EXPERT-STATISTICAL METHOD OF MANAGEMENT DECISION SUPPORT FOR AGRICULTURAL ENTERPRISES OF NORTHERN KAZAKHSTAN

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ABSTRACT

The article deals with the problem of making management decisions on the production scenarios of agricultural enterprises in Northern Kazakhstan. The problem is caused by the presence of a set of criteria (parameters) of production and market conditions, the correctness of the criteria determines the quality of making a management decision on the preferred scenario for the functioning of an agricultural object. The purpose of the study is to structure the problem and formalize the problem of decision-making on the choice of the scenario of rational organization of production at the enterprises of the agricultural sector of Northern Kazakhstan in the conditions of multi-criteria factors of influence. The research methodology is based on a systematic approach that allows us to consider a system of interdependent components (resources, production scenarios) as a closed logical structure that provides rules for analyzing a complex problem. The heuristic analytical hierarchy process is used as a mathematical tool of the system approach for solving the multi-criteria problem of choosing the preferred scenario. The hierarchical approach is implemented for the decomposition into groups of the considered set of interdependent components with the procedure of sequential clustering of the components. Based on this method, the problem of making management decisions on the scenarios of production of agricultural enterprises is structured in the form of a dominant hierarchy of four levels. Groups of criteria that characterize the production conditions of an agricultural enterprise are identified. To determine the degree of influence (priorities) of the criteria, it is recommended to introduce expert assessments of the criteria with a transition from qualitative to quantitative characteristics based on a verbal-numerical unified scale. The technology for calculating criteria priorities is based on the matrices of paired comparisons and their eigenvectors. The practical application of the expert-statistical method based on the analysis of hierarchies of interdependent criteria allows us to obtain a management decision on the choice of the optimal production scenario for agricultural enterprises in Northern Kazakhstan in the conditions of multi-criteria factors of influence.

Keywords: *Multi-criteria tasks, Analytical hierarchy process, Hierarchy of systems, Decision-making*.

1. INTRODUCTION

Currently, the development of methods to support management decision-making in agricultural industries is very relevant. This affects such areas as improving the efficiency of agricultural production, solving resource problems, and many others. A feature of the functioning of modern agricultural enterprises is the presence of many parameters (criteria) of production and market conditions, such as costs, profits, risks, etc., which determine the scenarios of the functioning of an agricultural object. This makes it difficult to choose the preferred scenario for the production of an agricultural enterprise for the decision-maker on a specific problem of forecasting and planning.

To solve such problems, there are two main types of methods: strict and heuristic methods [1]. Heuristic methods for solving economic problems are based mainly on a number of assumptions that simplify the understanding of the simulated real processes. Such abstraction allows you to choose an adequate mathematical model for the process under consideration, develop appropriate algorithms on this basis, create a program and use a computer to get an acceptable solution. It should be noted that in case of difficulty properly formalized model is the use of heuristic procedures – from the perspective of the decision maker is as acceptable, and sometimes even preferable (in terms of costs), the more accurate the algorithm for finding optimal solutions.

The analysis of sources on this subject - management decision-making in the agricultural industry-revealed the predominant trends in the use of heuristic methods from the group of methods of multi — criteria Decision Analysis (MCDA) [2].

These methods are designed to structure and solve decision-making and planning problems related to multiple criteria. The goal is to support the decision-maker facing such problems. As a rule, there is no single optimal solution for such problems, and to differentiate solutions, it is necessary to use the preferences of the decision maker.

In foreign agricultural industries, many problems in the conditions of multi-criteria problems are investigated using the analytical hierarchy process (AHP). This method, developed by the American mathematician Thomas Saati [3] in the 1970s, is a structured method for organizing and analyzing complex decisions, based on mathematics and psychology. It should be noted that the foundations of this method were laid by Russian scientists B. N. Brook and V. N. Burkov in 1972 [4].

The analysis of modern research in the field of decision-making for agricultural industries has shown that the use of the analytical hierarchy process in combination with other tools is aimed at the development and optimization of the most important areas of this industry.

One of the directions in the world practice of applying the analytical hierarchy process is the adoption of management decisions to improve the efficiency of agricultural production. In the context of the national policy of promoting the reform of the agricultural and industrial structure of China, a system of evaluation indices based on the AHP has been created for enterprises to conduct a systematic assessment of technologies, as well as make investment decisions and control risks before investing [5]. In order to study the variations in the yield of agricultural crops in China, a system of integrated assessment of their quality was developed using an improved hierarchy analysis process for various agroforestry systems [6].

The growing concern about agroecological problems has made the selection of green crops a major challenge for agriculture. The choice of alternative organic crops is a major challenge in developing countries, especially in Iran. An integrated method of combining the process of analyzing hierarchies and the life cycle of the system for comparing the agroecological efficiency of agricultural crops is proposed [7].

Multi-criteria decision-making models are widely used for resource problems in agriculture. In the research project on the use of treated urban wastewater in agriculture, an information system for multi-criteria decision-making was developed, in which the hierarchy analysis method was used to calculate the weight of criteria [8].

Modeling the suitability of agricultural land on a regional scale plays an important role in solving the problems of sustainable management. For example, to assess the various farming systems from the point of view of sustainable life support, a system of processing expert opinions with the method of hierarchy analysis was created in the provinces of Vietnam, which allowed taking into account a number of economic, water management and environmental aspects [9].

To make decisions on the assessment of the suitability of land for citrus cultivation in the Turkish province of Antalya, a geographical information system of multi-criteria assessment was created based on the method of hierarchy analysis, taking into account the points of view of local citrus producers and experts [10]. 13 exclusion criteria, 3 main evaluation criteria (13 sub-criteria), and 52 value ranges were identified for the citrus land suitability analysis. The researchers emphasize the importance of this development for agricultural

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land use planning.

The use of the hierarchy analysis method for making decisions on specific problems in agricultural enterprises in many countries is combined with other analytical methods. To make decisions on assessing the impact of the land consolidation project on the quality of cultivated land, AHP was used in combination with the method of correlation analysis (to determine the correction coefficients of land use) and regression analysis methods [11].

Noteworthy is the use of AHP with a probabilistic approach to measuring information for quantifying and diagnosing the region's resistance to agricultural drought [12]. This approach is due to the different probability of events and the amount of information obtained when the events are committed. In order to make decisions on the estimation of the capacity of agricultural water and land resources in Kazakhstan from 2001 to 2017, the AHP was combined with the entropy weight method and the fuzzy complex hierarchy model [13].

To make management decisions on various tasks in agricultural industries, a combination of MAI with environmental and technical and economic assessments of the life cycles of the objects under study is used [14, 15].

It should be noted that AHP is used in the field of agricultural development using high technologies [16]. In this area, a hierarchical system of indices for evaluating high technologies in agriculture is being created using AHP for decision-making in agricultural enterprises. In this case, a neural network with back propagation is used for complex evaluation.

A special modification of hierarchy analysis – fuzzy analytical hierarchy (Fuzzy AHP) has been widely used in recent years to solve decision-making problems in agricultural industries. For example, to study four different types of agriculture – "traditional agriculture", "agriculture using artificial intelligence", "vertical agriculture" and "plant – based meat" - a process of fuzzy analytical hierarchy with interval values of criteria was used [17]. The use of a fuzzy analytical hierarchy in combination with a geographic information system allowed researchers to model the suitability of agricultural land on a regional scale in order to choose a solution for sustainable management [18].

Experts in the field of agricultural sciences note that the analysis of the suitability of agricultural land is a prerequisite for achieving optimal use of available land resources for sustainable agricultural production. In the research project, decision-making models such as the hierarchy network analysis model and the fuzzy hierarchy analysis process were used to assess the suitability of agricultural land [19].

The problem of assessing the environmental and socio-economic indicators of various tillage systems in the production of maize grain at an agricultural experimental station in the Masovian Voivodeship (Republic of Poland) was solved using the integration of fuzzy analysis of the hierarchy and product life cycle [20]. The influence of the weights of the main criteria and conditions of the annual yield change on the overall efficiency of alternative production scenarios was noted.

The use of multi-criteria analysis methods, including AHP, for decision-making in various areas of agricultural production is noted. Successful results of research and practical work in this direction indicate the validity of the use of AHP for a wide range of multi-criteria tasks in the field of decision-making for agricultural enterprises. It should be noted that for each agricultural enterprise, a corresponding model of management decision-making was built. Each of the models implemented a specific hierarchical structure of goals, criteria, and alternatives, while there were no signs of adaptation for the universality of the application of models when changing the initial and boundary conditions of the problem.

Thus, to support managerial decision-making on the choice of scenario rational organization of production at agricultural enterprises in the context of multi-criteria factors appropriate to develop a model-specific application situation.

The problem of choosing the optimal scenario of agricultural production for specific enterprises in Northern Kazakhstan is that it is necessary to take into account many specific productions and market conditions that have a discrete influence on the choice and determine the specifics of the problem situation at the enterprise. Provided that the decision maker participates and makes decisions - intuitive or based on experience - the choice scenario reflects his understanding of the problem. To reduce the influence of the subjective factor of the decision maker's behavior on the choice of the optimal production scenario for an agricultural enterprise in Northern Kazakhstan, we propose in this study a solution to the problem based on the scientific method of decision analysis and a special mathematical method in decision theory - the hierarchy analysis method.

The purpose of this study is to structure and formalize the situational task of supporting decision-making on the choice of a production scenario in the conditions of multi-criteria and availability of expert information with statistical processing on the example of an enterprise in the agricultural sector of Northern Kazakhstan.

An agricultural enterprise of Northern Kazakhstan engaged in crop production can be considered as an agricultural object. Agribusinesses of this type are characterized by multi-criteria and the presence of the decision-maker for choosing an alternative with an already formulated initial idea, which is the result of a preliminary analysis of the conditions and requirements. Information about the significance of the criteria for each production scenario is provided by experts.

The universal motivation of this research is the development of an implementation model based on AHP, which is adaptive for solving the above-mentioned situational problem for agricultural enterprises.

The contribution of this paper consist of

• presentation of the problems faced by decision makers at agricultural enterprises in Northern Kazakhstan when choosing the optimal production scenario, which depends on many circumstances of the current period - production and market conditions

• presentation of a new decision-making algorithm for decision-makers according to one of the alternative based on the scientific method of decision analysis, as opposed to intuitive or based on experience.

The difference between our research contribution and the achievement of goals in comparison with the results of the analyzed sources is that the structuring and formalization of the task of supporting managerial decision-making on the choice of the optimal production scenario is carried out for the situational conditions of the presence of a variety of production and market criteria of influence typical for enterprises in the agricultural sector of Northern Kazakhstan.

2. DATASETS AND METHODS

2.1. Analytic hierarchy process

When choosing a method for solving the multi-criteria problem of finding the optimal scenario for the production of an agricultural enterprise, it is necessary to take into account the features of the situational model for the object of this subject area. The prerequisites for choosing a method for solving this problem are the following factors of the situational model of production of an agricultural enterprise.

A significant amount of information needs to be processed to evaluate and compare alternatives, i.e. to decide on the preferred scenario. The behavior of the Decision-maker can have a significant impact on both the decision-making process itself and the results of this process. The complexity of a correctly formalized model of the multi-criteria task of selecting a production scenario determines the feasibility of using a heuristic procedure. Management practice shows that this approach is acceptable and preferable for the decision-maker in terms of time spent. The initial information on the influencing criteria for agribusinesses can be provided by experts in a high-quality format. For the situational model of the work of an agricultural enterprise, the procedure for determining priorities by the experts themselves is impractical.

The task of supporting the adoption of control decisions on the choice of the optimal scenario in the conditions of a set of influence criteria belongs to the class of multi-criteria problems. Multi-criteria decision-making methods at the algorithmic level can include the following methods: main criterion, linear convolution, maximum convolution, lexigraphic optimization, Nelder-Mead, adaptive, AHP, etc.

In general, the mathematical model for multi-criteria decision-making problems can be represented by the following tuple [21]:

$$\langle S; E_1, ..., E_m; M \rangle, \quad (1)$$

where S many of the solutions to (for our problem – alternative production scenarios agribusinesses), – $E_1,..., E_m$ – criteria problem (for our problem is the selection criteria of the version of the script) that the company), m – is the number of criteria $(m \geq 2)$, M – a set of preference relations experts to comparison criteria (fuzzy preference relations).

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The set of values of $E_i(s)$, form a vector estimate of the solution option s from the set of options S.

In accordance with these factors of the situational model, a heuristic method of hierarchy analysis was chosen to optimize the choice of a management decision. The method is based on the processing of expert information obtained by pair comparison of the elements of the problem under consideration and subsequent hierarchical synthesis of the results. At the same time, it is possible to translate expert information from a qualitative form to a numerical one.

To analyze a multi-criteria decision problem from a set of alternatives, we present a mathematical model (1) in the form (2) to reflect the set of solution options, the number of hierarchy levels, the set of expert preference relations at each level, the number of criteria at each level:

$$\langle S^1, S^2, ..., S^z; E_1^1, E_2^1, ..., E_i^1; E_1^2, E_2^2, ..., E_j^2; ...; E_1^z, E_2^z, ..., E_f^z; M^1, M^2, ..., M^z \rangle \quad (2)$$

where S^z – multiple solution options (multiple alternative types of production scenarios), z - number of hierarchy levels $(z = 1,2,...,Z)$, $E_1^z,...,E_m^z$ – task criteria (scenario performance criteria), M^z – multiple expert preference relationships at each level, i, j, f – number of criteria at each level.

Each variant of the solution S from the set of variants is characterized by the values forming a vector estimate p(s) of this variant:

$$p(s) = (E_1(s),..., E_m(s)) \quad (3)$$

These preferences are modeled using the non-strict preference ratio M on P : $p'Mp''$, which means that the vector estimate p' is no less preferred than p'', and so on. Preferences are based on a set of criteria $E_1,...,E_m$ by which alternative solutions are evaluated. Let us assume for each criterion that its larger values are preferable to its smaller ones. Then, on the set of vector estimates of the variants, the Pareto relation can be determined.

Note that the criteria for the task of choosing the preferred option, presented by experts, may have a qualitative component. Therefore, the evaluation criteria are translated from qualitative to quantitative on the basis of a single scale.

Within the framework of the mathematical model of multi-criteria analysis, it is necessary to compare all the criteria and identify a generalized vector estimate of each alternative solution. Thus, the ranking of the elements analyzed using the pair comparison matrices will be based on the main eigenvectors obtained as a result of matrix processing.

To obtain a global vector of evaluation of alternative production scenarios, which will combine the vector evaluation P^z of each level, you can use the known convolution functions, by which all the vector evaluations of the criteria E_i^z are collapsed into a single generalized vector evaluation:

$$B(P_i, P_j'^i) = b(p_1, p_1'^1, ..., p_i, p_j'^i) \quad (4)$$

When evaluating the preference, the option is considered the better, the greater the value of the generalized vector (convolution) B.

The most common is the generalization based on the weighted average power function:

$$B_i = (\sum_{i=1}^{n} p_i p_j^i)^{1/z}, \; z \neq 0 \quad (5)$$

Since two adjacent levels are taken for convolution, we apply linear convolution:

$$B_1 = \sum_{i=1}^{n} p_i p_1'^i, \quad (6)$$

where B is the generalized vector p' – is the lower-level criterion, and p - is the importance vector of the criterion at the level z .

Let's accept the conditions for a pair comparison of the criteria:

1. Any $m_{ii} = 1$, because the result of

comparing the element with itself gives an equivalent result;

2. If $m_{ij} = x$, then $m_{ji} = \frac{1}{x}$, and $x \neq 0$, since the result of the inverse comparison of two elements can be, respectively, the inverse value (due to the backward compatibility property).

Then the corresponding matrix of pair wise comparisons of the hierarchy elements will have the properties of inverse symmetry (7):

$$M^z = \begin{bmatrix} 1 & m_{12} & \dots & m_{1j} \\ \frac{1}{m_{12}} & 1 & \dots & m_{2j} \\ \dots & \dots & \dots & \dots \\ \frac{1}{m_{1j}} & \frac{1}{m_{2j}} & \dots & 1 \end{bmatrix} \quad (7)$$

The further task is to match the criteria of the $E_1^z, E_2^z, ... E_n^z$ hierarchy with a set of numerical $\omega_1, \omega_2, ... \omega_n$ weights that would reflect the ideal dependencies and differences (correspond to the exact solution).

To achieve this goal, it is necessary to give a strict mathematical form to a vaguely formulated problem and, thereby, reflect the practical situation in an abstract mathematical structure. We describe how the ω_i weights depend on the m_{ij} judgments.

In the ideal case:

$$\omega_i = m_{ij}\omega_j (i, j = 1,2,...,n) \quad (8)$$

and for the close-to-reality variant (for each fixed one i),

ω_i = the average of $(m_{i1}\omega_1, m_{i2}\omega_2, ..., m_{in}\omega_n)$ (9)

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n} m_{ij}\omega_j \quad (i, j = 1,2,...,n), \quad (10)$$

corresponds to the formula for finding the average value. However, the need to be make sure that this will allow you to define the ω_i, under well-defined conditions m_{ij}.

It is important to note that for good (as close as possible to ideal) estimates m_{ij} approaches ω_i / ω_j and, therefore a small perturbation of this ratio. Since m_{ij} changes, the corresponding solution according to formula (10), which defines ω_i and ω_j, can also change in order to adjust to the deviation of m_{ij} from the ideal case. Then denoting n by $\lambda_{\max}$, we get the following expression:

$$\omega_i = \frac{1}{\lambda_{\max}}\sum_{j=1}^{n} m_{ij}\omega_j \quad (i, j = 1,2,...,n) \quad (11)$$

This expression has a solution, which, like the previous one (10), must be unique. Thus, the problem is transformed into an eigenvalue problem.

After composing the matrices and expressing the subjective pair judgments using a scale of relative importance, the set of eigenvectors for each matrix is calculated.

Normalizing the value of the eigenvector of each row of the matrix gives the value of the priority vector:

$$p_j = \frac{d_j}{\sum_{i=1}^{n} d_i}, \quad (i, j - 1,2,..., n), \quad (12)$$

where d_j – is the value of the priority eigenvector j of the row; $\sum_{i=1}^{n} d_i$ is the sum of all the eigenvector values for the matrix.

The consistency of the evaluation results obtained is carried out using the consistency index (CI) and the consistency ratio (CR). For an inversely symmetric matrix:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)}, \quad (13)$$

where $\lambda_{\max}$ – is the maximum eigenvalue, is the dimension of the matrix.

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The consistency ratio *CR* can be defined as *CR = CI/RI*, where *RI* is the value of the random consistency index for a matrix of a given dimension. *RI* corresponds to the average consistency indices for randomly generated matrices of the same dimension. To obtain acceptable consistency, it is necessary that $0 \le ИС \le 0{,}2$ and $0 \le OC \le 0{,}2$. For other values of consistency, a review of the expert judgment is necessary.

For a global assessment that takes into account the results of comparison at different levels of the complete dominant hierarchy of the task, it is advisable to use the linear convolution formula, which allows you to get the value of the global priority vector. The global priority vector takes into account the result of comparing criteria at two levels.

To identify the main or global priorities for two different levels of the hierarchy, combine the values of the priority vectors into a matrix. We denote the vector of the lower priority level as $p_i'^j$, where $i = 1,2,...,m$ – is the ordinal number of the element of the lower hierarchy level, and $j = 1,2,...,n$ – is the ordinal number of the element of the upper hierarchy level. Then, to find the global vector of the lower-level hierarchy element, you should perform the calculation using the formula:

$$b_i = \sum_{j=1}^{n} (p_i'^j \cdot p_j), \qquad (14)$$

where b_i - is a variable that characterizes the value of the global priority vector for the element i of the lower level of the hierarchy, which combines the value of the priority vectors for several levels of the hierarchy.

3. RESULTS

3.1. Hierarchy of control criteria for the task of selecting a production scenario

A comprehensive assessment of each alternative production scenario should be made taking into account the impact of all control criteria. Applied scientific studies of the production of the North Kazakhstan agro-industrial complex revealed the presence of criteria (parameters) of production and market conditions that affect the functioning of the agricultural enterprise [23]. The control criteria were presented in four groups:

– Group 1. Conditions for the structure of crops and crop rotations

– Group 2. Enterprise resources

– Group 3. Conditions for market capacity and contractual obligations

– Group 4. Risks

We identify the control criteria for all groups for the subsequent evaluation of the studied decisions on the choice of the production scenario of the agricultural enterprise. The hierarchy of control criteria for the task of selecting a production scenario is shown in Figure 1.

It should be noted that the number of criteria in each group may change due to changes in the socio-economic conditions of the agricultural enterprise.

3.2. Dominant hierarchy of the task of selecting the production scenario of an agricultural enterprise

We structure the problem of choosing the preferred scenario for the production of an agricultural enterprise in the conditions of multicriteria of the problem in the form of a complete dominant hierarchy. The dominant hierarchy of the task is built on 4 levels:

– the 1st (highest) level reflects the goal: the optimal scenario for the production of an agricultural enterprise;

– level 2 contains groups of criteria that characterize conditions for the structure of crops and crop rotation (group 1), enterprise resources (group 2), conditions for market capacity and contractual obligations (group 3) and risks (group 4);

– the 3rd level reflects the set of control criteria in each of the 4 groups;

– the 4th level contains alternative scenarios for the production of an agricultural enterprise, which should be evaluated in relation to the criteria

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of the 3rd level and the groups of managing criteria of the 2nd level.

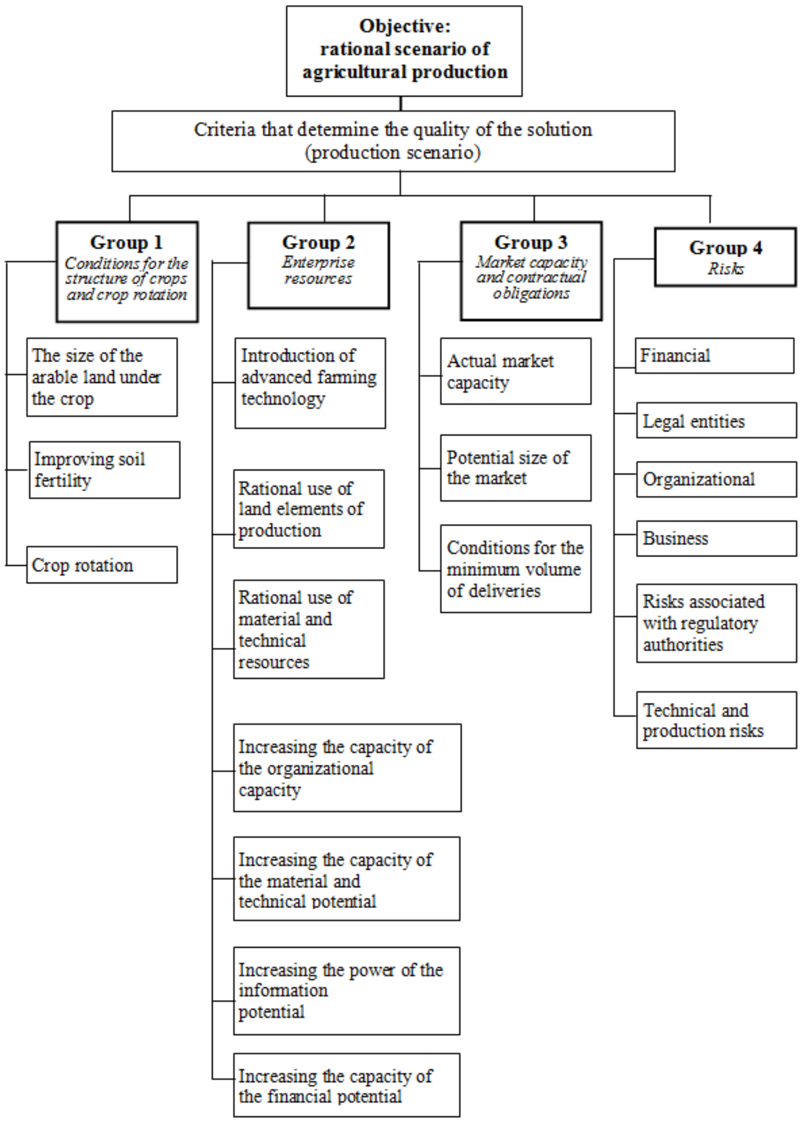

Figure 1: Hierarchy of criteria for selecting an agricultural production scenario

Note that the number of alternative strategies at the level 4 is chosen arbitrarily, as an example for specifying the model. Table 1 shows the criteria notation on the dominant hierarchy and in the comparison matrices.

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Table 1: Criteria designations on the dominant hierarchy and in comparison matrices

Criterion	Designation on the hierarchy and in the comparison matrix
Group 1. *Criteria that characterize conditions for the structure of crops and crop rotations*	E_1^2
The size of the arable land under the crop	E_1^3
Improving soil fertility	E_2^3
Crop rotation	E_3^3
Group 2. *Criteria that characterize the resources of the enterprise*	E_2^2
Introduction of advanced farming technology	E_4^3
Rational use of land elements of resources	E_5^3
Rational use of material and technical resources	E_6^3
Increasing the capacity of the material and technical potential	E_7^3
Increasing the capacity of the organizational capacity	E_8^3
Increasing the power of the information potential	E_9^3
Increasing the capacity of the financial potential.	E_{10}^3
Group 3. *Criteria that characterize conditions for market capacity and contractual obligations*	E_3^2
Actual market capacity	E_{11}^3
The potential size of the market	E_{12}^3
Conditions for the minimum volume of deliveries	E_{13}^3
Group 4. *Risk criteria*	E_4^2
Financial (economic) risk	E_{14}^3
Legal risk	E_{15}^3
Organizational risks	E_{16}^3
Business risk	E_{17}^3
The risk associated with regulatory authorities	E_{18}^3
Technical and production risks	E_{19}^3

3.3. Calculation algorithm

After building the dominant hierarchy of the problem of choosing the production scenario of an agricultural enterprise, the priorities of the criteria are set and each of the alternative scenarios is evaluated according to the criteria, identifying the optimal one. In accordance with the complete dominant hierarchy square $M^z = (m_{ij})$ matrices were formed to evaluate quantitative judgments about each pair of components (E_i^z, E_j^z):

– a matrix of paired comparisons of groups of control criteria among themselves (for the second level of the hierarchy);

– a matrix of paired comparisons of criteria by the structure of crops;

– matrix of paired comparisons of criteria that characterize the resources of the enterprise;

– matrix of paired comparisons of criteria that characterize the market capacity;

– matrix of paired comparisons of criteria that characterize risks.

Quantitative judgments of comparing pairs (E_i^z, E_j^z) in numerical terms are obtained on the basis of expert assessments. In other words, m_{ij} – the number corresponding to the significance of the element E_i in comparison with E_j.

Note that the values of these estimates have a qualitative (verbal) component. Therefore, the assessments of criteria from experts are translated from qualitative to quantitative on the basis of a single scale. The comparison scale was chosen as a 9-point scale, which allows experts to evaluate heterogeneous factors. As the works of T. Saati show, the comparison of this scale with many other scales proposed by different authors showed the advantages of the 9-point scale [22]. Recommendation T. Saati is justified by the fact that 10 is the optimal number of gradations that any qualified expert can distinguish and correctly evaluate.

After composing the matrices and expressing the subjective pair judgments using a scale of relative importance, the set of eigenvectors for each matrix is calculated. After normalization, the eigenvectors become priority vectors p_i. To compare alternative strategies for each control criterion, matrices are compiled for each criterion (in the conditions of this problem – 19 matrices. For example, Table 2 presents matrices for

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comparing alternative scenarios of agricultural production for three criteria of group 1 and one criterion of group 2.

Table 2: Comparison of alternative production scenarios of the enterprise according to some control criteria

Criterion: The size of the arable land under the crop (E_1^3)					
	s_1^4	s_2^4	s_3^4	s_4^4	The value of the vector of priorities
s_1^4	m_{11}	m_{12}	m_{13}	m_{14}	$p_1'^1$
s_2^4	m_{21}	m_{22}	m_{23}	m_{24}	$p_2'^1$
s_3^4	m_{31}	m_{32}	m_{33}	m_{34}	$p_3'^1$
s_4^4	m_{41}	m_{42}	m_{43}	m_{44}	$p_4'^1$
$\lambda_{\max} = \sum_{j=1}^{4} g_j$		$CI = \frac{(\lambda_{\max} - 4)}{(4-1)}$		$CR = \frac{CI}{0{,}90}$	

Criterion: Improvement of soil fertility (E_2^3)					
	s_1^4	s_2^4	s_3^4	s_4^4	The value of the vector of priorities
s_1^4	m_{11}	m_{12}	m_{13}	m_{14}	$p_1'^2$
s_2^4	m_{21}	m_{22}	m_{23}	m_{24}	$p_2'^2$
s_3^4	m_{31}	m_{32}	m_{33}	m_{34}	$p_3'^2$
s_4^4	m_{41}	m_{42}	m_{43}	m_{44}	$p_4'^2$
$\lambda_{\max} = \sum_{j=1}^{4} g_j$		$CI = \frac{(\lambda_{\max} - 4)}{(4-1)}$		$CR = \frac{CI}{0{,}90}$	

Criterion: Crop rotation (E_3^3)					
	s_1^4	s_2^4	s_3^4	s_4^4	The value of the vector of priorities
s_1^4	m_{11}	m_{12}	m_{13}	m_{14}	$p_1'^3$
s_2^4	m_{21}	m_{22}	m_{23}	m_{24}	$p_2'^3$
s_3^4	m_{31}	m_{32}	m_{33}	m_{34}	$p_3'^3$
s_4^4	m_{41}	m_{42}	m_{43}	m_{44}	$p_4'^3$
$\lambda_{\max} = \sum_{j=1}^{4} g_j$		$CI = \frac{(\lambda_{\max} - 4)}{(4-1)}$		$CR = \frac{CI}{0{,}90}$	

Criterion: Introduction of advanced farming technology (E_4^3)					
	s_1^4	s_2^4	s_3^4	s_4^4	The value of the vector of priorities
s_1^4	m_{11}	m_{12}	m_{13}	m_{14}	$p_1'^4$
s_2^4	m_{21}	m_{22}	m_{23}	m_{24}	$p_2'^4$
s_3^4	m_{31}	m_{32}	m_{33}	m_{34}	$p_3'^4$
s_4^4	m_{41}	m_{42}	m_{43}	m_{44}	$p_4'^4$
$\lambda_{\max} = \sum_{j=1}^{4} g_j$		$CI = \frac{(\lambda_{\max} - 4)}{(4-1)}$		$CR = \frac{CI}{0{,}90}$	

At the next stage of calculations, the principle of priority synthesis on the hierarchy was applied to weigh the eigenvectors of the matrices of paired comparisons of alternative scenarios with the weights of the criteria available in the hierarchy. The hierarchical synthesis for this task consists in the sequential determination of the priority vectors of alternative scenarios relative to the control criteria and groups of criteria (the 2nd and 3rd hierarchical levels).

For a global estimate that takes into account the results of comparison at different levels of the complete dominant hierarchy of the task, the linear convolution formula is used, which allows you to get the value of the global priority vector. The global priority vector takes into account the result of comparing criteria at two levels. The values of this vector are calculated according to the formula (14).

Table 3 shows a matrix of priorities of alternative strategies according to the task criteria for calculating the global vector for selecting the enterprise production scenario according to the criteria of group 1 "Conditions for the structure of crops".

Table 3: Calculation of the global vector of the choice of the production strategy of the enterprise according to the criteria of group 1 "Conditions for the structure of crops"

	Managing criteria for selecting a production development scenario			The value of the global priority vector
	E_1^3	E_2^3	E_3^3	
The value of the criteria priority vector	p_1	p_2	p_3	
s_1^4	$p_1'^1$	$p_1'^2$	$p_1'^3$	$b_1'^1$
s_2^4	$p_2'^1$	$p_2'^2$	$p_2'^3$	$b_2'^1$
s_3^4	$p_3'^1$	$p_3'^2$	$p_3'^3$	$b_3'^1$
s_4^4	$p_4'^1$	$p_4'^2$	$p_4'^3$	$b_4'^1$

The values of the global priority vector allow us to numerically assess the impact of the control criteria on the lowest level, where alternative scenarios of agricultural production are located, and choose the best option from them.

The model of making a management decision on the choice of the optimal scenario for the production of an agricultural enterprise is formed. The situational model reflects the specifics of the applied situation – the conditions of multi-criteria influence factors and the availability of expert information. The implementation model based on AHP is adaptive for solving this situational problem for agricultural enterprises. The initial matrix can be supplemented with criteria for each of the 4 groups and the number of alternative production scenarios. In this case, the change in the dimension of the matrix, that is, the corresponding linear space, minimally affects the changes in the calculation algorithm.

4. DISCUSSION

For agricultural enterprises of Northern Kazakhstan, the problem of choosing the optimal variant of the production scenario is typical. The problem is caused by the presence of many criteria (parameters) of production and market conditions and the peculiarities of the decision-maker's participation in the process. Information about the significance of the criteria is expected to be obtained from production experts.

In modern conditions, there is not enough experience, knowledge and intuition of a decision maker to develop good solutions in complex, responsible practical problems. The study presents a solution to the problem of choosing the optimal scenario for agricultural production for enterprises in Northern Kazakhstan with the use of a mathematical tool of a systematic approach to complex hierarchical multi-criteria and multi-alternative problems of expert decision-making - the method of hierarchy analysis. At the same time, expert information about the preferences of the decision maker is presented formalized in the model of the problem situation. In this study, the problem is presented as a set of tasks to formalize the situational task of decision support. It should be noted that in this study, the approach to solving the problem of choosing the optimal scenario of agricultural production for enterprises in Northern Kazakhstan is deliberately heuristic in nature, which simplifies the complete and detailed models to improve efficiency in complex situations of multi-criteria influence.

The quality of management decision on a preferred scenario of functioning of agricultural enterprises is determined by the correctness of accounting expertise and involvement in the process of decision maker the Initial position of development consists in the following. Do not prescribe any "correct" solution to the decision-maker, but rather allow the decision-maker to interactively find the production scenario that best matches his understanding of the problem and the requirements for solving it.

A well-grounded approach to the application of the hierarchy analysis method for the problem under study made it possible to structure the decision-making task in a rational way with respect to the initial conditions: the nature of the participation of the decision-maker and the use of expert assessments.

The developed model with the dominant hierarchy of the task of selecting the production scenario on the example of an agricultural enterprise in Northern Kazakhstan allows for calculations in a wide range of parameters. This quality of the model determined its versatility for performing large-scale calculations for predicting optimal production scenarios at similar agricultural enterprises in Northern Kazakhstan.

To assess the quality of the experts ' work, the use of the consistency mechanism built into the AHP is justified. If the recommended values of the index and the consistency ratio for the calculated sets of eigenvectors for each matrix are exceeded, a revision of the expert judgments is recommended.

The limitation of the implementation model of making managerial decisions on the choice of the preferred production scenario is the number of compared scenarios. When the number of compared options changes, there is always the likelihood of a rank reversal effect (the effect of changing the degree of preference). The essence of the rank reversal effect is that when the number of evaluated elements changes, their degree of preference (ranking) relative to each other can change. This will entail the need for additional normalization of the eigenvector of the inversely symmetric comparison matrix, in which the rank reversal effect was excluded. It should be noted that, as shown by numerous studies, with any method of normalization, the rank reversal effect exists and further research on the role of the effect of changing the degree of preference in the method of hierarchy analysis actualizes.

The limitation of the study is the impracticability in the developed model of using expert assessments of information in interval values. To do this, the Fuzzy Inference procedure or Fuzzy Inference System (FIS) must be applied. For future work, we hope to expand the developed model for processing heterogeneous and imprecise expert estimates of information with interval uncertainty.

The limitation of our method also consists in the inapplicability of the quantitative assessment of the criteria in the implementation model, if the possible events of their occurrence have different probabilities of implementation. This approach may turn out to be essential if it is necessary to take into account the relationship between the probability of events and the amount of information obtained when an event occurs, for example, according to the values of criteria from the risk group.

The implementation model of management decision-making on the choice of the optimal scenario of agricultural production is made with the properties of adaptability for the procedure of changing the input parameters. Changes in the number of alternative production scenarios and the number of influencing criteria are possible due to changes in the socio-economic conditions of the agricultural enterprise. At the same time, the calculation algorithm does not change. An important consequence of the adaptability of the implementation model, which determines the vector of further development, is the possibility of creating a computational software package for a wide range of agricultural enterprises.

The development of a computer decision support system for processing expert assessments is expected within the framework of research projects of the Kazakh Agrotechnical University named after S. Seifullin.

The work was carried out as part of the project on the scientific and technical program "Transfer and adaptation of technologies for point farming in the production of crop production on the principle of "demonstration farms" (landfills) in the North Kazakhstan region" S. Seifullin Kazakh Agrotechnical University.

5. CONCLUSIONS

Studies structured and formalized proposed support decision-making on the choice of scenario in conditions of multicriteria and availability of expert information on the example of enterprises of the agricultural sector in Northern Kazakhstan.

- The choice of the heuristic method of hierarchy analysis is justified as a mathematical tool of a systematic approach to the problem of making decisions on the optimal scenario of an agricultural enterprise in the conditions of multi-criteria factors of influence.
- The problem of making management decisions on the scenarios of production of agricultural enterprises is structured in the form of a dominant hierarchy of four levels. It is assumed that the elements of the system that determine the essence of the problem of optimizing the choice of a management solution can be grouped into unrelated sets.
- Groups of criteria that characterize the production conditions of an agricultural enterprise are identified. To determine the degree of influence of the criteria, it is recommended to introduce expert assessments.
- A 9-point evaluation scale recommended by T. Saati is proposed for the expert evaluation of the influencing criteria in the structuring of the calculated matrices.
- Implementation of the proposed solution algorithm allows to evaluate alternative production scenarios agribusinesses and choose the best pre-formulation of the original idea, which is the result of a preliminary analysis of the situation and the requirements of decision-makers.
- The specific application value of the work lies in the possibility of applying an adaptive implementation model for making management decisions on choosing the preferred production scenario for a wide range of agricultural enterprises.

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