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Research paper

Fuzzy Model of Attracting Investments in Zones of Risk Agriculture

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Abstract

An optimization model for attracting investments in risky farming zones and algorithms for solving problems of risk assessment is given. The two-criterion problem of finding the optimal combination "risk-return" was solved.

Keywords: *Optimization model, fuzzy sets, alternative, evaluative functional, model, efficiency criterion, risk.*

1. Introduction

There are a large number of publications on decision-making in a risk environment. Widely used minimax approach, optimizing the expected utility, minimizing the average damage or the probability of an adverse event, the model of stochastic programming, etc. [1-3].
However, these productions are not enough to make decisions in fuzzy conditions where it is impossible to focus on the average performance indicators of decisions, as they are justified in case of repeatedly recurring situations, while risk situations are unique, they can happen tomorrow, and never happen. The latter are characterized by the possibility of extremely unlikely but extremely large losses bordering on the survival of the system under consideration. Clearly, traditional risk indicators, such as variance, are inadequate in this case.
In this regard, to assess risks in fuzzy conditions, it is proposed to supplement the system of limitations of the standard decision-making task with a set of constraints on possible losses, namely, for selected scenarios, construct a model of their consequences (damages) as functions of control parameters and impose expert restrictions on an acceptable level of relative damage for of each scenario.
The results of the subsequent mathematical analysis depend to a large extent on how adequately the initial information about the subject of the study is used in modeling, i.e. what is the degree of adequacy of the model. In connection with this, the main tasks of developing models of weakly formalized processes are:
- collection, formalization and processing of information obtained from experts, which is of a non-quantitative, incomplete, linguistic nature and is represented in the form of logically interconnected linguistic expressions, i.e. in the logical-linguistic form;
- construction of soft models for risk assessment and prediction, based on fuzzy inference rules and neural networks;
- development of computational algorithms and software tools for intelligent information processing for risk assessment in various industries.
Find the ideal option "maximum profitability - the minimum risk" is possible only in very rare cases. Therefore, the following approaches are proposed for solving this optimization problem (Table 1).

Table 1: Approaches to the solution of the optimization problem

№	Approaches	Model
1	The "maximum win" approach is that of all options, the one that gives the greatest result (maximum F) is chosen at an acceptable risk for LPS ($R_{пр.доп}$).	$F \to \max$, $R = R_{пр.доп}$, $\sum_j x_j K_j \subset K.$
2	The "optimal probability" approach is that among the possible solutions, one is chosen in which the probability of the result is acceptable for LPS, where $M(F)$ – expected value *F*.	$M(F) \to \max$, $\sum_j x_j K_j \subset K.$
3	The combination of "optimal probability" and "optimal variability" approaches. The variability of the indices is expressed by their root-mean-square deviation and the coefficient of variation, where CV(F) – the coefficient of variation *F*.	$CV(F) \to \min$, $\sum_j x_j K_j \subset K.$
4	The "minimum risk" approach. Of all the possible options, one is chosen that allows you to get the expected gain, i.e. the maximum allowable value of F at the minimum risk.	$F = F_{пр.доп}$,

		$R \to \min,$ $\sum_j x_j K_j \subset K.$
5	The "maximum profitability is the minimum risk" approach	$F \to \max,$ $R \to \min,$ $\sum_j x_j K_j \subset K.$

To solve the two-criteria problem, the method of fuzzy parametric programming is used.
Problems of parametric programming with S independent parameters $T=\{t_i\}, i=\overline{1,s}$, or S-parametric programming problem in matrix form, is written as follows:

$$\sum_j x_j K_j \subset K$$

$$F=(\bar{a}_0+t'\bar{b})x+\bar{e}t \to extr$$

$$t \in R^s$$

Here, x is the solution of the multicriteria parametric programming problem, $K=\{y \mid y \in R^n,\ y \le g\}$ – a given convex subset of the space R_n, $\bar{a}_0, \bar{b}, \bar{e}$ - coefficients that are fuzzy values, usually represented in the form of fuzzy sets with specified functions of accessories $\mu_{\bar{a}_0}(a_0)$ ($\bar{a}_0 \subset A_0$), $\mu_{\bar{b}}(b)$ ($\bar{b} \subset B$) и $\mu_{\bar{e}}(e)$ ($\bar{e} \subset E$).
To solve the parametric programming problem with fuzzy initial data, two approaches are proposed:
Using various operations of defuzzification over fuzzy sets $\bar{a}_0, \bar{b}, \bar{e}$ (integration, summation, averaging, etc.), it is possible to obtain fuzzy estimates of the values of the coefficients a_0, b, e. Then, introducing them in (3) instead of fuzzy coefficients and writing the restriction in the form of the corresponding inequalities, we reduce the original problem to the form:

$$F=(a_0+t'b)x+et \to extr,$$

$$\sum_j a_{ij}x_j \le g_i,\ x_j \ge 0, t \in R^s.$$

We note that, due to the vagueness of the description of the coefficients $\bar{a}_0$ and $\bar{b}$ evaluation of any decision $x(t) \in X$ (and, accordingly, the values of the function *F(t) at x=x(t))* is a fuzzy subset of the numerical axis of the base set *X*.
2. Reduction of the solution of the original problem to the solution of linear programming problems for each discrete α - level.
Algorithms for solving problems of risk assessment are presented. The two-criteria problem of finding the optimal combination "risk-return" was solved.
The task of finding the optimal combination "risk-return" is solved using the following notation: $x_i -$ area sown in the region i; $c_i -$ the cost of cultivating crops per unit area in the region i; $\theta_i -$ crop yields in the region i under normal conditions; $l_{ij} -$ an expertly determined loss factor for acreage in the region i in a catastrophic scenario j; $m_{ij} -$ experienced yield loss in the region i in a catastrophic scenario j; $b_j -$ maximum area in the region i; $\lambda_j -$ allowable losses in shares of acreage for the scenario j; $v_j -$ allowable losses in shares of the total crop for the scenario j; $r -$ risk factor; $I -$ total investment. Then the optimization model of attracting investments in zones of risky farming is as follows:
maximize by $x=\{x_i\}$ rate of return

$$\sum_i \frac{\sum_{j=1}^n \mu(c_i^j)c_i^j}{\sum_{j=1}^n \mu(c_i^j)} x_i \to \max$$

and minimize the risk

$$\frac{\sum_{j=1}^n \mu(r^j)r^j}{\sum_{j=1}^n \mu(r^j)} \to \min$$

under constraints

$$\sum_i \frac{\sum_{k=1}^n \mu(m_{ij}^k)m_{ij}^k}{\sum_{k=1}^n \mu(m_{ij}^k)} \cdot \frac{\sum_{k=1}^n \mu(\theta_i^k)\theta_i^k}{\sum_{k=1}^n \mu(\theta_i^k)} x_i \le \frac{\sum_{k=1}^n \mu(r^k)r^k}{\sum_{k=1}^n \mu(r^k)} \cdot \frac{\sum_{k=1}^n \mu(v_j^k)v_j^k}{\sum_{k=1}^n \mu(v_j^k)} \sum_i \frac{\sum_{k=1}^n \mu(\theta_i^k)\theta_i^k}{\sum_{k=1}^n \mu(\theta_i^k)} x_i,\quad j=1,\dots,m;$$

$$\sum_i \frac{\sum_{k=1}^n \mu(l_{ij}^k)l_{ij}^k}{\sum_{k=1}^n \mu(l_{ij}^k)} x_i \le \frac{\sum_{k=1}^n \mu(r^k)r^k}{\sum_{k=1}^n \mu(r^k)} \frac{\sum_{k=1}^n \mu(\lambda_j^k)\lambda_j^k}{\sum_{k=1}^n \mu(\lambda_j^k)} \sum_i x_i,\quad j=1,\dots,m.$$

To solve the two-criteria problem, the method of fuzzy parametric programming is used.
Problems of parametric programming with *S* independent parameters $T=\{t_i\}, i=\overline{1,s}$, or S-parametric programming problem in matrix form, is written as follows:

$$F=(\bar{a}_0+t'\bar{b})x+\bar{e}t \to extr,$$

$$\sum_j x_j K_j \subset K, \qquad (3)$$

$$t \in R^s.$$

Here, x is the solution of the multicriteria parametric programming problem, $K=\{y \mid y \in R^n, y \le g\}$ – a given convex subset of the space R_n, $\bar{a}_0, \bar{b}, \bar{e}$ - coefficients that are fuzzy values, usually represented in the form of fuzzy sets with specified functions of accessories $\mu_{\bar{a}_0}(a_0)$ ($\bar{a}_0 \subset A_0$), $\mu_{\bar{b}}(b)$ ($\bar{b} \subset B$) и $\mu_{\bar{e}}(e)$ ($\bar{e} \subset E$).
The models for estimating and predicting risk on real objects using the theory of fuzzy sets and neural networks are applied according to the following stages.
Selection of significant factors. At the first stage, the maximum number of factors affecting the risk assessment is identified.
Preprocessing of data. At the second stage, nonessential, according to the expert, and not affecting the forecast, are eliminated.
Building a model. At the next stage, the most suitable structure of the neural network, as well as the algorithm and parameters of its learning, are chosen for this analyzed process.
Evaluation and forecasting (obtaining the result). Experiments are carried out according to a scheme similar to the one at which training was conducted.

The neural network implements a fuzzy inference system in the form of a five-layer neural network.
It is assumed that the following are known:
1) sample of experimental data (X_j, r_j), $j = \overline{1, M}$, where $X_j = (x_{j,1}, x_{j,2}, ..., x_{j,n})$ - The input vector in the j-th pair and r_j - the corresponding output;
2) rules of fuzzy knowledge base (1).
It is necessary to find such values of the coefficients of the conclusion of the rules that ensure the minimum of the quadratic residual:

$$E = \sum_{j=1}^{M} \left(r_j - \hat{r}_j \right)^2 \to \min,$$

Where $\hat{r}_j$ - result of output on a fuzzy model.

The algorithm for identifying fuzzy knowledge base parameters using (1) is as follows:
Step 1. Set the parameters of the algorithm: E^* - the allowable quadratic residual and z^* - the maximum amount of training period.
Step 2. Calculate the relative degrees of implementation of the conclusions of the rules for each line of the training sample $j = \overline{1, M}$.
Step 3. Set the training iteration count and the learning period counter:*j=1* and *z=1*.
Step 4. Set the initial values of the custom parameters.
Step 5. Calculate the error value for the j-th data pair from the sample and recalculate the values of the adjustable parameters using formula (2).
Step 6. Check the condition "$j < M$", If "yes", then increase the iteration count $j = j + 1$ and go to step 5.
Step 7. Calculate the value of the quadratic residual on the entire sample of data at the z-th learning period $E^{\langle z \rangle}$.
Step 8. Check condition "$E^{\langle z \rangle} \le E^*$?". if "Yes", then go to step 10.
Step 9.Check condition "$z < z^*$?". if "Yes", then increase the period counter $z = z + 1$, set the training iteration count to unit*y = 1* and go to step 5.
Step 10. The End.
Thus, the assessment and forecast of the risks of crop failure based on the construction of approximating models using expert data on risk were obtained. Using the results of a fuzzy model for assessing the risk of underfeeding, the multicriteria optimization task of attracting investment in zones of risky farming has been solved.
Algorithms and software for intellectual processing of information are developed when making a decision on risk assessment based on models of fuzzy parametric optimization with the addition of the constraint system of the standard problem by a set of loss constraints that are described with the help of fuzzy sets.

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