Features of modeling in agricultural production with risks

Abstract. For the modern economy, the agricultural sector is an important link. In a market economy, agricultural management processes have become significantly more complex, as they develop under conditions of uncertainty. This leads to the need to take into account not only traditional factors of economic activity, but also supply and demand for agricultural products, weather conditions, which largely determine the economic efficiency of the agricultural sector. The uncertainty inherent in the agro-industrial complex is the main difficulty in scientific research into the structural and functional organization of this complex. Uncertainty is generated by many factors, the most important for agricultural production are weather and market conditions, scientific and technological progress. The need to take into account and manage weather risk arises from the objective requirements of a market economy, which requires enterprises to find ways to better adapt to external and internal conditions of operation and development of production.

Agricultural production is constantly being reformed in market conditions. In this regard, there is a need to develop new methodological approaches to planning the safety and development of agricultural enterprises, associations and the agro-industrial complex as a whole. The study of these issues is possible through the use of economic-mathematical modeling and computers. The article discusses the concept of planning the use and development of agricultural enterprises under conditions of uncertainty. The concept is based on the development of organizational, economic and methodological approaches to the formation of the planning process, which provides agricultural enterprises with the prerequisites for better adaptation of production in conditions of weather risk, increasing the competitive level of enterprise sustainability.

1 Formulation of the problem

The agro-industrial complex is experiencing significant socio-economic and organizational changes, and objective processes of transformation of its production structure are taking place at agricultural enterprises. Today, the urgent task is to develop mechanisms of state agricultural policy aimed at increasing the efficiency of using the existing potential of the agricultural sector of the economy. For these purposes, special attention should be focused on creating the prerequisites for institutional support, which, first of all, includes:

- development of rural areas;
2 Analysis of the latest research and publications

Problems of planning under conditions of uncertainty were studied by economist M. S. Prishutova [3]; issues of planning and management in conditions of uncertainty of incomplete information are considered in many literary sources by such authors as: I. E. Gergiev, S. L. Anisimova [4], a number of works are devoted to issues of reliability and flexibility of economic systems. Risk management under conditions of state uncertainty in the work of S. S. Aristarkhov [5]. In essence, these are stochastic programming methods that reject or do not sufficiently take into account the mechanism of system adaptation to frequently changing environmental conditions. The main attention is paid to probabilistic, averaged estimates of
3 Purpose of the article

Explore methodologies and techniques for analyzing, modeling and optimizing the functioning and development of agricultural enterprises, associations and the agro-industrial complex as a whole under conditions of uncertainty (weather risk), as well as analyze the possibilities of overcoming uncertainty that creates instability in the functioning and development of the agro-industrial complex, economic risk, etc. Therefore, the methodology and planning methods for this complex must take this phenomenon into account.

4 Presentation of the main material

As the experience of economists shows, a comprehensive analysis of the economic system shows that under conditions of sustainable development it is inertial and, when disturbances occur, constantly strives to return to a position of equilibrium. One of the tools for such development of the economic system is the detailed development of forecast plans aimed at better adaptation of the economic system to changes in environmental conditions, and potential opportunities should be used most rationally. The use and creation of forecast plans at both the micro and macro levels of complex economic systems will allow us to identify the most promising areas of activity and timely concentrate the required number of production assets in selected areas with maximum economic effect.

In a market economy, one of the important places in the production activities of an enterprise is given to planning (forecasting), as one of the main factors in reducing the economic risk of enterprises. A radical change in the economic system is reflected in planning methods in a certain way. In market conditions, each enterprise needs to develop an individual production plan and forecast calculations, which are predominantly probabilistic in nature.

Currently, the scientific literature, although not enough, addresses the issues of managing economic systems under conditions of uncertainty. Interest in this problem arose relatively recently. The use of computer technology and economic and mathematical methods has created the prerequisites for the practical solution of control problems under conditions of uncertainty. But it is worth noting that the developed economic and mathematical models, as a rule, are deterministic, which means they do not adequately describe economic processes and therefore the optimal solutions obtained for them as plans for production activities and are rarely used in practice.

The question of taking into account the basic functional characteristics of plans (stability, risk) and their adaptive properties (reliability, flexibility, elasticity, tension) remains open. Therefore, much attention must be paid to the study of the functional characteristics and adaptive properties of the plans and decisions made.
The causes of risk are inherent in any branch of human activity, in particular agricultural production. The agro-industrial complex, unlike other industries, has a very important specific cause of risk—weather conditions. Weather conditions are one of the main factors of uncertainty in agricultural production. When developing the organization of production of an agro-industrial enterprise, it is necessary to take into account natural and climatic conditions. That is, when placing and specializing production and developing a general farming system, information about the quality of soils and climatic conditions of a certain region, which are considered conditionally constant and little variable, is used. In addition to climatic conditions, agricultural production processes are significantly influenced by weather conditions, which vary within significant limits.

Therefore, methods for organizing and managing the development and functioning of processes in the agro-industrial complex must take into account that climate and fluctuations in weather conditions are two different types of natural factors. Weather conditions change from year to year, directly affecting the main indicator of agricultural activity—crop yields.

It should be especially noted that fluctuations in weather conditions are not sufficiently taken into account in the theoretical developments and practical activities of the agro-industrial complex.

An essential feature of the weather factor is the random nature of its influence, which has a very significant impact on the performance of the agro-industrial complex both in a separate zone and throughout the country. Taking into account such influence in the planning, economic and management activities of the agro-industrial complex is possible only by analyzing the dependence of costs and production results on the random characteristics of weather conditions. This requires a significant modification of the methodology and methods of planning and management in the above areas of activity, that is, the use of the concepts of economic risk and sustainability of economic production.

The problem of weather economic stability and risk is much broader than the problem of production stability, since not only all sectors of the agro-industrial complex, but also the national economy of the country as a whole are closely related to agricultural production. The instability of agricultural production significantly affects all integral indicators of the national economy, including the volume of the national product.

In the agro-industrial complex, the most important is weather risk, and the main task of modeling and optimizing agricultural production is to develop ways to take into account and reduce weather risk.

The economic result, which is an indicator of production efficiency in agriculture, depends on the random characteristics of weather conditions, that is, it is a random variable. This applies to all regions, all forms of ownership, all types of agro-industrial activities.

Weather conditions cannot be controlled, but you can adapt to them to achieve the most comprehensive result. To do this, you need to select certain projects, strategic and tactical decisions from a variety of acceptable ones. At the same time, it is necessary to strive to obtain the maximum economic effect not only in a single weather situation, but also over a long period, so that this effect is as resistant as possible to random weather conditions in a certain climatic zone.

Due to the significant influence of weather fluctuations on the results of agricultural production, one of the ways to take into account weather risk is the detailed development of the production structure and options for management decisions for each specific situation.
is necessary to take into account that they are characterized by a certain set of weather conditions that affect the yield of industrial and feed crops and the associated livestock productivity.

One of the most effective methods of risk analysis is the use of mathematical modeling. Using mathematical methods, it is possible to conduct a detailed study of complex economic processes (phenomena), develop methods for reducing the impact of risk on production activities, and obtain the most effective management decisions.

Any production process is defined as the activity of a complex, probabilistic and dynamic socio-economic system. The complexity is due to the existence of various types of connections between the elements of the system, as well as a set of external factors influencing the activity of the system. Probability arises in connection with the properties of randomness and uncertainty in the development of economic processes and phenomena. The dynamics of the production process is reflected in changes in the parameters and structure of socio-economic systems over time. Socio-economic systems belong to the class of cybernetic systems [9]. The use of cybernetic systems to describe economic processes and phenomena is due to a certain number of properties inherent in this particular type of system. Cybernetic systems are controlled systems that have probable behavior and the ability to interact with the external environment, while it should be taken into account that there are reverse information channels that allow the most complete reflection of economic processes.

One of the main methods for studying systems is mathematical modeling. Mathematical modeling is a method of adequately reflecting the essential properties of an object or process by creating their mathematical models and studying these models. Economic and mathematical methods make it possible to obtain conclusions not only regarding the model itself, but also regarding some optimal solution.

Agricultural production is a segment of the economy in which methods of economic and mathematical modeling can be quite effectively applied. After all, this production is characterized by limited resources, has a certain system of performance indicators and a specific goal of its activities, and when considering the use of economic and mathematical modeling, it is necessary to take into account the specifics of the functioning of production.

production in agriculture, which will determine the specifics of the models.

So, agricultural planning must take into account all possible aspects of the development and functioning of the agro-industrial complex as a complex system, while taking into account the processes of production of agricultural products, optimization of its structure, placement of means of production and manufactured products.

To analyze processes in agriculture, it is advisable to use the economic indicators proposed in [10] and group them as follows:

1. According to the organizational structure of agricultural enterprises:
   - the number of enterprises in the agricultural sector of various forms of ownership, the relationships between them, the share of each type in the production of marketable products and national income;
   - cost of production of enterprises of various types of management, level of profitability, distribution of sown areas and the ratio of livestock productivity levels;
   - the size of agricultural enterprises, containing the value of fixed production assets, the total area of land and the number of livestock;

2. Indicators for analyzing the functioning of individual agricultural enterprises:
   - level of production efficiency, the criterion of which is profit, profitability;
   - management efficiency;
   - the presence of expanded reproduction, the social and financial situation of workers;
   - level of production costs, cost structure;
   - sales of manufactured products, execution (non-execution) of contracts.
complex as a whole:
- level of development of agricultural production: increasing the volume of gross output, increasing the profitability of farms;
- development of the main industries – crop production and livestock farming;
- intensification of agricultural production – the level of crop yields and livestock productivity.

It is impossible to build one complex model that could fully and adequately describe all agricultural production.

The solution to the problem became possible through the development of a whole set of models, the totality of which most accurately takes into account all the necessary factors and reflects as accurately as possible a specific economic process or phenomenon that is being considered.

For the agricultural sector, a sufficient number of basic models have been developed to describe agricultural production processes, on the basis of which it is possible to build a system of models necessary for each specific case. In the current state of building a diverse mixed economy, an important condition for creating an adequate model for the development of an agricultural enterprise is taking into account the dynamism and uncertainty of the external economic environment and the associated economic risk.

Human activity is constantly burdened with risk. Deterministic situations, when there is no risk, are quite rare in human activity. Most uncertain events that cause risk are not completely predictable and not controllable and cannot be eliminated, so even seemingly effective solutions can lead to significant losses.

The agricultural sector is saddled with much more risk than other industries. To effectively manage the agricultural sector, it is necessary to take into account important functional characteristics, including risk. In this regard, there was a need for detailed development of mathematical models for optimization under conditions of uncertainty. In accordance with the nature of information about random variables considered in economic problems, the following types of models can be distinguished:
- deterministic models – all quantities are known and constant or are functions of known parameters;
- stochastic models – known probability distributions of random variables;
- models under conditions of uncertainty – unknown distribution of at least one of the random variables.

In a market economy, the specificity of the functioning of agricultural enterprises lies in the simultaneous occurrence of uncertainty at the stage of decision-making in an unstable market environment and the significant influence of uncontrollable factors associated with the agricultural production process itself. That is, weather variability is one of the main causes of uncertainty in the agricultural sector.

Summarizing the influence of the uncertainty factors discussed above that influence the process of functioning and development of economic systems, we will highlight the most significant features of agricultural production:
- the production of crop products occurs naturally and the provision of the necessary conditions for the development of plants cannot be fully controlled by humans;
- finished livestock products depend on the development of living biological organisms and are also a source of uncertainty;
- agricultural enterprises use large areas in the production process, hence the significant territorial differentiation of economic entities;
- all processes of agricultural production are seasonal, which leads to a certain frequency of production of finished products and costs [11].

The basis for constructing a model of an agricultural enterprise are indicators related directly to the production process.
Therefore, the main factor in a rationally developed forecast can be a detailed mathematical description of the production process itself. When modeling production, an important problem arises of taking into account its state, which depends on the influence of random market processes. From this point of view, the ratio of industries in an agricultural enterprise and its specialization must satisfy the existing demand for products, while simultaneously using all types of farm resources to the fullest extent. This approach will ensure minimization of the financial risk of the enterprise. The result of calculations using the proposed model will be the optimal production structure for a specific agricultural enterprise, taking into account the available production resources and the conditions in which the farm operates. Using the results of optimizing the production structure allows you to most effectively use the production potential of the enterprise.

A stochastic, dynamic economic and mathematical model of the development of an agricultural enterprise, which takes into account the influence of uncontrollable factors on the production process by introducing variables into the model, corresponds to the optimal level of reserves for the conditions of a particular enterprise, which allows making optimal management decisions. Using a production structure developed using such a model will allow achieving maximum efficiency while minimizing the impact of economic risk on financial results.

A significant role in agricultural production is given to probabilistic factors. Among them, the main ones are random weather conditions and the development of biological organisms. Therefore, an important addition to the development of an effective financial plan is to take into account probabilistic factors associated with weather conditions, which can significantly reduce economic risk.

The tool for solving such a problem is stochastic programming. The stochastic optimization model differs from the deterministic one in that probabilistic distributions of random variables are taken into account. Solving this type of problem, as a rule, leads to a deterministic case of taking into account randomness, and therefore risk, using fixed properties of random variables: known values of variances and probabilities.

An important advantage of stochastic optimization models is the ability to develop a solution that is the best not only in one fixed situation, but also in relation to a whole set of possible situations. The most complex optimization problems under conditions of uncertainty, the solution of which is based on game theory. To model agricultural processes, optimization problems of this type are considered as a game in relation to nature. In the case where, given the complexity of the economic and mathematical model, it is impossible to obtain an analytical solution, they are used for simulation, that is, so-called simulation models are built. In fact, the simulation model in this case provides a calculation complex that allows you to fully analyze the process from the point of view of possible options for combining variable quantities of the corresponding sets of possible results.

Imitation of possible options for production development, conditioned by different weather conditions, based on the developed model for optimizing the production structure allows us to identify in advance the weaknesses of a given enterprise and develop ways to achieve maximum sustainability of production development.

Simulation modeling also makes it possible to conduct multifaceted studies not only of the behavior of the system as a whole, but also of the effectiveness of making certain management decisions regarding the activities of the enterprise.

The most complex optimization problems are those that are solved under conditions of uncertainty. Factors causing uncertainty can be grouped in two directions: socio-economic and technical-economic [12]. For example, socio-economic problems include the problem of unreliability of the information used. The technical and economic reasons for nondeterminism lie in production uncertainty associated with deviations of the real process from the ideal, well-developed one. For example, uncertainty may arise due to a rapid
increase in production costs due to an increase in the construction or operation of a facility compared to planned ones. All of the above reasons are important prerequisites for introducing factors that take into account uncertainty into models. The most adequate and comprehensive models consider the action of each of these factors, both individually and in interaction with each other. However, this significantly complicates the model itself.

To identify the main fundamental features of managing an economic system under conditions of uncertainty, it is enough to consider a situation where randomness occurs at least at one moment of operation. An important study of this kind is the model of managing a diversified economy under conditions of uncertainty, developed in the works of G. A. Kolomensky, L. A. Selivanova, N. V. Vasilyeva, E. V. Andrusenko [13, 14].

The non-determinism of product output per unit of design capacity is taken into account as a random variable of maximum power. Such uncertainty is a very common phenomenon in real economic processes and can be considered as the most important characteristic of the system as a whole.

The main goal of the problem is to describe the dependence of the distribution of macro-characteristics of the system on the distribution of the value $V$. Mathematically, the problem is to find the distribution of the minimum of many independent variables for random variables with different probability distributions.

For the case taking into account the uncertainty principle, the following model was obtained:

$$V_j = \Theta_j \xi_i$$

$$K = \Theta(n) \xi_0$$

$K$ is the maximum final yield of products in given proportions with limited production capacity; $V_j$ – maximum production capacity; $\Theta_j$ – scale factors for small values of reduced production capacity, $\xi_i$ – random variable.

The random variable $\xi_0$ and the random variable $\xi_i$ have the same distribution function – $1 - \exp\{-x\}$, $\Theta(n)$ is determined by the formula:

$$\frac{1}{\Theta(n)^a} = \sum_{j=1}^{n} \frac{1}{\Theta_j^a}$$

When implementing this model of a diversified economy, the values of controlled parameters were obtained. For large $n$ macrocharacteristics $K$ depend only on the parameters $a$ and $\Theta$. In this case, the controlled parameter $a$ characterizes the stability of the system.

When $\alpha \to \infty$, $[K/\Theta(n)] \to 1$. As for the behavior of characteristic $K$, based on (2), we have established that it is determined only by the macroparameter $\Theta(n)$, and $\Theta(n) \to 0$ for $n \to \infty$. That is, if the number of industries is large, then at least one of them will fail.

The authors (G. A. Kolomensky, L. A. Selivanova, N. V. Vasilyeva) proposed two solutions: stabilize the behavior of each industry and increase $\Theta$ with increasing industry scale.

They also pointed out some shortcomings of the model. For example, one of the significant drawbacks is the rigidity of the $K$ criterion, which does not imply product replacement. However, in general, the models allow a mathematically accurate description of the economic problems associated with incomplete information. Taking into account the principle of uncertainty when modeling the processes of economic functioning gives special content to optimization issues. An optimal plan is not only a task focused on obtaining maximum output in appropriate proportions, but also a plan that ensures a given level of...
stability and reliability of the achieved intensity of social production. In cases where analytical mathematical models are ineffective, it is advisable to use modeling methods that do not require either linearity or constancy of connections, that is, the structure of simulation models does not depend on the methods for solving these models. Such modeling allows the use of more than one mathematical method. Simulation models allow us to accurately reflect reality. In agriculture, simulation modeling can be effectively used to assess the economic efficiency of technology options and organization of production in crop production, livestock farming, or to assess the dynamics of the structural parameters of the production and economic process, but in cases where the number of such parameters is small.

In theory [15], simulation modeling is used to predict the development of farms under the influence of price, tax and credit policies of the state. The model provides for modeling the functioning of several farms that have the same number of fixed assets, material resources and the same production technology. Products are sold on the market as a whole under the same conditions for all. The model takes into account the interaction of farmers with markets for fixed assets and material resources. In this case, random price fluctuations within certain limits are taken into account and the expert sets the trend and dynamics of their changes. Much attention in the model is paid to credit and financial relations, and the taxation system is adequately modeled. An annual time step was introduced into the model. Modeling begins with a planned decision about the optimal use of resources. Further development is modeled as follows: the resulting products (taking into account stochastic returns) are sold in the form of profit, from which taxes, loan commissions and all that are paid. Based on the balance of money (if there is no money, a bankruptcy case is considered), a decision-making task for the next year is formed on the farm. Strategic and tactical plans are the result of optimization of linear models. The strategic plan is obtained as a result of the computer implementation of the following economic and mathematical model:

\[
\begin{align*}
\sum_{i \in I} a_{ik} x_i &\leq f_k - y_k + z_k \\
y_k &\leq \lambda f_k \\
\sum_{k \in K} d_k \sum_{i \in I} a_{ik} x_i &\leq D_0 \\
D_u + D_0 &\leq D \\
\sum_{i \in I} R_i x_i &\rightarrow \text{MAX}
\end{align*}
\]

Accordingly, we obtain a tactical plan using this model:

\[
\begin{align*}
\sum_{i \in I} a_{ik} x_i &\leq f_k \\
\sum_{k \in K} d_k \sum_{i \in I} a_{ik} x_i &\leq D + K \\
K &\leq K' \\
\sum_{i \in I} p_i x_i &- (1 + \eta) K \rightarrow \text{MAX}
\end{align*}
\]

\(a_{ik}\) – matrix of direct costs (product by type of funds); 
\(C_k\)’ is the purchase price of type \(k\) equipment; 
\(C_k'\) is the selling price of type \(k\) equipment; 
\(d_k\) – revolving fund; 
\(D_u\) – funds for the purchase of equipment; 
\(D_0\) – means of replenishing working capital; 
\(D\) – farmer’s funds; 
\(K\) is the loan that the farmer received; 
\(K'\) – credit limit; 
\(f_k\) – available fixed assets; 
\(\lambda\) – liquidity ratio of funds; 
\(p_i\) – profit of products of the \(i\)-th type; 
\(r_i\) – profitability of production of products of type \(i\); 
\(x_i\) – production plan; 
\(y_k\) – sold and \(z_k\) – acquired funds.

This model reflects real processes with insufficient accuracy. Attention is concentrated mainly on the main points. It is advisable to analyze economic problems both on the basis of calculations using models and on the basis of expert opinions. This technology belongs to a special scientific direction – experimental economics.
5 Conclusions

The priority direction for the development of modern methods of managing economic systems in unstable market conditions is the creation of adaptive organizational structures that quickly respond to changes in the internal and external environment. To do this, it is necessary to use new economic and mathematical models that accurately describe the complex, dynamic, stochastic processes of agricultural production. Thus, analyzing the models under consideration, we can conclude that they do not sufficiently take into account the main factors of uncertainty associated with both the natural aspects of agricultural production and fluctuations in the market environment.

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