

THE USE OF THE FUZZY GAME MODEL IN MANUFACTURE PLANNING AT THE AGROENTERPRISE

UDK 004: 519.631

DOI: <https://doi.org/10.35546/2313-0687.2018.24.101-113>

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Abstract. The market orientation of the agrarian sector is increasingly requiring agricultural managers not only to be able to see the prospects of their industry, but also to take effective managerial decisions in the given risky, crisis economic conditions. The manager, who takes decisions at a modern agroenterprise, must solve the problems of forming the product range and product yield, must evaluate the existing and expected market needs in this product, that is, solve the tasks of strategic management. To do this, he must have at his disposal mathematical methods and information technologies adapted to this subject area.

The purpose of the study is to use fuzzy game models of decision making when planning production at an agrarian enterprise. The issue of taking managerial decisions in agriculture requires more detailed mathematical processing and working out the principles and conditions for improving their efficiency. The methods of fuzzy set theory and game theory are used to create a manufacture planning model.

Research methods. The article considers the possibility of using fuzzy game models of decision making in manufacture planning at an agroenterprise. In order to improve the accuracy of manufacture planning forecasts, a production planning



model based on the data from previous sales has been proposed relying on the joint application of game theory and fuzzy mathematics.

The main results of research. The use of the proposed model will allow increasing the efficiency and quality of management decisions due to the integrated usage of mathematical models and methods.

Scientific novelty. To confirm the obtained results practically, the risk matrix, matrix of gain and criteria for decision making under conditions of uncertainty and risk were assessed, a set of fuzzy rules, which form together with the accepted conditions Wang-Mendel's fuzzy inference model, was given, and the value of gain for choosing a manufacture strategy based on a fuzzy game mode was calculated. The joint application of the game theory and fuzzy mathematics is determined, firstly by the conditions of uncertainty, and secondly by the refusal from the probabilistic approach applied in the theory of games. The proposed model allows carrying out calculations using modern information technologies.

Practical significance. The use of mathematical models and modern information technologies for agroenterprises will allow using the enterprise resources in a more efficient way; optimizing work; minimizing risks; analyzing thoroughly and accelerating the process of making managerial decisions. To take and implement decisions is the most important function of management, which successful execution ensures the enterprise to achieve its goals.

Keywords: *optimal manufacture planning, games with "nature", decision making criteria, Wang-Mendel's fuzzy inference model, fuzzy game model.*

Problem Statement. To take and implement decisions is the most important function of management, which successful execution ensures the enterprise to achieve its goals. The most well-developed subject is the construction of a mathematical model for optimizing a production programme. A large number of models of different completeness and complexity have been developed. However, there is a certain space for new investigations, especially in the area of adaptation of existing models and methods of optimizing the production programme to the peculiarities of a particular type of enterprises and a specific enterprise as well [5, 8, 11].

The issue of taking managerial decisions in agriculture requires more detailed mathematical processing and working out the principles and conditions for improving their efficiency [5, 11].

The need to consider the significant sources of uncertainty in planning at an agrarian enterprise, as well as to minimize their negative economic consequences, is nowadays obvious and widely recognized.

Review of the Literature. Problems of using the theory of games for the managing socio-economic facilities were considered in the works of D. Blackwell, V. Burkov, E. Ventsel, M. M. Girshik, M. Gubko, M. Dresher, G. Dyubin, Y. Zaychenko, M. Intriligator, S. Karlin, R. Keeney, P. Konyukhovskiy, N. Kremer, O. Larichev, D. McKinsey, O. Morgenstern, J. Neumann, S. Orlovsky, D. Pospelov, V. Suzdal, E. Trakhtengerts, D. Shapiro, D. Judin and others.

Despite the developed character of the theory of games and the diversity of its models and methods, in order to support decision-making in the matter of choosing a strategy there exist certain problems of their adaptation to a particular enterprise, because in most cases the task of choosing a strategy has a unique, individual character.

An overview of literary sources [5, 11, 14] meanwhile shows that the given difficulties can be eliminated when using the apparatus of fuzzy logical conclusions in game models [7, 8, 20, 33], with the help of which both wins and losses, and possible players' strategies are expressed in terms of fuzzy sets [7, 8, 12, 15].

The works of O. Altunin, V. Borisov, A. Kofmann A., V. Kruglov, S. Orlovsky, D. Pospelov, L. Wang, J. Mendel and other scholars are devoted to using the methods of the theory of fuzzy sets for solving the tasks of mathematical modeling.

The aim of the paper is to study the use of fuzzy game models of decision making in manufacture planning at an agrarian enterprise.

Presentation of research material. The problem of risk and profit is one of the crucial problems in economic activity, in particular in production and finance management. Risk is defined as the probability (threat) of loss by a person or organization of part of their resources, lack of income or the emergence of additional costs as a result of the implementation of certain production and financial policies [5, 11, 14].

One of the most common methods of strategic analysis, planning and management of agricultural enterprises are the methods of economic-mathematical modeling. These methods give an opportunity to conduct a comprehensive research of the structure of agricultural enterprises. At the same time, the methods of economic-mathematical modeling are used to make operative and strategic plans for the activity of agricultural enterprises. This is primarily due to the fact that these methods allow solving a number of issues related to the development of alternative ways of the activity of an enterprise, optimization of the structure of agricultural enterprises, optimization of production costs and sales of agricultural products [11, 14].

The use of methods of economic-mathematical modeling is firstly related to understanding of production processes and restrictions that operate in the manufacturing and sales of products. These restrictions form the structure of the economic-mathematical model of enterprise's activity and provide the basis for solving the given task. The restrictions of the economic-mathematical model are by their nature a mathematical interpretation of the statement of strategic management at agricultural enterprises.

The optimization economic-mathematical model is based on the restrictions of the activity of an agricultural enterprise. At the same time, these restrictions are divided into two groups: inequalities and equations. The first group of restrictions is the largest. A group of restrictions that consists of inequalities describes the process of manufacturing and sales of products. A group of restrictions that consist of equations most often describe the requirements to a task, but this group is rather rarely used in solving the optimization problem, since "hard" restrictions of the task do not allow conducting the modeling process using alternative solutions of the tasks [5, 11].

It is important that economic-mathematical modeling provides the opportunity to conduct a strategic analysis at all stages of agricultural production. In this case, the use of economic-mathematical modeling is possible for the analysis of the development of the activity of an enterprise in future periods, provided that the restrictions of the task will be established. Therefore, the most important factor influencing the quality of the carried out strategic analysis in agriculture is defining the restrictions of the enterprise's activity and being correctly reflected in the form of equations and inequalities.

One of the main advantages of using these methods is that economic-mathematical modeling provides an opportunity to investigate the effect of changing the certain restrictions of the task on forming the final result, thereby increasing the number of strategic alternatives without using a repeated full solution of the problem and finding the factors that have the largest influence on the final result of the task. The disadvantage of conducting economic-mathematical modeling is the lack of a clear mechanism that would take into account the restrictions of the modeling tasks of the activity of an enterprise, coming from the external environment of an agricultural enterprise [5, 11].

It is possible to optimize the manufacture of agricultural products of a particular enterprise with the help of methods of economic-mathematical modeling. The solution to the problem is to find the maximum yield from the sale of products in the conditions of limited amounts of manufacturing resources.

The structural model of the task has the form:

$$\left\{ \begin{array}{l} F_{\max} = \sum_{j=1}^n c_j x_j \\ \sum_{i=1}^m a_{ij} x_j \leq V_i \\ x_j \geq 0; \quad j = \overline{1, m} \end{array} \right.$$

where F – the income from sales of agricultural products (wheat) (thousand UAH);

c – the selling price of wheat (UAH);

x – the amount of agricultural products (wheat) (t);

a_{ij} – the norms of expenses of the i -type of resource for the production of 1 tonne of wheat (UAH / t);

V_i – the actual volume of the i -type of resource (UAH);

m – the number of available resources involved in the production process.

In order to make decisions in conditions of uncertainty and risk using the game model, the input information is presented in the form of a matrix, the lines of which are possible alternative solutions, and the columns are the states of the system (environment) [12-13, 15].

The matrix of possible wins (obtaining a conditionally net profit) - $\|V_{ji}\|$ is based on the data of Table 1 and Table 2. The set of managerial decisions is a finite number - R_j ($j = 380,67; 1818,92$ – from the minimum production to the possible maximum), S_i is the state of “nature” (in this case, production volumes for the previous periods). Implementation of the R_j solution in conditions when the “nature” is in a state will lead to a definite result in a quantitative terms.

The element of the matrix $\|V_{ji}\|$:

$$V_{ji} = \begin{cases} V_{prod_i} \cdot P - V_{vyrob_j} \cdot C, & V_{prod_i} \leq V_{vyrob_j} \\ V_{vyrob_j} \cdot P - V_{prod_i} \cdot C, & V_{prod_i} > V_{vyrob_j} \end{cases}$$

where V_{prod_i} – sales for the first year;

$i = 1,8$;

C – the purchase price of wheat;

P – the selling prices of wheat;

V_{vyrob_j} – the production volume;

$j = 380,67; 1818,92$.

The volume of production is adjusted taking into account the balances of wheat:

$$V_{vyrob_j} = \begin{cases} V_{vyrob_{j+1}} + (V_{vyrob_j} - V_{prod_i}), & V_{vyrob_j} \geq V_{prod_i} \\ V_{vyrob_j}, & V_{vyrob_j} < V_{prod_i} \end{cases}$$

Several criteria are used to make decisions under the conditions of uncertainty: Wald’s, Laplace’s, Savage’s, Hurwitz’s. The decision-making criterion is a function that expresses the benefits of the decision maker (DMP) and defines the rule according to which the acceptable or optimal solution is chosen [2, 3, 12, 13, 15].

Of course, choosing a decision-making criterion under the conditions of uncertainty is the most complicated and responsible step in the study of operations. There are no general tips or recommendations. The choice of the criterion should be developed by DMP, taking into account the

specific character of the problem to be solved and in accordance with their goals, and also based on past experience and own intuition.

In order to select the strategies more precisely, we should consider the same task but only from the standpoint of risk. Uncertainty predetermines the emergence of situations that do not have an unambiguous result (decision). Among the various types of situations faced by enterprises in the process of production, risk situations stand out.

The situation of risk should be understood as a combination, a set of different circumstances and conditions that create the situation of a particular type of activity. It is accompanied by three conditions:

- the presence of uncertainty;
- the need to choose an alternative (the refusal to choose such ones is a kind of alternative);
- a possibility to evaluate the probability of oncoming of the chosen alternatives.

Thus, if there is a possibility to determine the degree of probability of one or another option quantitatively or qualitatively, then this will be a situation of risk.

In order to exclude the risk situation, business managers are forced to make decisions and seek to implement them. The risk for decision-making processes under conditions of uncertainty and risk (under information deficiency or uncertainty in the reliability of the information) will be defined as purposeful actions, during which there is an opportunity to estimate quantitatively and qualitatively the probability of achieving the desired result, failure and deviation from the goal (positive or negative properties) [15].

The matrix of possible risks (the underdrawal of conventionally net profit) - $\|r_{ji}\|$ is based on the data of Table 1 and Table 2. The risk matrix gives a more vivid picture of an uncertain situation than the matrix of wins. The risk, therefore, is the difference between the result that can be obtained if you know the real state of “nature” and the result obtained with the j -strategy.

The matrix element $\|r_{ji}\|$:

$$r_{ji} = \begin{cases} (V_{vyrob_j} - V_{prod_i}) \cdot P - (V_{vyrob_j} - V_{prod_i}) \cdot C, & V_{vyrob_j} > V_{prod_i} \\ (V_{prod_i} - V_{vyrob_j}) \cdot P - (V_{prod_i} - V_{vyrob_j}) \cdot C, & V_{vyrob_j} \leq V_{prod_i} \end{cases}$$

In case when the situation is not the same, it is suggested to solve each of the payment matrices with the help of the apparatus of game theory and to obtain a solution.

The games will be final, because each player has a finite number of strategies. The game is classified as a game with "nature" because there is uncertainty caused by the lack of information about the conditions in which the action (demand) is carried out [12, 13, 15].

After selecting the optimal strategies (with the maximum received conditionally net profit and the minimum underdrawn conditionally net profit), the decision-making task is considered according to the chosen strategy based on the fuzzy game model. Classical matrix game models are used as models that represent risk, with looking for solutions in the class of mixed strategies, that is, based on the probabilistic approach [12, 13, 15].

We use the proposed approach [14] to justify the correct choice of manufacture planning strategy.

This strategy may be: 1) the minimum or average production strategy (defined expertly) that can bring losses (because the potential of the enterprise is not fully used) or income – d_1 can be chosen; 2) the optimal strategy (based on the choice of several criteria of optimality) is fully im-

plemented and will bring a certain income – d_2 ; 3) the maximum production strategy (determined by the optimization task) can be chosen, which will also bring losses (since not all manufactured products can be fully sold) or income – d_3 . The value of income is counted with a "+" sign, losses are counted with a "-" sign. The numerical values d_1 , d_2 and d_3 are known (or at least their estimates are known).

Whereas the project is unique. DMP can choose one of the two behaviour strategies: 1) to adopt an optimal production strategy; 2) not to adopt this strategy.

It is necessary to choose the strategy of DMP behavior in which their gain would, at least, be inseparable, and in the worst case, the losses would be zero. This situation is described by the player's A gain matrix A (DMP) of the matrix game between two players (Table 1).

Next the matrix model becomes fuzzy [1, 4, 6]. Expertly we can determine the degree of belonging to the alternatives of "nature" γ_j - the degree of certainty that the nature will choose the variant B_j . Expert assessments are selected according to E. Harrington's scale for formalizing heuristic information.

Table 1

The matrix of DMP wins

	B_1 (minimum or average production strategy)	B_2 (optimal strategy)	B_3 (maximum production strategy)
A_1 (DMP accepts the strategy)	d_1	d_2	d_3
A_2 (DMP does not accept the strategy)	0^*	0^*	0^*

* - DMP does not lose or gain anything.

The interpretation of the model in case the player A chooses the alternative A_1 is reflected in this case by a set of fuzzy production rules:

R_1 : if x is B_1 , then y is d_1 ,

R_2 : if x is B_2 , then y is d_2 ,

R_3 : if x is B_3 , then y is d_3 .

Here the variable x represents the player's B state (the state of "nature"), and y is the player's A (DMP) gain (loss).

The degree of truth of the premise of the first rule (R_1) is obviously γ_1 , the second - γ_2 and the third - γ_3 .

At the same time the set of the given fuzzy rules together with the accepted conditions build Wang-Mendel's fuzzy inference model [4, 10], according to which the exact value of the output variable (in this case, the value of the gain Q_1) is determined by the formula:

$$Q_j = \frac{\sum_{j=1}^3 a_j \cdot \gamma_j}{\sum_{j=1}^3 \gamma_j} \quad (1)$$

If player *A* selects the strategy *A2*, the wins (losses) of DMP obviously are zero $Q_2 = 0$.

The question of choosing a strategy is now solved by checking inequality: $\gamma_1 > Q_2$ or $Q_1 > 0$ [14]. If this inequality is fulfilled, then the strategy should be accepted, if it is not fulfilled, the strategy should be rejected.

In our case the wins and losses, as well as the degree of confidence for the “nature” alternatives (set by the experts) are given in Table 4 (the sum of alternatives are not necessary equal 1 [14]).

According to the output data of Table 2 and Table 3, the income matrix was determined and established according to the criteria:

- even without taking into account the choice of strategies, only at the expense of defining the conventionally received income (at the average price of sales in

2018), the chosen strategy - the production of 1818,29 thousand tons of wheat, then the income will reach its maximum (1181,89 thousand UAH). For most DMPs in practice in such cases solutions based on the criterion of maximizing the average expected income (or minimizing the expected expenses) are sufficient. Additional recommendations may be ambiguous, depending on the susceptibility to DMP risk;

- according to Laplace’s criterion it is the highest expected gain, according to Wald’s criterion – “pessimistic”, the best of the worst strategies, according to Savage’s criterion – the least value in the most unfavourable situation – the strategy of production of 380,67 thousand tons of wheat is recommended (income – 247,44 thousand UAH);

- according to Hurwitz’s criterion – when the decision maker tends to pessimism and optimism at 0.5 – the strategy of production is recommended when the chosen strategy is the production of 1818,29 thousand tons of wheat, then the income will reach its maximum (1181,89 thousand UAH) .

Table 2.

Production of agricultural crops – wheat in Kherson region (according to the website of the Main Department of Statistics in the Kherson region <http://ks.ukrstat.gov.ua>)

Year	2011	2012	2013	2014	2015	2016	2017	2018
Thousand tons	1589,97	380,67	900,78	1424,94	1818,29	1300,44	1696,24	1531,63

Table 3.

Sales of wheat at agricultural enterprises, except small ones (January-September) (according to the website of the Main Department of Statistics in the Kherson region <http://ks.ukrstat.gov.ua>)

Year	2011	2012	2013	2014	2015	2016	2017	2018
Thousand tons	493,8	162,2	196,1	506,0	650,3	617,8	525,3	535,3

Evaluating the matrix of risks:

- by the size of minimum average risk, according to Laplace's, Wald's, Savage's and Hurwitz's criteria the optimal production of 380,67 thousand tons of wheat (2352,22 thousand UAH – minimal losses) is determined.

In such a way, 380,67 thousand tons of wheat match the strategy of production: the highest expected gain and the smallest of the biggest risks. This solution will be optimal because there are signs that this solution is the best than all the rest.

Table 4.

Output data for determining strategy adoption

	B_1 (The average strategy production - the production of 1330,37 thousand tons of wheat)	B_2 (The optimal strategy production – the production of 380,67 thousand tons of wheat)	B_3 (The maximum strategy production – the production of 1818,29 thousand tons of wheat)
A_1 (DMP accepts the strategy)	The underdrawal of conventionally net profit (thousand UAH) - 118,56	The conventionally net profit (thousand UAH) – 245,50	The underdrawal of conventionally net profit (thousand UAH) - 183,72
A_2 (DMP does not accept the strategy)	0	0	0
the degree of confidence for the "nature" alternatives	0,2	0,5	0,5

After selecting the optimal strategies (the maximum of conditionally net profit and the minimum of conditionally underdrawn net profit), the task of decision-making on the chosen strategy is considered and is based on the fuzzy game model. The wins and losses, as well as the degree of confidence of experts for the "nature" alternatives are given in Table 4 (the sum of which is not necessary equal to 1). The decision should be taken if the value of the winning is bigger than zero.

If the values of the conditionally net profit and the conditionally underdrawn net profit have the value indicated in Table 4, then the value of the wins according to the formula will be (1):

$$Q_1 = \frac{-118,56 \cdot 0,2 + 245,50 \cdot 0,5 - 183,72 \cdot 0,5}{0,2 + 0,5 + 0,5} \approx 5,982$$

thousand UAH – the value is positive, therefore it is possible to accept the strategy. 5,982 thousand UAH is a value which sign determines the choice of one or another alternative.

This decision was made only as for wheat. On the basis of the proposed model, all selected strategies should be considered for reasoning. This scheme should be applied in the context of each type of agricultural production. After that the optimization actions in manufacturing all types of products should be carried out.

The proposed information technology of modeling the strategy choice for manufacture planning on the basis of a fuzzy game model, which uses fuzzy set theory and game theory tools, that allows us to determine the optimal strategy for manufacture planning, has the following algorithm:

- 1) determination of the maximum possible volume of production within the scope of the enterprise;
- 2) the formation of matrices of conditionally net profit or underdrawal of conditionally net profit (with different production variants and data from previous sales);
- 3) selection of manufacture planning strategy according to the criteria;
- 4) in the case the strategies coincide according to different criteria – the winning matrix of DMP is built (the list of the "nature" strategies is formed, the degrees of belong-

The software implementation of the prototype of information technology (Fig. 1 - Fig. 3) is carried out on the data of a particular enterprise using MS Excel and VBA for MS Excel.

Conclusions. Manufacture planning on the basis of data from the previous sales, with the help of the joint application of the theory of games and fuzzy mathematics allows us to choose the strategy of enterprise development. The joint application of the theory of games and fuzzy

mathematics is determined, firstly, by the conditions of uncertainty, and secondly, the refusal from the probabilistic approach applied in the theory of games. The use of the proposed model will increase the efficiency and quality of management decisions due to the multipurpose use of mathematical models and methods. The approach is realized on the data of the particular enterprise, the proposed model allows carrying out calculations using modern information technologies.

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**ВИКОРИСТАННЯ НЕЧІТКОЇ ІГРОВОЇ МОДЕЛІ ПРИ ПЛАНУВАННІ
ВИРОБНИЦТВА НА АГРОПІДПРИЄМСТВІ**

Анотація. Ринкова орієнтація аграрного сектора все більше вимагає від керівників сільськогосподарських підприємств не тільки вміння бачити перспективи своєї галузі, а й приймати ефективні управлінські рішення в сформованих ризикованих, кризових умовах господарювання. Керівник, який приймає рішення на сучасному сільськогосподарському об'єкті, повинен вирішувати проблеми формування номенклатури і обсягів продукції, що випускається, оцінювати існуючі та очікувані в перспективі потреби ринку в цій продукції, тобто вирішувати задачі стратегічного управління. Для цього він повинен мати в своєму розпорядженні математичні методи та інформаційні технології, адаптовані до даної предметної області.

Метою дослідження є використання нечітких ігрових моделей прийняття рішень при плануванні виробництва на аграрному підприємстві. Питання прийняття управлінських рішень в сільському господарстві потребують більш детальної математичної обробки та вироблення принципів і умов щодо підвищення їх ефективності. Для створення моделі планування виробництва використано методи теорії нечітких множин та теорії ігор.

Методи дослідження. У статті розглянуто можливість використання нечітких ігрових моделей прийняття рішень при плануванні виробництва на агропідприємстві. Для підвищення точності прогнозів планування виробництва запропоновано модель планування виробництва на основі даних попередніх продаж на базі спільного застосування теорії ігор і нечіткої математики.

Основні результати дослідження. Використання запропонованої моделі дозволить підвищити ефективність і якість прийняття управлінських рішень за рахунок комплексного використання математичних моделей та методів.

Наукова новизна. Для практичного підтвердження отриманих результатів були проведені оцінки матриці ризиків, матриці вигравів та критеріїв для прийняття рішень в умовах невизначеності та ризику, приведено набір нечітких правил, які разом з прийнятими умовами утворюють модель нечіткого логічного висновку Ванга-Менделя та розраховано значення вигравів для вибору стратегії виробництва на основі нечіткої ігрової моделі. Спільне застосування теорії ігор і нечіткої математики обумовлено, по-перше, умовами невизначеності, по-друге, відмовою від імовірнісного підходу, застосовуваного в теорії ігор. Запропонована модель дозволяє виконувати розрахунки із застосуванням сучасних інформаційних технологій.

Практична значимість. Використання математичних моделей та сучасних інформаційних технологій для агропідприємств дозволить ефективніше використовувати ресурси підприємства; оптимізувати роботу; мінімізувати ризики; ґрунтовно аналізувати та пришвидшити процес прийняття управлінських рішень. Прийняття та реалізація рішень є найважливішою функцією управління, успішне здійснення якої забезпечує досягнення підприємством його цілей.

Ключові слова: *планування оптимального виробництва, ігри з «природою», критерії прийняття рішень, модель нечіткого логічного висновку Ванга - Менделя, нечітка ігрова модель.*



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**ИСПОЛЬЗОВАНИЕ НЕЧЕТКОЙ ИГРОВОЙ МОДЕЛИ ПРИ ПЛАНИРОВАНИИ
ПРОИЗВОДСТВА НА АГРОПРЕДПРИЯТИИ**

Аннотация. Рыночная ориентация аграрного сектора все больше требует от руководителей сельскохозяйственных предприятий не только умения видеть перспективы своей отрасли, но и принимать эффективные управленческие решения в сложившихся рискованных, кризисных условиях хозяйствования. Руководитель, принимающий решения на современном сельскохозяйственном объекте, должен решать проблемы формирования номенклатуры и объемов выпускаемой продукции, оценивать существующие и ожидаемые в перспективе потребности рынка в этой продукции, то есть решать задачи стратегического управления. Для этого он должен иметь в своем распоряжении математические методы и информационные технологии, адаптированные к данной предметной области. Целью исследования является использование нечетких игровых моделей принятия решений при планировании производства на аграрном предприятии. Вопрос принятия управленческих решений в сельском хозяйстве требуют более детальной математической обработки и выработки принципов и условий по повышению их эффективности. Для создания модели планирования производства использованы методы теории нечетких множеств и теории игр. Методы исследования. В статье рассмотрена возможность использования нечетких игровых моделей принятия решений при планировании производства на агропредприятии. Для повышения точности прогнозов планирования производства предложена модель планирования производства на основе данных предыдущих продаж на базе совместного использования теории игр и нечеткой математики. Основные результаты исследования. Использование предложенной модели позволит повысить эффективность и качество принятия управленческих решений за счет комплексного использования математических моделей и методов. Научная новизна. Для практического подтверждения полученных результатов были проведены оценки матрицы рисков, матрицы выигрышей и критериев для принятия решений в условиях неопределенности и риска, приведены набор нечетких правил, которые вместе с принятыми условиями образуют модель нечеткого логического вывода Ванга-Менделя и рассчитано значение выигрыш для выбора стратегии производства на основе нечеткой игровой модели. Совместное применение теории игр и нечеткой математики обусловлено, во-первых, условиями неопределенности, во-вторых, отказом от вероятностного подхода, применяемого в теории игр. Предложенная модель позволяет выполнять расчеты с применением современных информационных технологий. Практическая значимость. Использование математических моделей и современных информационных технологий для агропредприятий позволит эффективнее использовать ресурсы предприятия; оптимизировать работу; минимизировать риски; основательно анализировать и ускорить процесс принятия управленческих решений. Принятие и реализация решений является

важнейшей функцией управления, успешное осуществление которой обеспечивает достижение предприятием его целей.

Ключевые слова: планирование оптимального производства, игры с «природой», критерии принятия решений, модель нечеткого логического вывода Ванга - Менделя, нечеткая игровая модель.

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