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Application of fuzzy inference system to increase efficiency of management decision-making in agricultural enterprises

Abstract. Application of fuzzy inference system to increase efficiency of management decision-making in agricultural enterprises. Theoretical and methodological issues, practical recommendations on improvement of management decision-making in agricultural enterprises to increase their competitiveness have been intensified and developed in the article. A simulation example of a quality management system for agricultural products on the basis of the theory of fuzzy sets and fuzzy logic has been proposed. The factors that affect the quality of agricultural products have been defined.

Key words: fuzzy sets, fuzzy logic, linguistic variables, efficiency, product quality management system, administrative decisions, manager, agricultural enterprises

Introduction

A manager plays a vital role in the daily functioning of an agricultural enterprise, notably in the effective administrative decision-making that provides it with steady development. Success functioning of a company depends on many personal features of a leader: leadership abilities, organizational capabilities, qualification and working experience specifically in the agricultural arena, ability to set goals and reach them sequentially, and also to make decisions on time and based on considerable theoretical and practical knowledge and which contain scientific substantiation.

The realities of the modern market environment lend themselves to active application of innovative approaches, for example methods of mathematical design, in particular, application of fuzzy system modeling in administrative decision-making, which makes it possible to calculate final results and to choose more rational options.

Analysis of recent research and publications

Fundamental studies of the manager's role in management decision-making has been carried out by such scholars as Albert M., Boddi D., Drucker P., Kabushkin M., Knorring V., Ladanov N., Lantsyski E., Lutens, Meskon M., Mintzberg K., Peyton R., Yukl G., Skibitska L., Taylor, F., Faiol A. and others.

Considerable contribution to the application of fuzzy logic was done by the following scientists: Lotfy Zadeh, Leonenko A., Kruglov V., Nyedosekin O., Saaty T., Fishburne, Shtovba D.

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However, the problem of choosing the appropriate approaches to the acceptance of administrative decisions in domestic agricultural enterprises with application of artificial intelligence needs further research.

The purpose. To substantiate the use of the process approach in management decision-making. To identify and specify the factors that affect the quality of agricultural products. To investigate the possibility of applying fuzzy logic systems to improve decision-making in agricultural enterprises.

Results. The process of administrative decision-making envisages a conscious leader's choice among existent alternative actions, that will provide the achievement of the desired organization state for a certain period of time, and that corresponds to the general aims of the enterprise. The types of administrative decisions according to the classification criteria are shown in Table 1.

This process passes three stages:

1. finding out the problem (collection of information, determination of topicality, determination of the conditions when the problem is considered to be solved);
2. development of a decision plan (search of alternative decisions, analysis of a decision and its comparison with present resources, study of possible economic and social consequences after the decision-making, development of a detailed decision-realization plan);
3. decision implementation (to give information about a decision to concrete performers, motivation and control in decision implementation).

The result of administrative decisions is clear coordination of personnel, and also financial and economic indicators of industrial and business activities of enterprises. Thus, the more effective and efficient are decisions made by authorities, the more competitive products will be, and as a result, the more profitable the organization will be. Low quality of administrative decision-making leads to economic and social losses.

For effective development and rational decision-making by the authorities in the modern stage of organization management it is possible to use special technologies: "Management technology according to the results", "Management technology on the basis of necessities and interests", "Management technology by using permanent monitoring and guidance", "Management technology in exceptional cases", "Management technology on the basis of artificial intelligence", "Management technology on the basis of activation of personnel activity".

Due to intensive development of modern information technologies, application of "Management technology on the basis of artificial intelligence" is in greater demand. This technology envisages application of mathematical methods, statistics and economics, and special computer programs for the development and implementation of effective leadership decision-making. The method of mathematical programming allows calculation of the best variant in accordance with optimality criteria.

Decision-making becomes actual in the conditions of vagueness, namely insufficient amount of reliable information, data that are based on the use of fuzzy logic content rules. Practical applications of the theory of fuzzy logic take place in the different areas of science and industry in a national economy. Fuzzy logic is used in cases when, next to quantitative descriptions in Knowledge Base Intelligent Systems, there are also quality descriptions of a phenomenon or object. Fuzzy logic is used while analyzing new markets, for political rating, and to estimate the correlation of risks and profits, efficiency of personnel, choice of optimal pricing strategy, etc. [Asai 1993, Borisov 1990].

Table 1. Types of administrative decisions according to classification features

Classification feature	Groups of administrative decisions	Comments
Degree of problem repetition	Traditional	Constantly used in management practice
	Untypical	Require the search of alternatives
The significance of the purpose and action duration	Strategic	Designed the decision of perspective long-term tasks
	Tactical	Provide realization of strategic tasks
	Operating	Decisions of current issues in order to reach tactical and strategic aims
Sphere of influence	Global	Decisions that influence activity of organization in general
	Local	Decisions that are made in a single department
Duration of selling process	Long-term	Selling process takes up to few years
	Short-term	Selling process requires a few hours, days or months
Method of solution development	Formalized	Made according to predetermined algorithm
	Unformalized	Decisions made in non-standard and untypical situations
Number of selection criteria	According to one criterion	Typical for formalized decisions
	According to many criteria	Typical for unformalized decisions
Type of decision-making	Individual	Made by one person
	Collective	Made by group
Method of solution fixing	Documented	In written form
	Non documented	Declared in oral form
Character of used information	Determined	Made in conditions of certainty
	Credible	Made in conditions of uncertainty
Background for decision-making	Intuitional	Made on the basis of accuracy
	Decisions based on assertions	Made on the basis of experience
	Rational	Made on the basis of analytical thinking
Role and functions in management process	Informative	Information transformation into the form, that corresponds to task decision in the best way
	Organizational	Determination of structure, distribution of functions between subdivisions and public servants in accordance with the scheme and established procedures
	Technological	Setting goals and objectives, readiness to work fulfillment, facilities and methods

Source: own research.

Methods of fuzzy sets application should also be used in agricultural production as well, where there are a great deal of factors that influence stability of the system. The theory of fuzzy sets makes possible the use of subjective expert knowledge about this problem for making decisions, to form the field of alternative actions, and to forecast system behavior.

The management of an agricultural enterprise is interested in rational decision-making and sequential fulfillment of procedures aimed at increasing production of competitive goods and increasing profits. One of the key questions is to take into account the factors that influence product quality of during its life cycle.

Among the investigated totality of agricultural enterprises of the Bilotserkivskyi and Zhashkivskyi districts in Ukraine, a considerable part of agricultural production is occupied by sunflower growing. According to the State Statistics Service, Ukrainian agrarians harvested 11051 sunflower seed in 2013 with an average yield of 21,7 hundredweight per hectare [Asai 1993]. Under the perspective of European Integration and getting new markets, the quality of raw materials and the factors that influence product quality are significant issues. Therefore, taking into account the considerable production potential of agricultural enterprises and the strong position of sunflower growing as a strategically important crop, we have proposed a fuzzy model of quality management system of vegetable oil in the agricultural enterprise.

Traditional system modeling, in view of a lack of full information as to growing conditions, seed storage and processing of oil crops can not be applied. In such cases it is advisable to use methods that are specifically focused on building models that take into account the accuracy of input data, in particular fuzzy modeling [Leonenkov 2005, Shtovba 2007].

Fuzzy system of quality management of vegetable oil in an agricultural enterprise consists of ten knowledge bases combined into a hierarchical system of three levels: technology, quality and cost effectiveness. The efficiency of sunflower growing, its harvesting and distribution is determined by the level of profitability Z.

The level of technology includes four knowledge bases:

- crop capacity (y_1);
- oil content (y_2);
- moisture (y_3);
- impurity (y_4).

Knowledge base that characterizes the sunflower productivity (capacity) is presented in the formula:

$$y_1 = f_1(x_1, x_2, x_3, x_4),$$

where x_1 – is a linguistic variable (LV) of soil; description; x_2 – LV of climatic conditions; x_3– LV of category of sowing material; x_4– LV of agricultural technologies.

Knowledge base that characterizes the oil content of sunflower is calculated by the formula:

$$y_2 = f_2(x_1, x_2, x_3, x_4)$$

Knowledge base that characterizes moisture of sunflower is calculated by:

$$y_3 = f_3(x_5, x_6, x_7),$$

where x_5 – LV weather conditions during harvesting; x_6 – LV of harvesting; x_7 – LV of sunflower transporting and storage.

Knowledge base that characterizes the presence of garbage and oil additives in sunflower seed – “Impurity" is described by the following formula:

$$y_4 = f_4(x_4, x_6, x_8),$$

where x_8 – LV of sunflower cleaning.

The level of quality consists of four knowledge bases:

– quality of products (y_5);
– quality of production (y_6);
– quality of organization (y_7);
– quality of selling process (y_8).

Knowledge base that characterizes quality of products (class of sunflower seed) – "Quality of products" is calculated by:

$$y_5 = f_5(y_2, y_3, y_4).$$

Knowledge base that characterizes the quality of production – "Quality of production" is calculated by:

$$y_6 = f_6(x_9, y_1, x_{10}, x_{11}),$$

where x_9 – LV of technical level of equipment; x_{10} – LV metrology provision; x_{11} – LV minimization of environment influence.

Knowledge base characterizes the quality of organization is calculated by:

$$y_7 = f_7(x_{12}, x_{13}, x_{14}),$$

where x_{12} – LV of administrative decisions quality; x_{13} – LV of personnel qualification level; x_{14} – LV of processes clearness and perfection.

Knowledge base that characterizes the quality of selling process is calculated by:

$$y_8 = f_8(x_{15}, x_{16}),$$

Where x_{15} – LV of logistics; x_{16} – LV of marketing.

The level of economic efficiency includes two knowledge bases:

- cost of seed (y_9);
- selling price (y_{10}).

Knowledge base determines the cost of seed and is calculated by:

$$y_9 = f_9(y_6, x_{17}, y_7),$$

where x_{17} – LV of expenses on growing and harvesting.

Knowledge base that characterizes the cost of sunflower seed selling is calculated by:

$$y_{10} = f_{10}(x_{18}, y_5, x_{19}),$$

where x_{18} – LV of demand; x_{19} – LV of inflation index.

Let's define linguistic variable models and their term-set. Thus, for denotation of variables we have used terms: very low (VL), low (L), medium (M), high (H) and very high (VH) [Lofti, Zadeh 2002].

Indexes mentioned above will be input variables for the system of unclear conclusion.

Output parameters are indicated by the following indicators:

- the first knowledge base of sunflower productivity is given in centner per hectar;
- the second knowledge base of oil content – in percentage;
- the third knowledge base of moisture – in %;
- the fourth knowledge base of impurity – in %;
- the fifth – the class of seed is estimated in relative units – in points;
- the sixth is a sort of seed – in points;
- the seventh knowledge base of the cost of sunflower oil – in hryvna;
- the eighth is the selling price of oil – in hryvna. We will get a profitability parameter on the output model.

We have used MatLab software for system implementing. We have introduced linguistic variables for the construction of unclear conclusion systems. Model authenticity first of all depends on the degree of correspondence of rules to real agricultural production and on the terms belonging to functions. Further we have defined the functions of terms belonging to input and output parameters of the model (Fig. 1). Then we have introduced them to each knowledge base using the operations of fuzzy logic (min-crossing of term set of dependences).

To phase the variables we will use the piece-linear functions of belonging "triangular" and "trapezoid", because it is necessary to set properties of an uncertainty set like "located in a range" [Shtovba 2007]. Data of sunflower growing and its processing into oil have been used in phasing the variables and making rules of the fuzzy system.

Taking into account the number of freedom degrees of input linguistic variables that are included in equations of knowledge bases we have calculated the maximal amount of base rules of unclear system $3·3·3·3 + 3·3·3·3 + 3·3·3 + 3·3·3 + 5·4·3 + 3·3·3·5 + + 3·3·3 + 3·3 + 3·3·5 + 3·3·3·4 = 600$.

The modeling of the unclear conclusion system was carried out by the Mamdani algorithm [Mamdani 1974]. Then aggregating of sub-terms in unclear rules was carried out according to the following principle: those rules, the true degree of which differs from zero, are considered to be active and used in the following calculations.

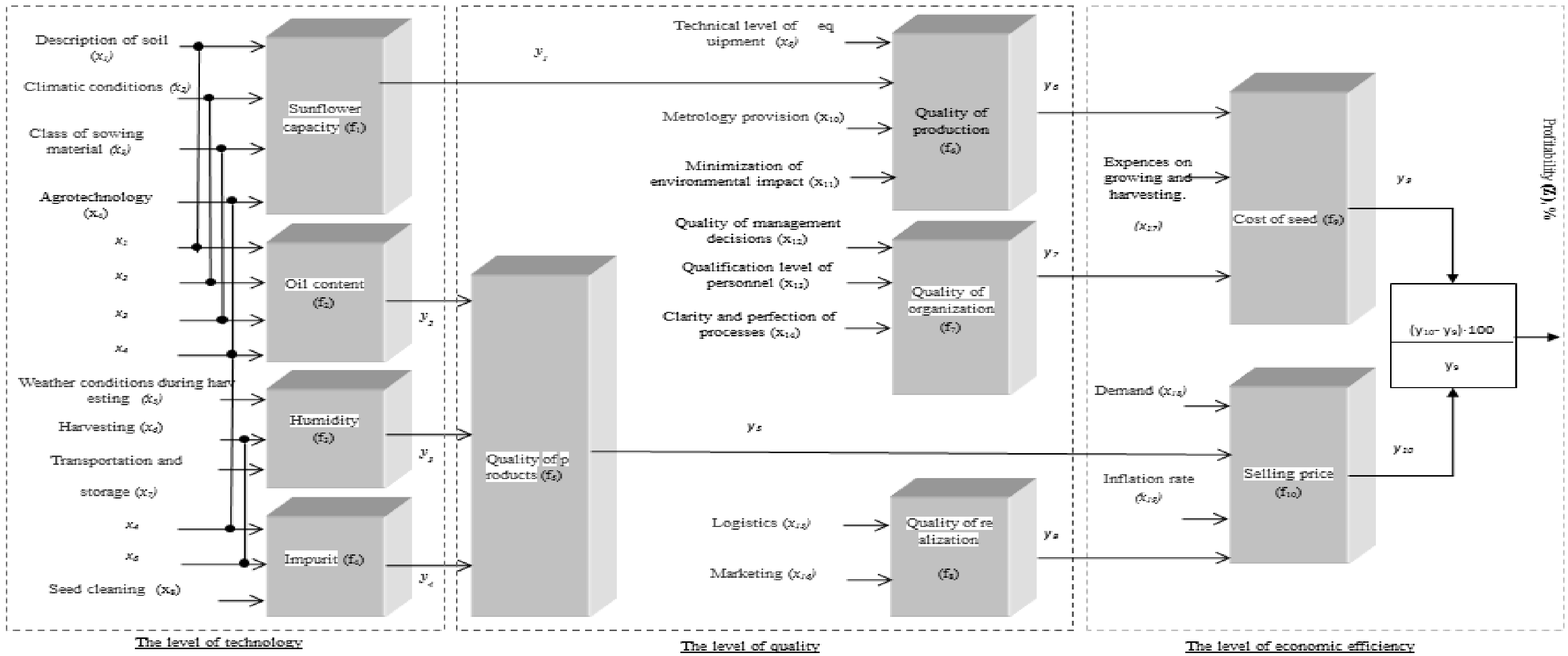

Fig 1. Hierarchical system of fuzzy logic of sunflower seed quality management in agricultural enterprise

Source: own research.

Activation was implemented in accordance with a method of min-activation using Mamdani algorithm [Mamdani 1974]:

$$\mu'(y) = \min\{c_i, \mu(y)\},$$

Where $\mu'(y)$ – is the result of activation of belonging function of output fuzzy set; c_i – is the degree of truth of conclusions for every rule; $\mu(y)$ – is the function of belonging of output fuzzy set.

We have calculated accumulation for obtaining belonging functions of output variables by the formula [ ]:

$$\mu_D(x) = \max\{\mu_A(x), \mu_B(x)\} \qquad (\forall x \in M_x),$$

where $\mu_D(x)$ – is the belonging function of output fuzzy set D; $\mu_A(x), \mu_B(x)$ – is the belonging function of input fuzzy sets A and B.

Dephasing of output linguistic variable sets Mx = {X1, X2, ..., Xs} was calculated according to the method of gravity centre (centroid) [Knorring 2001] by formula:

$$y = \frac{\int_{Min}^{Max} x \cdot \mu(x)dx}{\int_{Min}^{Max} \mu(x)dx},$$

where y – is the result of dephasing; x – is the variable that corresponds to the output linguistic variable X; $\mu(x)$ – is the belonging function of fuzzy set that corresponds to the output variable X after accumulation stage; *Min* and *Max* –is left and right points of interval of fuzzy set.

MatLab software allows to present graphically the surface of input parameters of vegetable oil quality management system in an agricultural enterprise and output parameters such as: influence of soil quality, climatic terms, sowing material and agricultural technology on productivity; influence of harvesting, transporting and storage on seed moisture; influence of material moisture and impurity on quality of products; effects of level of equipment and minimization of environment impact on quality of production; role of personnel qualification and clearness of organizational processes on production organization quality; influence of logistics and marketing on seed distribution results, etc. (Figure 2, Figure 3).

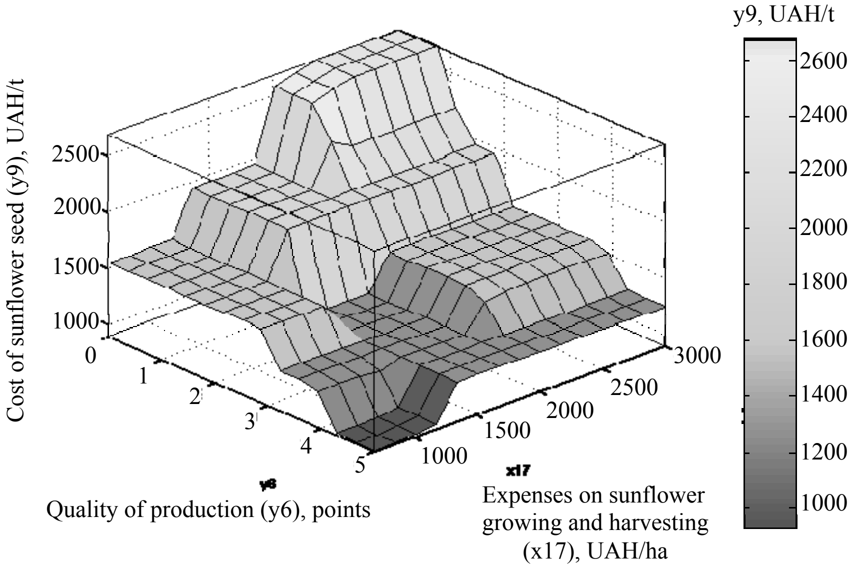

Fig. 2. Surface of response of production organization quality, costs on sunflower growing and harvesting to the cost of seed

Source: see fig. 1.

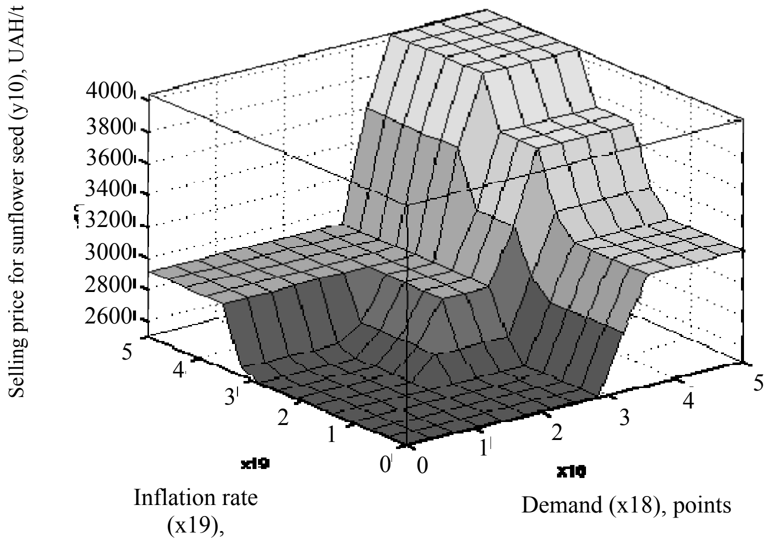

Fig. 3. Surface of response of demand and inflation rate to the selling price of seed

Source: see fig. 1.

Thus, by means of a clear management system of oil and sunflower seed quality in agricultural enterprises, a manager can make reasonable and effective decisions that will allow increasing profitability of sunflower seed and oil production.

Conclusions

Alongside the use of traditional approaches to the practical problems that can arise today in management systems of agricultural enterprises, the application of the theory of fuzzy sets and the fuzzy logic built on its basis is becoming more and more popular. The synthesis of classic and innovative methods in management and decision-making allows enterprises in the agricultural sector in Ukraine to realize their potential and to achieve a maximal effectiveness that has positive impact on quality of products and on production organization in general.

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