the state against the formation of framework conditions for agricultural sector development	Creation of a common institutional base for the formation of results of management in the industry
	A. Zanchenko (2004), Principles and actions taken by the government to resolve problem situations in agricultural exchange	Implementation of formal rules of stimulating influence
Agricultural policy	S. Mocherniy (2005), Strategic course of the state and a system of measures aimed at substantial improvement of living conditions of the population and ensuring food security of the country	Positioning of the general contours of the incentive under the state doctrine of control of the agricultural sector
	G. Kaletnik and G. Zabolotniy (2011), System of values, core imperatives around which the content and practical effectiveness of the managerial regulation of agro-economic system is conceptualized.	Approval of the institutional construction of the national identity of incentive mechanisms
Mechanism of state regulation	V. Andriychuk (2005), National economy management system through the use of economic laws, solution of contradictions in the social method of production, implementation of ownership, etc.	Functional combination of leverage, tools, techniques of direct implementation of state-market incentives

Source: compiled by the authors

2. METHODOLOGY

When analyzing the current state of development of the agricultural sector of Ukraine, we can say that market reforms in the agricultural sector are not completed, the institutional reform of the agricultural production support system is delayed, and its results cannot be considered to be those that significantly stimulate the agricultural production development.

Economic institutions for agricultural production support can be generally considered dysfunctional for the following reasons: formal and functional institutions (rules) for introduction of the

market of agricultural lands turnover are not formed; reasons for the price disparity and nonequiva-lence of interindustry exchange are not eliminated; investment and innovative attractiveness of the agricultural sector is unstable; effective system for legal protection of producers and employees, as well as guarantees of the adequate level of wages, land rents, and property are lacking. Therefore, we can assume that market institutions in the agricultural sector of Ukraine's economy are not yet fully formed.

The complexity and complexity of the problem under study does not allow the use of one indi-cator as a generalization criterion for assessing and forecasting the level of economic and adminis-trative stimulation of agricultural production in Ukraine. Using the methodology of system analysis and proceeding from the need to consider the agrarian sector as a complex hierarchical structure.

In order to ensure economic development of the agrarian sector of Ukraine in the conditions of globalization changes, it is expedient to use the following methods:

– Observation of the magnitude of the main macroeconomic indicators and their comparison with the threshold values for which the values of indicators are not lower than in the average world. An indicator approach that is used here allows you to analyze the state of the agrarian sector, taking into account its peculiarities.
– Comparison, that is, the calculation of the rates of economic growth by the main macroeco-nomic indicators and determining the dynamics of their changes.
– Expert evaluation, which enables to describe the qualitative characteristics of the investigated process.
– Scenario, which gives an opportunity to estimate the most probable course of development of events and possible consequences of the decisions taken on the basis of the expert's consid-eration of the smallest details of the current state of development of the phenomenon under study.
– Discriminant analysis, which involves establishing the essence of an unknown object based on the study of differences between several classes of objects in one or more parameters.

The aim of this work is to develop economic and mathematical models of forecasting the level of economic and administrative stimulation of agricultural production in Ukraine on the basis of the theory of fuzzy logic.

3. RESULTS

The peculiarity of Ukraine's agricultural sector is the fact that economic institutions for agricul-tural production support are functioning in the market conditions close to perfect competition. At the same time, the agricultural market is a very complex institutional body and it is a set of institu-tions, economic relations and a set of goods and services produced in different markets: market of agricultural products, market of agricultural services; market of raw materials and food, market of material and technical resources, financial, capital, means of production market, land market, la-bour market, etc. Within these markets and under the influence of the results (effects) of their ac-tivities and development, appropriate mechanisms to encourage the members of agricultural pro-duction are formed and operate.

The conditions of reproduction and the efficiency of agricultural production, as well as con-structiveness (rationality) of this process, are entirely dependent on the continuity of agricuural production, which, in turn, is due to the availability in agricultural producers of the necessarlty eco-nomic resources. The lack of economic resources can completely paralyze the development of agricultural production, which results in necessity for continuous diagnostics of its provision with the necessary raw materials, means of production, financial resources, etc. As the experience of developed countries shows, effective use at the micro level of the economic potential of agricultur-

al product manufacturers largely depends on the quality, reliability and credibility of information received by them.

The conditions in which the agricultural sector is functioning have a high level of variability and uncertainty, and this circumstance requires producers of agricultural products to find ways to obtain reliable information about the condition of the agricultural products market, organizational-functional connections between the economic market entities, prices of agricultural products, etc. One of the ways of addressing this issue is the use of economic and mathematical models of monitoring, diagnostics and forecasting built by means of the theory of fuzzy logic, which certainly will help to improve the efficiency and effectiveness of agricultural producers and ensure the development of Ukraine's agricultural sector as a whole.

Modern methodological approaches to the assessment and forecasting of the level of economic and administrative stimulation of agricultural production in Ukraine will include assessment of the risk magnitude. Therefore, one of methods of assessment and forecasting the level of economic and administrative stimulation of agricultural production in Ukraine is the development of algorithms using modern information technologies that enable to significantly improve the accuracy of the assessment and improve the efficiency and quality of managerial decisions taken on the basis of this assessment.

In presenting the results of research to solve the problem raised, it is proposed to use economic and mathematical methods of the new type allowing to conduct a problem-focused search, analyze information and provide the user with factual information in an accessible way (Mazur and Kozlovskyi, 2017). Fig. 1 shows a diagram of economic and mathematical models for assessment and forecast of the level of economic and administrative stimulation of agricultural production in Ukraine, which allows to implement the process described above.

Figure 1. Diagram of mathematical models of assessment and forecast of the level of economic and administrative stimulation of agricultural production in Ukraine
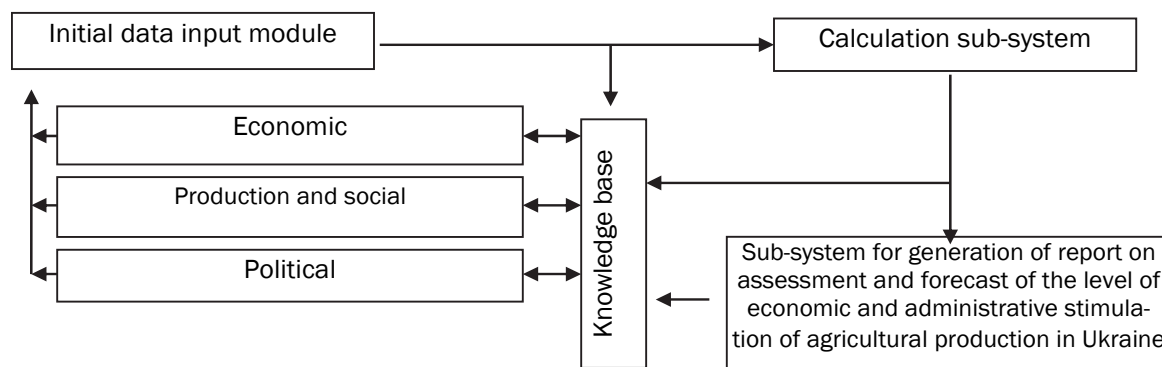
Source: compiled by the authors

The mathematical model shown in Fig. 1 suggests that at the state level, a responsible employee, based on the results of the accounting period (month, quarter, year), shall enter the initial data (information) which characterize specific components of agricultural production in Ukraine. The information further undergoes consolidation and analysis. That is, the responsible employee has the option, using the table and/or graphical ways to display the initial information, to compare the initial indicators with their threshold values and over any period of time in order to identify possible threats of reduction of the level of agricultural production in Ukraine.

Depending on how the interaction of different levels of stimulation of the agricultural sector is organized, we can distinguish two main classes of architectures of multilevel economic and math-

ematical models for assessing and forecasting the level of stimulation of agricultural production:
horizontally organized architecture and vertically organized architecture (S. Kozlovskyi, Gera-
symenko and V. Kozlovskyi, 2010].

In a horizontally organized architecture, all levels of economic and mathematical models are
interconnected by the level of perception and action (in other words, all model levels can com-
municate with each other). In a vertically organized architecture, only one of the levels is associat-
ed with the level of perception and action, and each of the other levels only interacts with a pair of
adjacent levels. The main problems of implementation of horizontal architectures are due to the
complexity of coordinating the work of individual levels. The disadvantage of a vertically organized
architecture is considered to be congestion of the execution levels (actions).

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

Input parameter (variable)	Name of the input parameter (variable)	Range of variability of the input parameter	Linguistic evaluation of the input parameters (terms)
x_1	Gross output of agricultural production in Ukraine	150-400 billion UAH.	Low, 150-200 billion UAH (L) Average, 200-300 billion UAH (A) High, more than 300 billion UAH (H)
x_2	Net profit of companies of the agro-industrial complex	100-200 billion UAH	Low, 100-120 billion UAH (L) Average, 120-150 billion UAH (A) High, 150-200 billion UAH (H)
x_3	Inflation rate in Ukraine	0-100 %	Low, 0-8 %, (L) Average, 8.1-15 %, (A) High, 15.1-100 %, (H)
x_4	Level of profitability of business activity of the agro-industrial complex	3-50 %	Low, 3-5%, (L) Average, 5.1-20%, (A) High, 20.1-50%, (H)
x_5	Amount of subsidies in the agri-cultural sector from the budget	50-500 million UAH	Low, 50-100 million UAH, (L) Average, 101-300 million UAH, (A) High, 301-500 million UAH, (H)
x_6	Number of companies of the agro-industrial complex	1-5 million units	Low 1-1.5 million units, (L) Average, 1.51-3 million units, (A) High, 3-5 million units, (H)
x_7	Average number of people employed in the agri-cultural sector	3-7 million people / year	Low, 3-4 million people / year, (L) Average, 4-6 million people /year, (A) High, 6-7 million people / year, (H)
x_8	Average salary of employees of the agro-industrial complex of Ukraine	4-15 thousand UAH / month	Low, 4 - 6 thousand UAH /month, (L) Average, 6 - 9 thousand UAH/ month, (A) High, 9-15 thousand UAH / month, (H)
x_9	Intellectual potential (human development index) of the country	0-1 units	Low, 0-0.5 (L) Average, 0.6-0.7 (A) High, 0.8-1 (H)
x_{10}	Level of political stability in the country	0-100 points	Low, 0-30, (L) Average, 31-60, (A) High, 61-100, (H)
x_{11}	Level of legislative support of development of the agro-industrial complex of Ukraine	0-100 points	Low, 0-30, (L) Average, 31-60, (A) High, 61-100, (H)
x_{12}	International political and eco-nomic influence on the agro-industrial complex of Ukraine	0-100 points	Low, 0-30, (L) Average, 31-60, (A) High, 61-100, (H)

Source: compiled by the authors

At the present time, these problems are solved through the application of modern methods of economic and mathematical modeling, namely fuzzy set theory (V. Kozlovskyi and S. Kozlovskyi, 2005). The main provisions of the theory of fuzzy sets and fuzzy logic that will be used later are given in L. Zadeh (1976), A. Rotshtein (1999), we will take them as a basis. Taking into account the need to respect fundamental principles for modeling the level of economic and administrative stimulation of agricultural production in Ukraine and the current conceptual apparatus of the theory of fuzzy logic, the input parameters of the model for assessment and forecast of the level of economic and administrative stimulation of agricultural production in Ukraine are given in Table 2.

To establish hierarchical relationships between the factors influencing the level of economic and administrative stimulation of agricultural production in Ukraine, it is advisable to group them into the following groups (according to Table 3): economic (e) production and social (v); political (p). These groups of influence factors as an "output tree" are shown in Figure 2-4.

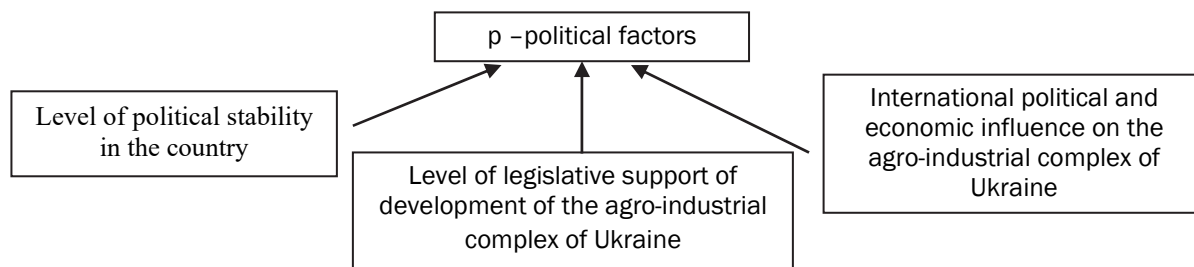**Figure 2.** Classification of economic factors
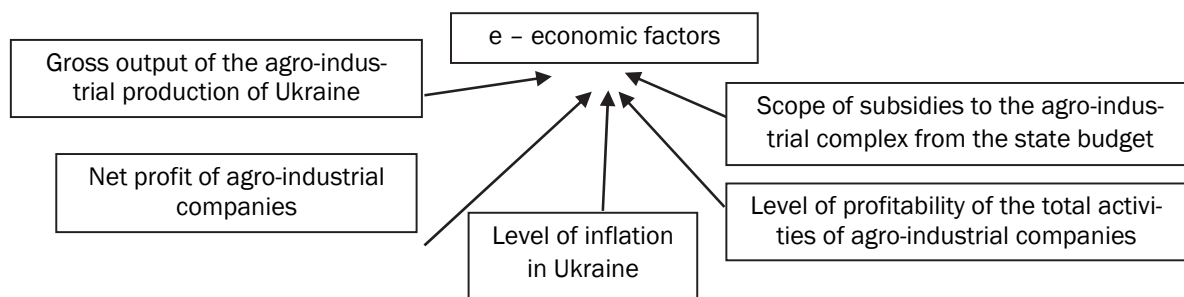
Source: compiled by the authors

Figure 3. Classification of production and social factors
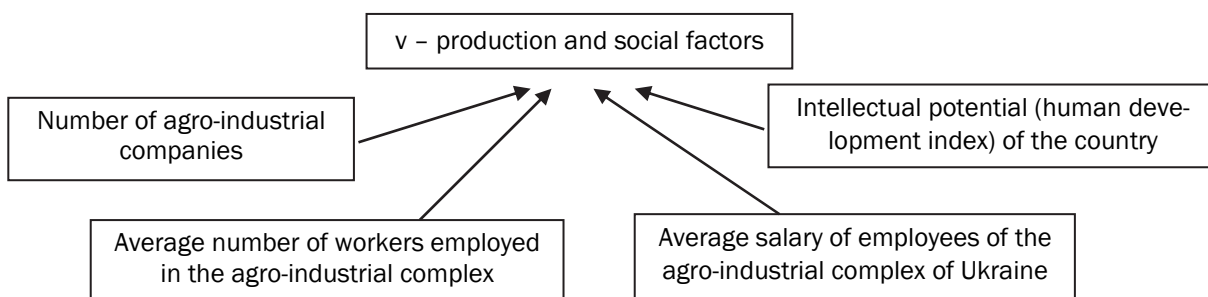
Source: compiled by the authors

Figure 4. Classification of political factors

Source: compiled by the authors

Using the diagrams shown in Fig. 2-4, we shall denote linguistic variable factors e, v, p with such relationships:

$$e = f_e(x_1, x_2, x_3, x_4, x_5), \qquad (1)$$
$$v = f_v(x_6, x_7, x_8, x_9), \qquad (2)$$
$$p = f_p(x_{10}, x_{11}, x_{12}), \qquad (3)$$

where $x_1 \div x_5$ – economic factors;

$x_6 \div x_9$ – production and social factors;

$x_{10} \div x_{12}$ – political factors.

The initial value, i.e. the level of economic and administrative stimulation of agricultural production of Ukraine, Z can be determined by formula (4):

$$Z = f_z(e, v, p, t), \qquad (4)$$

where e, v, p and t are linguistic variables describing the economic, production and social, political factors of influence and the forecast period, respectively. The forecast period t will be further encoded as two characters as in the sample: (6M, 1Y, 2Y, 3Y, where the letters M and Y indicate month and year).

Using the advice of experts (Official site of the Institute for Economic Research and Policy Consulting and Official website of the Ministry of agrarian policy and food of Ukraine) and in accordance with the specific economic situation that has developed in the Ukrainian, the level of economic and administrative stimulation of agricultural production of Ukraine can be characterized by the following levels (on a scale from "0" to "100"):

- Z_1 (85-100) – a high level of stimulation   (class A or 1);
- Z_2 (66-84) – an average level of stimulation   (class B or 2);
- Z_3 (51-65) – a satisfactory level of stimulation   (class C or 3);
- Z_4 (31-50) – an unsatisfactory level of stimulation   (class D or 4);
- Z_5 (0-30) – no stimulation   (class E or 5).

Table 2 shows the universal set and the evaluation terms of influence factors $x_1 \div x_{12}$, and the generalized variables are e, v, p evaluated at a single scale with a range from "0" to "100" points (see Table 3).

Table 3. Generalized input variables and their linguistic evaluation

Name	Denomination	Input parameters	Linguistic evaluation of input parameters (terms)
Economic factors	e	$x_1 - x_5$	Low, 0-30, (L)
Production and social factors	v	$x_6 - x_9$	Average, 30-50, (A)
			Above average, 50-75, (AA)
Political factors	p	$x_{10} - x_{12}$	High, 75-100, (H)
State determination (or prediction) period	t	t	t_1=6 months t_2=1 year; t_3=2 years; t_4=3 years

Source: developed by the authors

The structure of the economic model for assessment and forecast of the level of economic and administrative stimulation of agricultural production in Ukraine will be presented in the form of a so-called "tree of inference". Tree of inference is a graph which shows the logical connections between the predicted value Z and factors $\{x_1...x_{12}\}$ that influence this predictive value Z following the relations given in formulas (1) to (4). Structural model for assessing and forecasting the level of economic and administrative stimulation of agricultural production in Ukraine will have the form shown in Figure 5.

Figure 5. Structural model of assessing and forecasting the level of economic and administrative stimulation of agricultural production in Ukraine
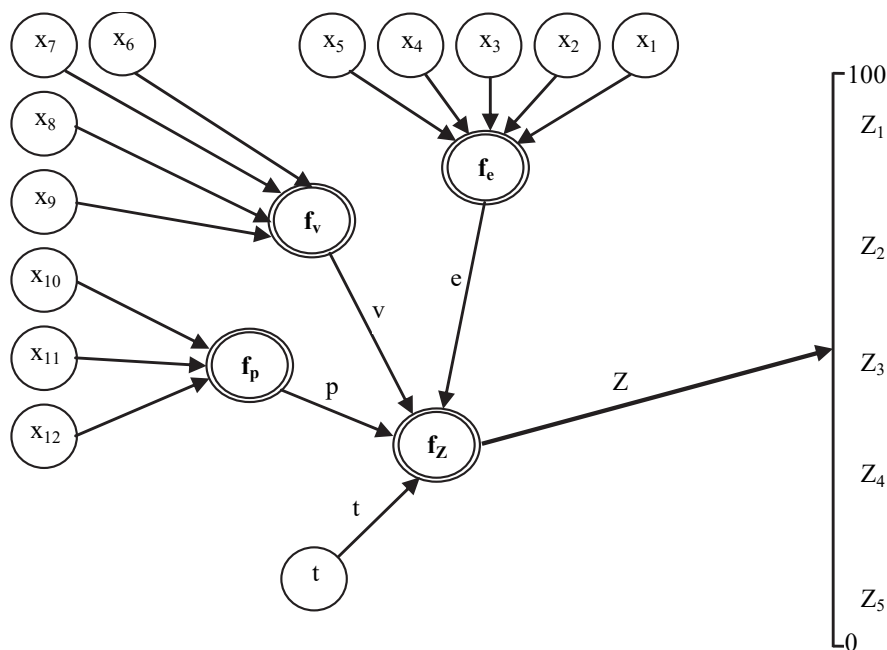
Source: developed by the authors

The nodes of the "tree of inference" are interpreted as follows: the root of the tree f_Z corresponds to the level of economic and administrative stimulation of agricultural production in Ukraine; the terminal nodes $x_1 \div x_{12}$ are the relevant factors of influence; non-terminal nodes f_e, f_v, f_p (double circles) are a set of partial influence factors in their totality. Terminal and non-terminal nodes of the "tree of inference" represent linguistic variables of a universal set which are given in Tables 2-3.

The structural analysis of the presented model of economic and administrative stimulation of agricultural production in Ukraine shows that this model actually consists of three interrelated models: 1) model of economic factors of stimulation of agricultural production in Ukraine; 2) model of production and social factors of stimulation of agricultural production in Ukraine; 3) models of political factors of stimulation of agricultural production of Ukraine.

It is worth noting that in building the model, we simultaneously employed the input quantitative and input qualitative parameters. Input parameters $\{x_1...x_9\}$ are quantitative, and statistical data were used for their description; parameters $\{x_{10}...x_{12}\}$ are qualitative, therefore, rating scale from "0" to "100" points was used for their description.

Since fuzzy set theory suggests the definition of levels (terms) of changes in the initial parameter, according to our model, we received three initial parameters for the assessment of which are fuzzy terms with scales given in Table 3 were used. Each term s presented as a fuzzy set with respective membership function. To describe the terms, we will use the technique given in [18]. We will be present the terms in the form of fuzzy sets using a model of membership function (MF):

$$\mu^T(x) = \cfrac{1}{1 + \left[\cfrac{x-b}{c}\right]^2} , \qquad\qquad (5)$$

where b and c are parameters of the membership function (MF); b – coordinate of the function maximum; c – rate of concentration expansion.

Values of b and c for the variables $x_1...x_{12}$ are given in Table 4 (as an example).

Table 4. Values of b and c parameters of the membership functions of variables $x_1... x_{12}$ and e, v, p models

| Input variables	Name of the input variable (parameter)	Linguistic evaluation of the input variables (terms)	b	c
x_1	Gross output of agricultural production in Ukraine	Low, (L)	7	3
		Average, (A)	20	8
		High, (H)	30	4
x_2	Net profit of companies of the agro-industrial complex	Low, (N)	5	10
		Average, (A)	15	9
		High, (H)	35	12
x_3	Inflation rate in Ukraine	Low, (N)	3	8
		Average, (A)	12	16
		High, (H)	50	35
x_4	Level of profitability of business activity of the agro-industrial complex	Low, (N)	4	10
		Average, (A)	14	32
		High, (H)	60	25
x_5	Amount of subsidies in the agricultural sector from the budget	Low, (N)	75	50
		Average, (A)	220	110
		High, (H)	400	90
x_6	Number of companies of the agro-industrial complex	Low, (L)	1	1
		Average, (A)	2	1
		High, (H)	3	1
x_7	Average number of people employed in the agricultural sector	Low, (L)	25	12
		Average, (A)	35	9
		High, (H)	45	8
x_8	Average salary of employees of the agro-industrial complex of Ukraine	Low, (L)	2	1
		Average, (A)	3.5	2
		High, (H)	5.5	3
x_9	Intellectual potential (human development index) of the country	Low, (N)	0.2	0.5
		Average, (A)	0.5	0.3
		High, (H)	0.7	0.4
$x_{10}... x_{12}$	Level of political stability in the country Level of legislative support of development of the agro-industrial complex of Ukraine International political and economic influence on the agro-industrial complex of Ukraine	Low, (N)	15	30
		Average, (A)	45	25
		High, (H)	85	38
e,v,p	Economic factors. Production and social. Political.	Low, (N)	15	12
		Average, (A)	42	15
		Above average, (AA)	60	25
		High, (H)	85	20

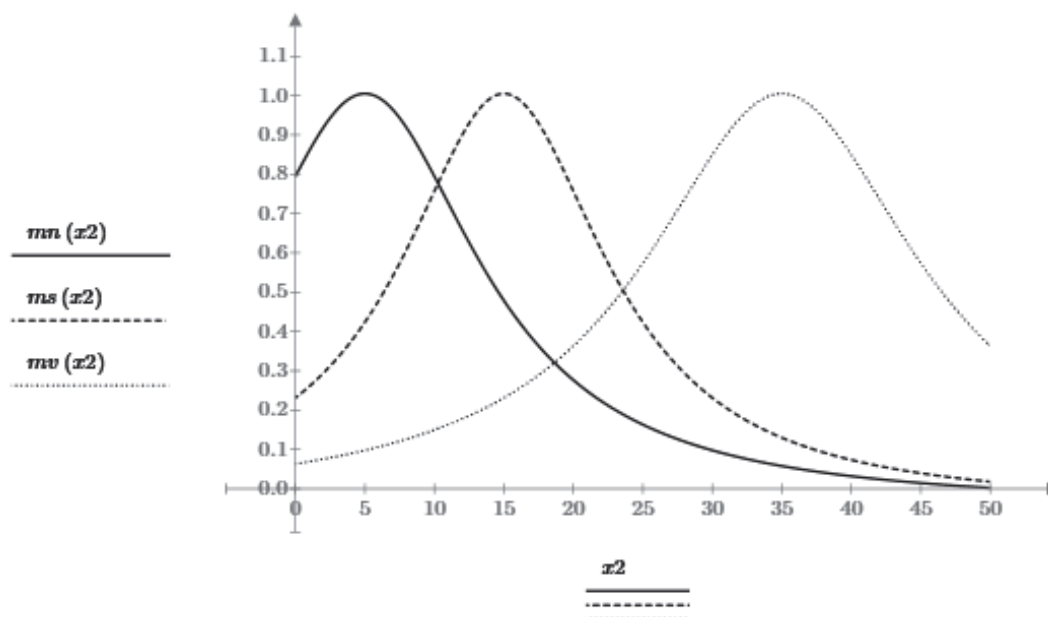Source: developed by the authors

The choice of the membership function of this type (see formula 5) is associated with the fact that this function is quite flexible and simple, as it is defined by only two parameters, and is also more convenient for further arrangement of the model. Membership function for variables x_1 and x_2, are shown in Fig. 6 as example.

Figure 6. Membership function for x_1 and x_2 variables of the model of economic and administrative stimulation of agricultural production in Ukraine

Figure 6a. Membership function for x_1 variable
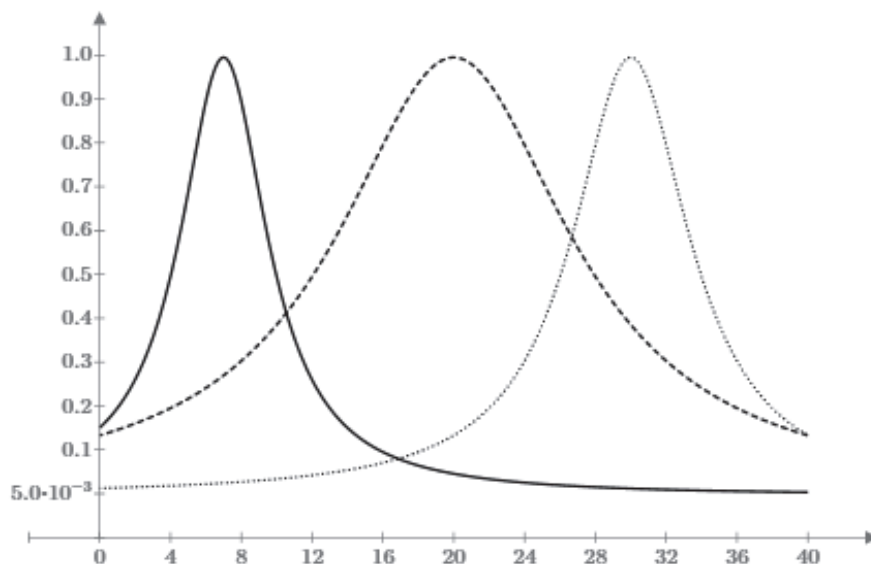
Figure 6b. Membership function for x_2 variable

Source: developed by the authors

The next step of modeling the level of economic and administrative stimulation of agricultural production in Ukraine is building up a hierarchical knowledge base. To build the knowledge base, we used the information obtained from the specialists of central executive authorities of Ukraine and information obtained from the specialists of the industry.

Let's consider equation (4). For assessment of the values of linguistic variables that show a causal relationship between the level of economic and administrative stimulation of agrarian production in Ukraine (Z) and the economic, production and social, political factors of influence, we will use the term-set system given in Table 3. Then the knowledge base for Z variable, which characterizes the level of economic and administrative stimulation of agrarian production in Ukraine (see equation 4), will be of the form given in Table 5.

Table 5. Knowledge base of Z variable

e	v	p	Z	w
L	L	L	Z_5	w_1
L	C	C	Z_5	w_2
A	L	A	Z_5	w_3
L	A	L	Z_4	w_4
A	A	L	Z_4	w_5
A	L	A	Z_4	w_6
A	A	A	Z_3	w_7
AA	L	A	Z_3	w_8
H	L	H	Z_3	w_9
A	AA	AA	Z_2	w_{10}
AA	A	AA	Z_2	w_{11}
H	H	H	Z_2	w_{12}
H	H	H	Z_1	w_{13}
H	AA	AA	Z_1	w_{14}
AA	H	H	Z_1	w_{15}

Source: developed by the authors

Similar to the above, knowledge bases for initial e, v, p values (not presented here) are being developed. It is known that each rule of the knowledge base represents the statement "IF-THEN". Rules that have the same initial parameter are combined in the table lines with a logical statement "OR". The weight of the w rule expresses the subjective confidence of the expert in this rule. At the stage of formation of the structure of a fuzzy model, the weights of all rules of the knowledge base are assumed to be equal to 1 (Zadeh, 1976). For Table 5, the statement "IF-THEN" is given in formula 6.

IF [e=L] and [v=L] and [p=L] OR [e=L] and [v=A] and [p=A] OR [e=A] and [v=L] and [p=A], THEN $Z=Z_5$;
IF [e=A] and [v=L] and [p=A] OR [e=A] and [v=A] and [p=L] OR [e=A] and [v=L] and [p=A], THEN $Z=Z_4$;
IF [e=A] and [v=A] and [p=A] OR [e=AA] and [v=L] and [p=A] OR [e=H] and [v=L] and [p=H], THEN $Z=Z_3$;
IF [e=A] and [v=AA] and [p=AA] OR [e=AA] and [v=A] and [p=AA] OR [e=H] and [v=H] and [p=H], THEN $Z=Z_2$;
　　IF [e=H] and [v=H] and [p=H] OR [e=H] and [v=AA] and [p=AA] OR [e=AA] and [v=H] and [p=H], THEN $Z=Z_1$.　　　　(6)

For implementation of fuzzy inference, it is necessary to make the transition from logical statements to fuzzy logical equations (Zadeh, 1976). Such equations can be obtained by replacing the linguistic values with the values of the membership functions, and operations "AND" and "OR" – with fuzzy logical operations of intersection $\wedge$ and integration $\vee$. The weight of rules in the knowledge base is taken into account by multiplying the fuzzy expression that corresponds to each row of the knowledge base by the corresponding weight value. Then, the following fuzzy logical equations will correspond to linguistic statements given in Table 5 and formula 6 (formula 7):

$$\mu^{Z_5}(Z) = w_1 \cdot [\mu^H(e) \cdot \mu^H(v) \cdot \mu^H(p) \cdot \mu^{1M}(t)] \vee$$

$$w_2 \cdot [\mu^H(e) \cdot \mu^C(v) \cdot \mu^C(p) \cdot \mu^{6M}(t)] \vee$$

$$w_3 \cdot [\mu^C(e) \cdot \mu^H(v) \cdot \mu^C(p) \cdot \mu^{1P}(t)];$$

$$\mu^{Z_4}(Z) = w_4 \cdot [\mu^H(e) \cdot \mu^C(v) \cdot \mu^H(p) \cdot \mu^{1M}(t)] \vee$$

$$w_5 \cdot [\mu^C(e) \cdot \mu^C(v) \cdot \mu^H(p) \cdot \mu^{6M}(t)] \vee$$

$$w_6 \cdot [\mu^C(e) \cdot \mu^H(v) \cdot \mu^C(p) \cdot \mu^{1P}(t)];$$

$$\mu^{Z_3}(Z) = w_7 \cdot [\mu^C(e) \cdot \mu^C(v) \cdot \mu^C(p) \cdot \mu^{1M}(t)] \vee$$

$$w_8 \cdot [\mu^{BC}(e) \cdot \mu^H(v) \cdot \mu^C(p) \cdot \mu^{6M}(t)] \vee$$

$$w_9 \cdot [\mu^C(e) \cdot \mu^{BC}(v) \cdot \mu^{BC}(p) \cdot \mu^{1P}(t)];$$

$$\mu^{Z_2}(Z) = w_{10} \cdot [\mu^C(e) \cdot \mu^{BC}(v) \cdot \mu^{BC}(p) \cdot \mu^{1M}(t)] \vee$$

$$w_{11} \cdot [\mu^{BC}(e) \cdot \mu^C(v) \cdot \mu^{BC}(p) \cdot \mu^{6M}(t)] \vee$$

$$w_{12} \cdot [\mu^B(e) \cdot \mu^B(v) \cdot \mu^B(p) \cdot \mu^{1P}(t)];$$

$$\mu^{Z_1}(Z) = w_{13} \cdot [\mu^B(e) \cdot \mu^B(v) \cdot \mu^B(p) \cdot \mu^{1M}(t)] \vee \qquad (7)$$

$$w_{14} \cdot [\mu^B(e) \cdot \mu^{BC}(v) \cdot \mu^{BC}(p) \cdot \mu^{6M}(t)] \vee$$

$$w_{15} \cdot [\mu^{BC}(e) \cdot \mu^B(v) \cdot \mu^B(p) \cdot \mu^{1P}(t)].$$

Values of degrees of membership functions in equation (7) are determined by fuzzy knowledge bases which characterize the economic, production and social, political factors of influence. Fuzzy logical equations (7) are the mathematical implementation of the model of assessing and forecasting the economic and administrative stimulation of agricultural production in Ukraine. The procedure of dephasing is the last stage of modeling and represents the inverse transformation of the found fuzzy logic statements (conclusion) into the initial evaluating or forecasting parameter (variable) that is subject to modeling and forecasting. There are various methods of dephasing, the choice and application of which depends on the object of modeling (Kozlovskyi and Kozlovskyi, 2005).

Based on the characteristics of the object of modeling and the nature of the initial parameter (variable), for the solution of logical equations we will select a method of dephasing which is called "method of center of weights, expanded" [18]. In this case, in order to determine the "center of weights", it is necessary to artificially extend the range of the initial parameter (variable). In our case, when the initial parameter (variable) has n terms, the calculation of the center of weights is reduced to the solution of equation 8:

$$Z = \frac{\sum_{i=1}^{n}\left[Z_E + (i-1) \cdot \frac{Z_A - Z_E}{n-1}\right] \cdot \mu^{Zi}}{\sum_{i=1}^{n} \mu^{Zi}}, \qquad (8)$$

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

Within the mathematical package Matlab 6.1 (Pratar, 1999), an experiment was conducted using the above technique. Fig. 7 shows the results of assessing and forecasting the level of economic and administrative stimulation of agricultural production in Ukraine until 2022. The results were obtained on the basis of analysis of values of influence factors (development) for 2012-2016.

Analyzing the results of modeling the level of economic and administrative stimulation of agricultural production in Ukraine for 2018-2022, one can make a forecast: in 2020 and 2021, the level of economic and administrative stimulation of agricultural production in Ukraine will be assigned to class D – "unsatisfactory level of stimulation". In 2018-2019, the forecast level of economic and administrative stimulation of agricultural production in Ukraine will deteriorate to class E – "lack of stimulation". In 2022, the forecast level of will improve to C level – "satisfactory level of stimulation". We emphasize again that this forecast is based on the analysis of the influence factors of 2012-2016.

Figure 7. Results of assessment and forecast of the level of economic and administrative stimulation of agricultural production in Ukraine
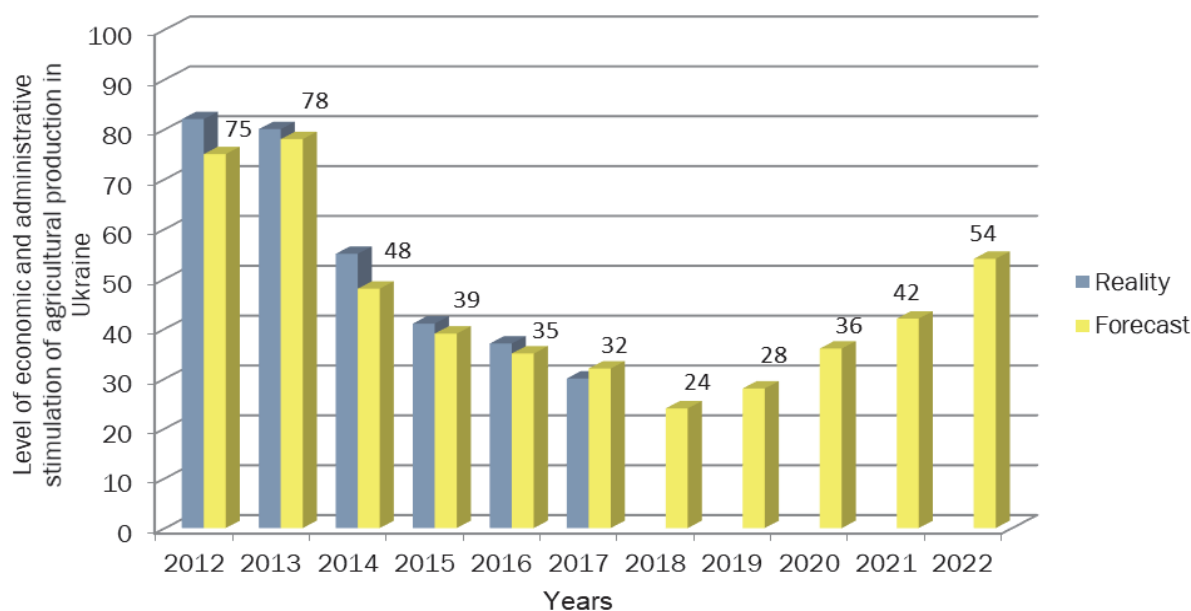
Source: developed by the authors

To improve the reliability of the forecast of the level of economic and administrative stimulation of agricultural production in Ukraine, it is necessary to optimize (setup) the model; this task, however, is beyond the scope of this study. As noted earlier, the advantage of economic and mathematical models constructed on the basis of fuzzy logic is the ability to use input parameters of linguistic statements (opinions) of experts, which largely compensates for the lack of analytical dependences between input and output parameters (variables) of the forecast object.

CONCLUSION

Developed innovative model for predicting the level and condition of economic and administrative stimulation for the development of agricultural production in Ukraine based on the theory of fuzzy logic allows defining the condition and the level of economic and administrative stimulation of the agricultural sector with dynamic change of linguistic model parameters. This model enables to make a linguistic assessment of factors in the macro environment influencing the effectiveness of stimulation that cannot be quantified, which is particularly relevant.

The use of this economic and mathematical model in practice will enable heads of government agencies, businessmen, farmers to assess and forecast the level of state stimulation of agricultural production in Ukraine. This assessment will allow taking certain managerial decisions related to business activities. It will also allow reducing business risks and carrying out effective agricultural activities in Ukraine.

The developed economic and mathematical model for assessment and forecast of economic and administrative stimulation of agricultural production in Ukraine can be considered as typical for this class of objects, and the modeling methodology developed on its basis can be applied to modeling of any economic processes characterized by a fuzzy relationship between the input and output parameters, significant difficulties in formalization of impacts, ability to draw linguistic statements (opinions) of experts to build models, etc.

REFERENCES

Andriychuk, V., Zubec, M., Yrchishen, V. (2005), *Modern agrarian policy: problematic aspects*, Agrarian science, Kiev (in Ukrainian).
Biliovsky, K., Matkovska, O. (2013), „Application of fuzzy logic to solve economic problems", avaible at: http://elartu.tntu.edu.ua/handle/123456789/19979
Burlaka, O. (2014), *«Methodological approaches to the sustainable development of the agrarian sector», Agrosvit,* No. 1, pp. 56-61 (in Ukrainian).
Kaletnik, G. M., Zabolotnyi, G. M. Kozlovskyi, S. V. (2011), «Innovative models of strategic management economic potential within contemporary economic systems», *Actual Problems of Economics,* Vol, 4(118), pp. 3-11.
Kozlovskyi, V., Kozlovskyi, S. (2005), *Macroeconomic modeling and forecasting of the exchange rate in Ukraine, Kniga-Vega,* Vinnitsa (in Ukrainian).
Kozlovskyi, S. V. (2010), „Economic policy as a basic element for the mechanism of managing development factors in contemporary economic systems", *Actual Problems of Economics,* Vol. 1(103), pp. 13-20.
Kozlovskyi, S. V. Gerasymenko, Y. V. Kozlovskyi, V. O. (2010), „Conceptual grounds for construction of support system for investment decision-making within agroindustrial complex of Ukraine", *Actual Problems of Economics,* Vol. 5(107), pp. 263-275.
Kovtun, O. (2006), *State regulation of economy,* Noviy svit, Lviv (in Ukrainian).
Krupka, Y. (2006), *Agrarne Law of Ukraine, Universitet Ukraina,* Kiev (in Ukrainian).
Latin, M. (2007), *"Improvement of the mechanism of state regulation of the agrarian sector development of the Ukrainian economy",* avaible at: http://www.kbuapa.kharkov.ua/e-book/db/2007-1-1/doc/2/06.pdf
Law of Ukraine (2015), *On Principles of the State Policy for the Period until 2015,* avaible at: http://zakon5.rada.gov.ua/laws/show/2982-15
Law of Ukraine (2004), *On the State Support of Agriculture of Ukraine,* avaible at: http://zakon4.rada.gov.ua/laws/show/1877-15
Law of Ukraine (1996),*«Constitution of Ukraine,* avaible at: http://zakon3.rada.gov.ua/ laws/show/254к/96-вр
Matviychuk, A. (2007), *Modeling of economic processes using methods of fuzzy logic, KNTEU,* Kiev (in Ukrainian).
Mazur, G., Kozlovskyi, S. (2017), *«Modeling and forecasting of the state stimulation of agroindustrial production in Ukraine on the basis of the theory of fuzzy logic», Economika ta derjava,* Vol. 9, pp. 8-15.
Mihasuk, I. (2006), *State regulation of economy,* Magnolia Plus, Lviv (in Ukrainian).
Mocherniy, S., Larina, Y., Ustimenko, S., Yriy, S. (2005), *Economic encyclopedia dictionary,* Svit, Lviv (in Ukrainian).
Novichkov, V., Kalashnikov, I. (2001), *Agrarian policy,* IKC Marketing, Moscow (in Russian).

Official website of the Food and Agriculture Organization of the United Nations, avaible at: http://www.fao.org

Official site of the Institute for Economic Research and Policy Consulting, avaible at: http://www.ier.com.ua/

Official website of the Ministry of agrarian policy and food of Ukraine, avaible at: http://minagro.gov.ua/en/node/15828

Panoshichen, Y., Kozachko, O. (2010), *"Fuzzy model for assessing the creditworthiness of individuals-borrowers of commercial banks", Visnik HNU,* No. 1, T2, pp. 161-168.

Pavlova, H. (2013), *State regulation of the agrarian sector as a component of the system of regulation of the economy of Ukraine,* avaible at: http://www.rusnauka. com/33_DWS_2013/Economics/15_149177.doc.htm

Pratar, R. (1999), *Getting started with Matlab 5. A quick introduction for scientists and engineers,* Oxford University Press, Oxford.

Project of Law of Ukraine (2017), *On stimulating the development of the agro-industrial complex of Ukraine*, avaible at: http://minagro.gov.ua/node/18940

Rotshtein, A., Teodorescu, A. (1998), *Design and Tuning of Fuzzy Rule – Based Systems for Medical Diagnosis, In Fuzzy and Neuro – Fuzzy Systems in Medicine,* CRC Press, Israel.

Rotshtein, A. (1999), *Intellectual identification technologies: fuzzy logic, genetic algorithms, neural networks, Universum, Vinnitsa* (in Ukrainian).

Rotshtein, A., Shtovba, S. (2009), «Modeling of the Human Operator Reliability with the Aid of the Sugeno Fuzzy Knowledge Base», *Automation and Remote Control,* Vol. 70, pp. 163-169.

Saati, T. (1991), *Analytical planning,* Radio, Moscow (in Russian).

Surai, I. (2003), «The concept of state administration of the agrarian sector of Ukraine's economy», *Scientific papers of NADU,* Vol. 2, pp. 259-270 (in Ukrainian).

Vakulenko, V. (2016), «Basic promotion of agricultural sector in Ukraine», Modeling and information of economic development of Ukraine*,* Vol. 1, pp. 13-18 (in Ukrainian).

Zadeh, L. (1976), *The concept of a linguistic variable and its application to making approximate decisions,* World, Moscow (in Russian).

Zanchenko, A., Nazarenko, V., Shaikin, A. (2004), *Agrarian policy,* Kolos, Moscow, (in Russian).