

## **Forecasting the competitiveness of the agrarian sector of Ukraine in the conditions of War and European integration**

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### **Abstract**

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The war in Ukraine, since 24 February 2022, the processes of integration of Ukraine into the European Union in June 2022, the presence of powerful competitors in the European markets encourage the formation of a set of measures with the distinction of tools to ensure the competitiveness of the agrarian sector of the state. The necessity of ensuring the competitiveness of Ukraine's agrarian sector on the basis of determining the competitive advantages dictate the urgency of scientific search for new methods, forms, tools for its enhancement, which will further promote the market relations in Ukraine and will have a direct impact on the well-being of the population. The aim of the work is to develop an innovative economic-mathematical model for assessing and forecasting the level of competitiveness of the agrarian sector of Ukraine, based on fuzzy sets in the conditions of war and European integration.

The object of the research is the process of ensuring the competitiveness of the Ukrainian agrarian sector. The subject of the research is methodological aspects of economic and mathematical modeling of the competitiveness of the agrarian sector of Ukraine in the conditions of war and European integration. The methodology of the study is based on the principles and mathematical provisions of fuzzy sets, which allows to use both qualitative and quantitative indicators of influence on the process under study. As a result of the research, based on fuzzy set theory, which allows taking into account both quantitative and qualitative factors of influence on the level of competitiveness, an innovative economic-mathematical model of valuation and forecasting of the level of competitiveness of the agrarian sector of Ukraine has been developed. The classification of factors influencing the level of agrarian sector competitiveness has been formed. The forecast (before the war and after the war), until 2026, of the level of competitiveness of the agrarian sector of Ukraine has been made, which will allow formulating a strategy of development of the agrarian sector of Ukraine in the conditions of war and European integration.

*Keywords:* modeling; forecasting; agrarian sector; competitiveness; fuzzy set theory; European integration; war; Ukraine

## Introduction

The war against Ukraine, launched by Russia on February 24, 2022, created many problems for the development of the agrarian sector of Ukraine. Economic processes in Ukraine in context of integration into the European economic community, the presence of strong competitors in the European markets and high requirements for both quality and food safety, condition the formation of a set of measures with the distinction of methodological tools to ensure the competitiveness of the national agrarian sector, which is directly related to the country's food security especially in times of war. In addition, it is important to address the problematic issues of entering the European market for the sectors of production, storage, processing and sale of agricultural products, as well as industries that directly manufacture the means of production and service for the agrarian sector in the context of integration processes.

The problems of the logistics of agricultural products during the war, created new problems for Ukraine, created completely new difficulties for the world economy.

At the same time, considering the constant increase of the level of markets openness and decrease in the degree of protectionism, competitiveness will be one of the most important factors that will determine in the future the ability of a product, an agricultural producer, agrarian sector and the country, as a whole to face the challenges in the domestic and European markets. The need to ensure the competitiveness of the national agrarian sector based (Halkiv et al., 2016; Jiang et al., 2019) on determination of competitive advantages and modern economic and mathematical methods dictate the relevance of the research topic.

While paying tribute to the scientific knowledge base of existing developments, in the field of justification of the sectoral competitiveness model, it should be noted that the task of provide the competitive advantages of the agrarian sector of Ukraine, in the context of war and European integration, sets new challenges for science to solve. One of them is the problem of entry of industrial producers into the EU market. Conceptual approaches to enhancing the competitiveness of the agrarian sector in the context of the Deep and Comprehensive Free Trade Area between Ukraine and the European Union require further scientific substantiation. There is an objective need for further reflection on the methodological component of national agricultural policy formation in the conditions of war and European integration, which can be developed, based on modern economic and mathematical methods.

## Material and Methods

A review of the literature on the provided goal of this paper shows that few studies have been devoted to modeling the level agrarian sector competitiveness of Ukraine. There are, especially few works devoted to the problems of modeling the level of competitiveness in war conditions. Existing studies on the use of methods of economic-mathematical modeling, methods theory of fuzzy set, have not previously been used to address the aim of this work.

Thus, Nykolyuk (2016) states that the imperfection of the institutional environment is an essential condition for shaping the competitiveness of agricultural enterprises. This can be solved by modeling the process of consolidation of agricultural enterprises.

Diachenko (2017) has another approach to the use of economic and mathematical methods. He notes that to achieve the quality of forecasting of the level of competitiveness in the agrarian sector, it is advisable to use SPACE analysis, which means selection of certain evaluation criteria and finding the integral development vector.

Bulger (2016) offers modern insights into the solving of competitiveness modeling task. She solves this problem using integrated economic intelligence systems. This integrated intelligence model means that competitive intelligence capabilities must include economic, market, competitive, commissioned and technological intelligence.

Badu (2017) believes that, it is possible to ensure the competitiveness of the agrarian sector by developing a typology of impact factors, based on the distinction of food security components.

Yaro et al. (2017) proved that, the effects of the models on household and local development are coproduced by their interaction, with pre-existing conditions and wider national economic structures.

Squalli et al. (2008), based on the report on the Global Competitiveness of the World Economic Forum, suggested using structural modeling that determines the weights of the competitiveness index. At the same time, this method is very difficult to implement, as it takes a very large amount of information and time to process it.

Mobius (2018) in his work, provides a thorough research on the definition of sustainable competitiveness and economic and mathematical methods of its description. The aforementioned scientist proposed an approach to determining the level of competitiveness, based on structural equation models and economic statistics. This approach allows evaluating the causal link between the various bases of sustainable competitiveness and empirical evidence.

It is determined that the most modern method of estimating the economic state of any processes is the methods of fuzzy set theory. The application of fuzzy set theory to solve the problem of economic evaluation in the agrarian sector of the Ukrainian economy is presented in the work by Kozlovskiy et al. (2018). The use of fuzzy set theory (Zadeh, 1965) makes it possible to operate both qualitative and quantitative indicators, to form an artificial intelligence system and to develop forecasts of the level of rating. The fuzzy set theory is an innovative mathematics that can be used to solve a research problem. Advantages of fuzzy set theory over other mathematical methods are provided in the work by Nikolenko et al. (2018) and Matviychuk (2013), which confirm the effectiveness of using fuzzy logic theory to solve the research problem.

Therefore, it is advisable to use a modeling method, based on theory fuzzy set to model, evaluate and predict the level of competitiveness of the Ukrainian agrarian sector.

The aim of the work is to develop an innovative economic-mathematical model for assessing and forecasting the level of competitiveness of the agrarian sector of Ukraine based on fuzzy sets in the conditions of war and European integration.

The methodological basis of the study is the economic and mathematical apparatus of the theory of fuzzy sets. The factual basis for the study is economic information on the development of the economy of Ukraine and its industries in the conditions of war. Expert information used in the research, is information from experts from both Ukraine and the European Union.

The general modeling methodology based on fuzzy logic theory assumes the following tasks (Kozlovskiy, 2010):

- identification of the main factors of influence that characterize the competitiveness of the national agrarian sector;
- formalizing the relationship between the factors of influence in a generalized form;
- definition and formalization of linguistic assessments of factors of influence;
- building a fuzzy knowledge base that identifies relationships between factors of influence;
- inference of fuzzy logical equations on the basis of linguistic assessments and fuzzy knowledge base;
- optimization of fuzzy model parameters.

The basic principles of fuzzy set theory and fuzzy logic, which are needed for further study, were provided by Rotshtein (1999), Panoshichen & Kozachko (2010), Rotshtein & Shtovba (2009).

## Results

Based on the theory of fuzzy set, the input parameters (Yousuf et al., 2019) of the assessment and forecasting model of the level of competitiveness will be the indicators developed by the authors in the scientific work by Varshavska (2018). These parameters are grouped in the following way: production and economic ( $v$ ); financial ( $f$ ); spatial ( $p$ ) (Table 1).

Using the classification links provided in Table 1, the linguistic variables of the factors  $v, f, p$  will be marked through the following relations:

$$v = f_v(x_1, x_2, x_3, x_4, x_5, x_6), \quad (1)$$

$$f = f_e(x_7, x_8, x_9, x_{10}), \quad (2)$$

$$p = f_p(x_{11}, x_{12}, x_{13}, x_{14}, x_{15}, x_{16}, x_{17}) \quad (3)$$

where  $x_1 \dots x_6$  – production and economic factors;

$x_7 \dots x_{10}$  – financial factors;  $x_{11} \dots x_{17}$  – spatial factors.

The initial value, i.e. the level of competitiveness of the agrarian sector of Ukraine, can be determined by the formula (4):

$$K = f_k(v, f, p, t), \quad (4)$$

where,  $f, p$  and  $t$  are linguistic variables describing, respectively, production and economic, financial, spatial factors of impact and forecasting period.

The prediction period  $t$  will then be encoded by two characters according to the pattern: (6M, 1Y, 2Y, 3Y where the letters M and Y mean month and year, respectively).

Using expert advice (Ministry of Economy of Ukraine), and according to the specific context in the agrarian ambit, the level of competitiveness can be characterized by the following level (on a scale of “0” to “100”):

- $K_1$  (85-100) – High competitiveness level (class 1);
- $K_2$  (66-84) – Medium competitiveness level (class 2);
- $K_3$  (51-65) – satisfactory competitiveness level (class 3);
- $K_4$  (31-50) – unsatisfactory competitiveness level (class 4);
- $K_5$  (0-30) – no competitiveness (class 5).

Based on the proposed impact factors (see Table 1). a generalization of model inputs is made and a single point scale with a range from zero to one hundred points is given (Table 2).

The structure of the economic-mathematical model of estimation and forecasting of the competitiveness level of the agrarian sector of Ukraine, will be presented in the form of “logical tree” (Derbentsev et al., 2020). Logical tree is

**Table 1. Input factors of the model**

Input parameter (variable)	Input parameter name (variable)	Change range of input parameter	Linguistic evaluation of input parameters (terms)
Classification of production and economic factors (v)			
x <sub>1</sub>	Gross production volume of agrarian sector	200-900 UAH billion.	Low, 200-300, (H); Medium, 300-700, (C); High, 700-900 (B)
x <sub>2</sub>	Number of enterprises in agrarian sector	10-100 thousands of units	Low, 10-30, (H); Medium, 30-50, (C); High, 50-100, (B)
x <sub>3</sub>	Number of employed population in agrarian sector	0,5-7 million people	Low, 0,5-2, (H); Medium, 2-4, (C); High, 4-7, (B)
x <sub>4</sub>	Labor productivity of agrarian sector enterprises	100-800 thousands UAH per 1 employee	Low, 100-200, (H); Medium, 200-400, (C); High, 400-800, (B)
x <sub>5</sub>	Activities profitability level of agrarian sector enterprises	0-100 %	Low, 0-20, (H); Medium, 20-50, (C); High, 50-100, (B)
x <sub>6</sub>	Production quality level of agrarian sector (generalized)	0-100 points	Low, 0-30, (H); Medium, 30-60, (C); High, 60-100, (B)
Classification of financial factors (f)			
x <sub>7</sub>	Price indices of agro-industrial production	0-100 %	Low, 100-105, (H); Medium, 105-110, (C); High, 110-130, (B)
x <sub>8</sub>	Net profit of agrarian sector enterprises	10-200 UAH billion.	Low, 10-30, (H); Medium, 30-60, (C); High, 60-200, (B)
x <sub>9</sub>	Capital investment in agrarian sector	5-100 UAH billion.	Low, 5-30, (H); Medium, 30-60, (C); High, 60-100, (B)
x <sub>10</sub>	Inflation level in Ukraine	1-50 %	Low, 1-3, (H); Medium, 3-8, (C); High, 8-50, (B)
Classification of spatial factors (p)			
x <sub>11</sub>	Social space development level in agrarian sector	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)
x <sub>12</sub>	Level of information and cyberspace development in agrarian sector	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)
x <sub>13</sub>	Level of infrastructure development in agrarian sector	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)
x <sub>14</sub>	The level of innovative technologies application in agrarian sector	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)
x <sub>15</sub>	The level of economic stability of Ukraine	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)
x <sub>16</sub>	The level of political stability and risk of war of Ukraine	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)
x <sub>17</sub>	Level of international impact on development of agrarian sector	0-100 points	Low, 0-30, (H); Medium, 31-60, (C); High 61-100, (B)

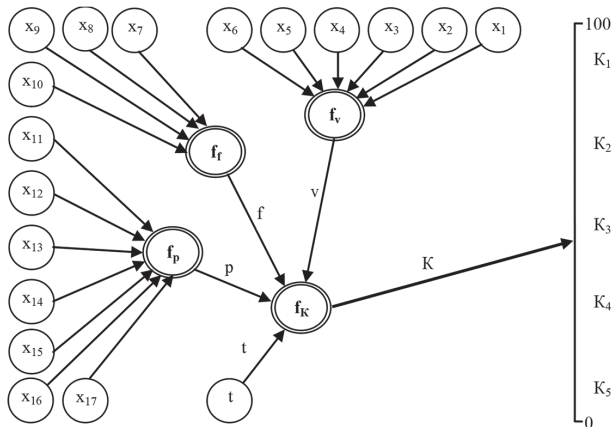
Developed by the authors based on Varshavska (2018)

**Table 2. Generalized indicators**

Name	Indication	Inputs	Inputs linguistic evaluation (terms)
Production and economic factors	v	x <sub>1</sub> ...x <sub>6</sub>	Low, 0-30, (H)
Financial factors	f	x <sub>7</sub> ...x <sub>10</sub>	Medium, 30-60, (C)
Spatial factors	p	x <sub>11</sub> ...x <sub>17</sub>	High, 60-100, (B)
Status determination period (or forecasting)	t	t	t <sub>1</sub> = 6 months; t <sub>2</sub> = 12 months; t <sub>3</sub> = 12 months; t <sub>4</sub> = 36 months

Developed by the authors

a picture that shows logical connections between the forecast indicator K and factors {x1...x17}, that influence this forecast indicator K being subject to the relations given in the formulas (1) – (3). A structural model for assessing and forecasting the competitiveness level of the agrarian sector will have the form shown in Figure 1.



**Fig. 1. A structural model for estimation and forecasting the competitiveness level of the agrarian sector of Ukraine**  
Developed by the authors

The vertices of the “logical tree” are interpreted as follows: the root of the tree  $f_k$  corresponds to the level of competitiveness of the agrarian sector; terminal vertices  $x_1...x_{17}$

are the relevant factors of influence; non-terminal vertices  $f_v, f_f, f_p$  are a set of partial factors of influence in their totality.

It is worth noting that when constructing the model, the input quantitative and input qualitative parameters were used simultaneously at the same time. Input parameters  $\{x_1...x_5, x_7...x_{10}\}$  are quantitative, and statistics were used to describe them; parameters  $\{x_6, x_{11}...x_{17}\}$  are qualitative, so a point scale from 0 to 100 points was used to describe them.

Since the theory of fuzzy sets involves determining the levels (terms) of changes in the output index, according to the described model, three output indicators were received, which are used to estimate fuzzy terms with the scales, given in Table 2. Each term is represented by a fuzzy set in the form of a membership function.

To describe the terms, the method described in works of Kozlovskiy et al. (2018), Rotshtein (1999), Rotshtein & Shtovba (2009) will be used. In this case, the terms are presented in the form of fuzzy sets, using the model of membership function:

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

where  $b, c$  – parameters of membership function (MF);  
 $b$  – function maximum coordinate;  
 $c$  – stretching concentration factor.

The values of the coefficients  $b$  and  $c$  for the variables  $x_1$  to  $x_{17}, v, f, p, K$  are presented in Table 3.

**Table 3. Values of the parameters  $b$  and  $c$  of variables membership function  $x_1...x_{17}, v, f, p, K$**

Input variables (parameter)	Input variable name	Terms	b	c
$x_1$	Gross production volume of agrarian sector	Low, 200-300, (H) Medium, 300-700, (C) High, 700-900 (B)	220 350 800	100 150 120
$x_2$	Number of enterprises in agrarian sector	Low, 10-30, (H) Medium, 30-50, (C) High, 50-100, (B)	15 40 75	20 30 25
$x_3$	Number of employed population in agrarian sector	Low, 0,5-2, (H) Medium, 2-4, (C) High, 4-7, (B)	1 3 5	2 3 2
$x_4$	Labor productivity of agrarian sector enterprises	Low, 100-200, (H) Medium, 200-400, (C) High, 400-800, (B)	150 300 600	100 180 150
$x_5$	Activities profitability level of agrarian sector enterprises	Low, 0-20, (H) Medium, 20-50, (C) High, 50-100, (B)	10 35 75	10 25 20
$x_6$	Production quality level of agrarian sector (generalized)	Low, 0-30, (H) Medium, 30-60, (C) High, 60-100, (B)	15 45 80	10 15 20

Table 3. Continued

$x_7$	Price indices of agro-industrial production	Low, 100-105, (H) Medium, 105-110, (C) High, 110-130, (B)	102 107 120	12 12 15
$x_8$	Net profit of agrarian sector enterprises	Low, 10-30, (H) Medium, 30-60, (C) High, 60-200, (B)	15 45 140	30 50 65
$x_9$	Capital investment in agrarian sector	Low, 5-30, (H) Medium, 30-60, (C) High, 60-100, (B)	15 45 80	20 25 20
$x_{10}$	Inflation level in Ukraine	Low, 1-3, (H) Medium, 3-8, (C) High, 8-50, (B)	2 6 25	3 10 20
$x_{11}$	Social space development level in agrarian sector	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$x_{12}$	Level of information and cyberspace development in agrarian sector	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$x_{13}$	Level of infrastructure development in agrarian sector	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$x_{14}$	The level of innovative technologies application in agrarian sector	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$x_{15}$	The level of economic stability of Ukraine	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$x_{16}$	The level of political stability and risk of war of Ukraine	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$x_{17}$	Level of international impact on development of agrarian sector	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$v, f, p$	Production and economic factors. Financial factors. Spatial factors.	Low, 0-30, (H) Medium, 31-60, (C) High 61-100, (B)	15 45 75	20 25 20
$K$	Competitiveness level of national agrarian sector	1 class, (1) 2 class, (2) 3 class, (3) 4 class, (4) 5 class, (5)	90 70 60 40 15	10 12 15 20 25

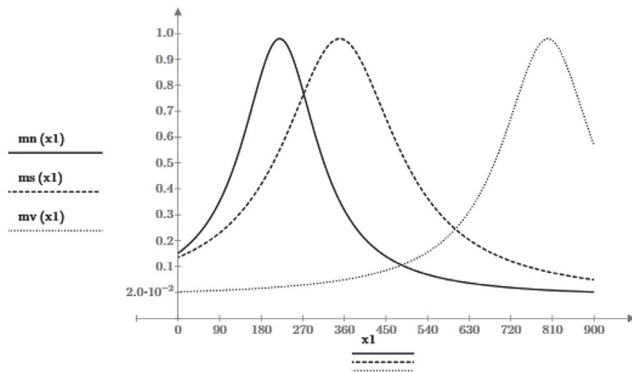
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The membership function of this type (see formula 5) was chosen because this function is quite flexible and simple.

The next step in modeling the level of competitiveness of Ukraine's agrarian sector is building a hierarchical knowledge base (Baidala et al., 2018; Fonitska et al., 2013; Kozlovskiy et al., 2010). For knowledge base creation the information was used (Ministry of Economic Development, Trade and Agriculture of Ukraine; Koziuk et al., 2018), as well as factual information of the central executive bodies of Ukraine and information of experts in this field.

The correlation (4), will be considered further. To estimate the value of linguistic variables, which show the causal relationship between the level of competitiveness of the agrarian sector  $K$  and production and economic, financial, spatial factors of influence, the term-sets system was used, which is shown in Table 2. Then the knowledge base for the variable  $K$ , which characterizes the competitiveness level of the agrarian sector, will have the form shown in Table 4 (and Figures 2 and 3 for example membership function  $x_1$ .  $K$ ).

Thus, following fuzzy logical equations will correspond to linguistic statements from Table 4 (see formulas 6-10).



**Fig. 2. Membership function for variable  $x_1$**   
Developed by the authors

**Table 4. Base of variable K**

v	f	p	t	K	w
H	H	H	$t_1$	$K_5$	$w_1$
H	C	C	$t_2$	$K_5$	$w_2$
C	H	C	$t_4$	$K_5$	$w_3$
H	C	H	$t_2$	$K_4$	$w_4$
C	C	H	$t_3$	$K_4$	$w_5$
C	H	C	$t_1$	$K_4$	$w_6$
C	C	C	$t_4$	$K_3$	$w_7$
B	H	C	$t_1$	$K_3$	$w_8$
B	H	B	$t_2$	$K_3$	$w_9$
C	B	C	$t_3$	$K_2$	$w_{10}$
B	C	C	$t_2$	$K_2$	$w_{11}$
B	B	B	$t_1$	$K_2$	$w_{12}$
B	B	B	$t_3$	$K_1$	$w_{13}$
B	C	B	$t_4$	$K_1$	$w_{14}$
C	B	B	$t_2$	$K_1$	$w_{15}$

Developed by the authors

$$\begin{aligned} \mu^{K_5}(K) &= w_1 \cdot [\mu^H(v) \cdot \mu^H(f) \cdot \mu^H(p) \cdot \mu^{t_1}(t)] \vee \\ w_2 \cdot [\mu^H(v) \cdot \mu^C(f) \cdot \mu^C(p) \cdot \mu^{t_2}(t)] \vee \end{aligned} \quad (6)$$

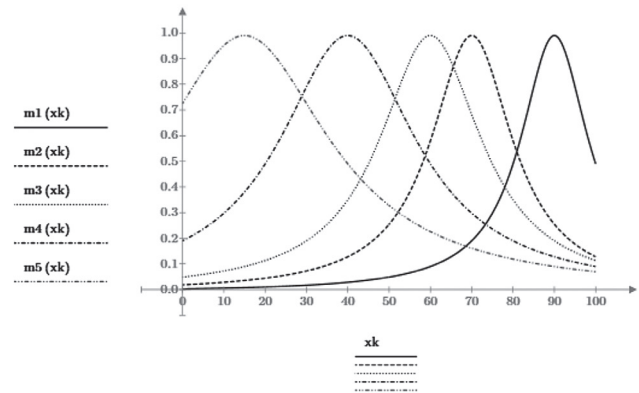
$$\begin{aligned} w_3 \cdot [\mu^C(v) \cdot \mu^H(f) \cdot \mu^C(p) \cdot \mu^{t_4}(t)]; \\ \mu^{K_4}(K) &= w_4 \cdot [\mu^H(v) \cdot \mu^C(f) \cdot \mu^H(p) \cdot \mu^{t_2}(t)] \vee \\ w_5 \cdot [\mu^C(v) \cdot \mu^C(f) \cdot \mu^H(p) \cdot \mu^{t_3}(t)] \vee \end{aligned} \quad (7)$$

$$\begin{aligned} w_6 \cdot [\mu^C(v) \cdot \mu^H(f) \cdot \mu^C(p) \cdot \mu^{t_3}(t)]; \\ \mu^{K_3}(K) &= w_7 \cdot [\mu^C(v) \cdot \mu^C(f) \cdot \mu^H(p) \cdot \mu^{t_4}(t)] \vee \\ w_8 \cdot [\mu^B(v) \cdot \mu^H(f) \cdot \mu^C(p) \cdot \mu^{t_1}(t)] \vee \end{aligned} \quad (8)$$

$$\begin{aligned} w_9 \cdot [\mu^B(v) \cdot \mu^H(f) \cdot \mu^B(p) \cdot \mu^{t_2}(t)]; \\ \mu^{K_2}(K) &= w_{10} \cdot [\mu^C(v) \cdot \mu^B(f) \cdot \mu^C(p) \cdot \mu^{t_3}(t)] \vee \\ w_{11} \cdot [\mu^B(v) \cdot \mu^C(f) \cdot \mu^C(p) \cdot \mu^{t_2}(t)] \vee \end{aligned} \quad (9)$$

$$\begin{aligned} w_{12} \cdot [\mu^B(v) \cdot \mu^B(f) \cdot \mu^B(p) \cdot \mu^{t_1}(t)]; \\ \mu^{K_1}(K) &= w_{13} \cdot [\mu^B(v) \cdot \mu^B(f) \cdot \mu^B(p) \cdot \mu^{t_3}(t)] \vee \\ w_{14} \cdot [\mu^B(v) \cdot \mu^C(f) \cdot \mu^B(p) \cdot \mu^{t_4}(t)] \vee \\ w_{15} \cdot [\mu^C(v) \cdot \mu^B(f) \cdot \mu^B(p) \cdot \mu^{t_2}(t)]. \end{aligned} \quad (10)$$

It is known that every rule of the knowledge base is an expression of “IF THEN”. Rules that have the same output parameter are combined in rows of tables by a logical expression «OR». The weight of rule  $w$  expresses the subjective confidence of the expert in this rule. At the stage of forming the structure of the fuzzy model, weights of all rules of the knowledge base were considered as one. In order to realize a fuzzy logical conclusion, it is necessary to make the transition from logical statements to fuzzy logical equations Rotshtein & Teodorescu (1998).



**Fig. 3. Membership function for output indicator K**  
Developed by the authors

The values of the degrees of membership functions in equations (6) – (10) are determined by fuzzy knowledge bases that characterize production and economic, financial, and spatial factors of influence.

Equations (6) – (10), are a mathematical implementation of the model of estimation and forecasting of the level of competitiveness of the agrarian sector of Ukraine.

The dephasification procedure is the last stage of modeling and is the inverse transformation of the found fuzzy logical statement (conclusion) into the original estimation or forecast parameter that is subject to modeling and forecasting.

There are various methods of defuzzification, the choice and application of which depends on the object of modeling (Kozlovskiy et al., 2018).

To solve this equation, we choose a method of dephasing, called the “center of gravity method extended” described in works by Rotshtein (1999); Rotshtein & Shtovba (2009) was chosen. In this case, to determine the “center of gravity” it is necessary to artificially expand the range of the output parameter. The center of gravity will be the value of the abscissa, which determines the position of the “center of gravity” that lies below the graph of its membership function.

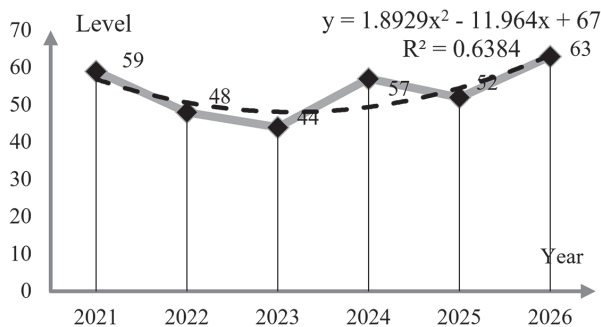
The calculation of the “center of gravity” is given by formula 11:

$$K = \frac{\sum_{i=1}^n [K_E + (i-1) \frac{K_A - K_E}{n-1}] \cdot \mu^{K_i}}{\sum_{i=1}^n \mu^{K_i}}, \tag{11}$$

- where n – the number of terms of variable K;
- bottom (top) limit of range of variable K;
- membership function of variable K to fuzzy term  $K_i$ .

In the pre-war period in Ukraine, namely December 1, 2021 there was an experiment in Matlab 6.1 mathematical package (Pratar, 1999) that used the above-mentioned method. The result of the assessment and forecasting of the level of competitiveness of the agrarian sector of Ukraine until 2026 is shown in Figure 4. The results were obtained based on the analysis of the values of factors of influence for 2017-2021.

In the pre-war period in Ukraine, analyzing the results of modeling the level of competitiveness of the agrarian sector of Ukraine for the years 2022-2026, the following forecast can be made: in 2024-2026, the competitiveness level of the agrarian sector will be assigned to the class 3 – “satisfactory competitiveness level”. Also, the developed model, showed



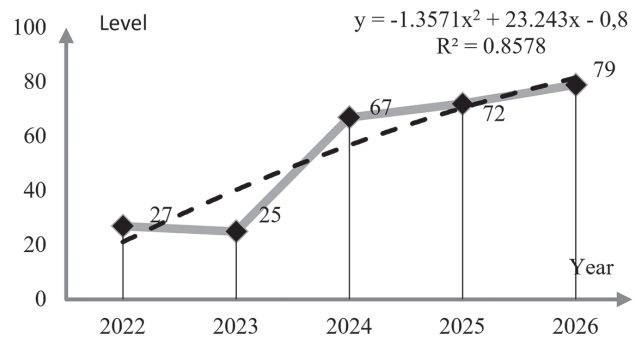
**Fig. 4. Estimation and forecasting of the level of competitiveness of the agrarian sector of Ukraine (made before the war on December 1, 2021)**  
Developed by the authors

with a verification level of 98.7% compliance that the competitiveness of the agrarian sector of Ukraine, in 2021, was at the level satisfactory competitiveness level (class 3). In 2022-2023, the forecast competitiveness level of the agrarian sector will deteriorate to class 4 – “unsatisfactory competitiveness level”.

Also, using this economic and mathematical model, based on updated data until March 2022, a new forecast was made for the level of competitiveness of the agrarian sector of Ukraine (Figure 5).

The simulation results showed that in 2022-2023, the level of competitiveness of the agricultural sector of Ukraine will be at the level of “no competitiveness” (class 5). But in 2024-2026, this figure will increase to “medium competitiveness level” (class 2).

Such a change in forecasts indicates a significant impact of the war on the economy of Ukraine. For further research, the authors will set the task of modernizing this economic and mathematical model for military factors (logistics problems, planting and harvesting problems, energy problems, fertilizer delivery problems, etc.).



**Fig. 5. Estimation and forecasting of the level of competitiveness of the agrarian sector of Ukraine (made in the conditions of war on June 1, 2022)**  
Developed by the authors

To improve the reliability of the forecast of the level of competitiveness of the agrarian sector, it is necessary to optimize this economic-mathematical model, but this task is beyond the scope of this study.

## Conclusion

The developed economic-mathematical model of forecasting the state and level of competitiveness of the agrarian sector of Ukraine in the conditions of war, and European integration, based on fuzzy, sets theory allows determining



the state and competitiveness level of the agrarian sector of Ukraine, with the dynamic change of the linguistic parameters of the model. This model makes it possible to make a linguistic assessment of competitiveness factors that influence the effectiveness of managerial decisions that are not quantifiable, which is especially relevant today.

Using this economic-mathematical model in practice, will allow heads of state institutions, businessmen, agrarians, EU representatives, to be able to make an assessment and forecast the level of competitiveness of the agrarian sector of Ukraine. In turn, this assessment will allow making justified business decisions. In addition, it will reduce business risks and implement effective economic policies in the conditions of war.

The developed economic-mathematical model of estimation and forecasting of the level of competitiveness of the agrarian sector of Ukraine in the conditions of war and European integration can be considered as typical for this class of objects. The modeling methodology developed on its basis can be used to model any economic processes characterized by fuzzy connection between input and output parameters, significant difficulties in formalizing the factors of influence and the ability to involve linguistic statements of experts to build a model etc.

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