

# **Application of Fuzzy Sets within Measuring and Managing certain Agricultural Risks**

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**Paper prepared for presentation at the 120<sup>th</sup> EAAE Seminar “External Cost of Farming Activities: Economic Evaluation, Environmental Repercussions and Regulatory Framework”,  
Chania, Crete, Greece, date as in: September 2 - 4, 2010**

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**ABSTRACT TITLE:**

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**Abstract:** The aim of this paper is to set-up the algorithm for determining the degree of workability of the soil, to help the owners of family farms to plan working hours of agricultural machines, i.e. with the machine park management. The plans, which would be made by use of these algorithms and based on the accurate information of the cultivation conditions, would result in the appropriate use of time and capacity of the agricultural machines. In some sectors, such as agriculture or certain industries, chance that certain event occurs plays a very important role. The influence of random events, however, can be significantly reduced if decision makers are counting on them, reveal their nature and gather as much information about them as possible. Justification of new testing methods applied in the economy follows from the fact that, according to economic policy, the growing burden of risk that comes from the uncertainty is borne by farmers.

The method that was used in the study is based on the Fuzzy mathematical modeling. Treating uncertain, vague and linguistically described phenomena and situations is facing difficulties in classical mathematics. In fact, a large degree of uncertainty is primarily resulting from uncertain external events. Fuzzy mathematical modeling can satisfactorily treat those parameters that are uncertain, vague and subjectively evaluated. The algorithm of risk assessment should be based on the opinion of economic experts, on the experience of the makers of planned decisions and on all the available data. Solving this problem can be approached in three ways: a) conventional method, b) applying the expert system, c) applying the theory of fuzzy sets.

The main characteristic of the traditional way of solving the problem of evaluation is the almost exclusive reliance on measurable economic effects (time and money). Only in some rare cases, additional criteria are taken into account. Because of the importance of additional criteria, it is possible to develop a prototype of an expert system. Modeling problems in which the interdependence between the variables is very complex, fuzzy logic can be successfully applied. The complete review and analysis of the problem relying only on knowledge, experience of experts, without the fuzzy logic, would be impossible.

**Key words:** Agriculture, Family Farms, Machine Park Management, Fuzzy Systems

## 1. Introduction

Today, optimal use of all resources is an imperative factor in decision-making processes. Agricultural production cannot be imagined without significant investment in the modernization of equipment and facilities. Given the current global economic crisis, it is clear that the current credit policy does not allow family farms any important investment in terms of renewing their machine parks. For that reason, it will be of great importance for all owners of family farms to make the use their machinery as efficiently and economically as they can, since the right selection and rational use of means of mechanization greatly affect the cost of grain products, and produce best financial effects.

Furthermore, optimal use of existing capacity of machine park requires making economically rational short-term plans. Actually, every decision-maker, including farmers, has to predict the expected future. Best practices in risk management now include the use of some model risk from all its sources (Ray, 2010). This paper aims to show how family farms, with fuzzy logic, can determine the degree of workability of the soil, i.e. how they can use all available data to make a plan of working hours of agricultural machines.

## 2. Fuzzy logic

For the modeling process, we often use methods of probability theory. In many cases, the use of vague, incompletely defined (fuzzy) events can be used. Zadeh, L. A. (1965) extended the theory of probability to define the fuzzy event. He considered a *non-fuzzy probability of the fuzzy event* based on classic probability.

Input variable of the fuzzy systems are, so-called, linguistic variables (i.e. "full", "several", "almost all", "set", "old", "rare", "dangerous"). Values of joined output variables correspond to the weights of belonging to fuzzy set. Therefore, it is necessary to do a *defuzzification* or to select one-value output variables. The elements of fuzzy logic are fuzzy truth-values: true, very true, more or less true, and mostly false.

Fuzzy logic (used in models to introduce rules based on *IF THEN* form) must be defined in advance, similar to functions of belonging. Usually, for the generalized conjunction operator we adopt minimum section, and for the union operator or disjunctions, we take a maximum.

### ***Fuzzy modeling approach and classical approach***

*Probability* - It is necessary to distinguish the terms *dimness* (blur, fuzzyness) and *probability*, which are fundamentally different. The probability shows the percentage of a possibility that one very specific event, of all possible, happens; dimness, on the other hand, is the extent in which event occurred. After the event occurs, the entire counting that provides the probability to predict whether it's going to happen, is losing meaning, while the blur remains a necessary component for the description of the event.

## ***Fuzzy game theory***

The basic assumption of the *fuzzification* is to obtain an efficient instrument for various kinds of uncertainty and for the use of natural language in the shaping of decisions. In the area of the multiple hierarchies' decision-making in business, a series of problems (whose solution is not possible to find with a classical methods of quantitative analysis) can occur. This primarily refers to issues such as the following:

1. Ambivalence of goals,
2. Variability factors,
3. Subjective vision
4. Linguistic description of the variables.

The theory of fuzzy sets provides a conceptual framework for addressing problems with vague and imprecise information, statements, and uncertainties, which predominantly have a non-statistics nature. We can say that the limitation of the fuzzy game theory is in mastering uncertainty for a long time. When some environment is turbulent the weakness of statistical methods are always highlighted, since they are based on the naive postulate of logical continuity between past, present and future.

In every economic problem, the source of imprecision and uncertainty is not only in the presence of random events. There are also inability to operate exact data, due to the complexity of the system, or inaccuracies in defining the limits and goals. Therefore, by using the fuzzy sets theory, it is possible to complete the knowledge and experience in the field of business strategy (investment, market economy, financial functions, features or product development research).

When some company defines its policies, strategies and objectives, the possibility of combining fuzzy analysis and game theory is recommended in order to find better solutions. In a fact, "*Fuzzy games*" connect the theory of games and theory of fuzzy sets as a one tool in decision-making process. They are provided to model any conflict situation with imprecise information and linguistic described input data (Matrix elements of the profit, strategies, etc. can be presented in "fuzzy size").

Thus, for example, we can imagine a two-player zero-sum matrix game with fuzzy random payoffs  $\underline{S1}$  and  $\underline{S2}$  are the final strategies of two players ( $I, II$ ), and  $\tilde{K}(S_1, S_2)$  is a fuzzy set of  $R$ , which defines the fuzzy values if the player  $I$  chooses a strategy  $S1$  and if player  $II$  chooses a strategy  $S2$ . Both players want to maximize the gain. In this case, it is assumed that each player knows the selected strategy of the other. Player  $I$  maximize its profits  $KI (S1, S2)$  through its fuzzy set strategy, but for a given  $S2$ .

Even without taking into consideration what the player  $II$  does, the player  $I$  can obtain at least:

$$\max_{s_1 \in \tilde{S}_1} \min_{s_2 \in \tilde{S}_2} \tilde{K}(S_1, S_2) = \tilde{v}_1$$

Similarly, the player *II* may provide at least:

$$\min_{s_2 \in S_2} \max_{s_1 \in S_1} \tilde{K}(S_1, S_2) = \tilde{v}_2$$

Existence of the  $\tilde{v}_1 \cap \tilde{v}_2$  value is a proof of beingness of *saddle point*. Thus, a sure strategy *S1* for player *I* is:

$$\min_{s_2 \in S_2} \tilde{K}(S_1, S_2) = \tilde{v}_1$$

which gives the value  $v$ . That value is fuzzy and its function of gain also has a fuzzy character (Xu, Zhao, Ning, 2006).

In conclusion, combining methods of game theory and fuzzy sets, i.e. *Fuzzy games* is a helpful theory, especially when decision-makers need to:

- make a structure of the problem and precise its description,
- develop all possible solutions,
- make an appropriate choice,
- find a possible and acceptable way of implementing the decision.

It is difficult to determine which method should be used in solving a specific problem. Therefore, when analyzing a problem, decision-maker should always take into consideration the possibility of connecting, combining methods (like in this case: the method of game theory and fuzzy sets). But, *the fuzzification* for any price is justified because the “need for combining” arises from the nature of the problem.

### 3. Fuzzy set-based example of approximate reasoning

Rational use of machine park significantly affects the farmers’ prices of grain products. To obtain best financial effects, it is necessary to use optimally the existing resources. In the most of cases, problems that farmers have with the organization can be generalized, and their resolution is the use of set algorithms. Programmed and applied on the computer, they can serve to landowners as an aid in decision-making process. Surely, the introduction of a PC in agricultural production provides access to a large number of information to direct managers about the production process.

Farmer is making a plan of his one-year work, based on the data from previous years. The necessary technical equipment for the next production period is determined by many factors, such as:

- size of land,
- structure of agricultural production,
- existence of the appropriate means of mechanization on the market,
- possibility of obtaining the necessary capital,
- relationship between price and rented machines,
- machine utilization, and
- required human resources.

Since all the mentioned factors can be quantified, a general model that will determine the optimal structure of agricultural production and required technical equipment can be set up. Optimal use of

existing capacity machine park requires making rational economic plan for the next week or day (short-term planning). Agricultural production of grain is seasonal, depends on climate, weather conditions, the type, quality, and soil moisture. It is very difficult to quantify any condition of the above-mentioned factors.

The aim was to set-up algorithm that can determine workability of land. Furthermore, owner of family farms will be more precise in the planning of working hours of agricultural machines. The lack of plans (due to the lack of accurate data on appropriate cultivation conditions) is often resulting in improper use of time and capacity of the machines. The consequence is *reduced number of profitable operations* (Louisot, 2005). It is difficult to make a decision weather to work on the farm, when certain decisions are made for the next few days in conditions of uncertainty and high risk. Factors that contributes to this are:

- large number of relevant variables,
- impossibility of measuring the relevant variables,
- instability and nonlinearity of the relevant variables,
- lack of information in terms of quantification and measurement of activities of relevant variables, and
- lack of accuracy and inaccessibility of information.

Treating uncertain, vague, and linguistic phenomena, and described the situation facing difficulties in classical mathematics. A large degree of uncertainty is primarily a result of biological nature of farming, as well as dependency on meteorological conditions. Fuzzy mathematical modeling can satisfactorily treat this type of parameters. Algorithm should be based on the available data, but also on the opinion of agricultural experts and the experience of agricultural workers.

If one farmer makes a decision for the upcoming period, he is making a plan on how and when to perform, by taking into account a large number of attributes. For example, when the land is wet, agricultural work causes serious damage to the soil, increase the costs of processing and the additional cost of machine downtime, the strength of the traction machine tools is reduced, and the time required to perform certain tasks is increased. The ground is considered arable if the machine can move on it and do its function without damaging the land. Damaged land is under-defined parameter, and to determine the workability of the soil is very hard work.

One of the most influential factors in the selection decision "to work or not" is determined by the workability of land, existing and predicted weather conditions over the next few days. The parameters that determine the weather conditions are:

- soil moisture,
- expected rainfall,
- temperature,
- expected temperature,
- the wind and expected wind.

### ***Methods and analysis***

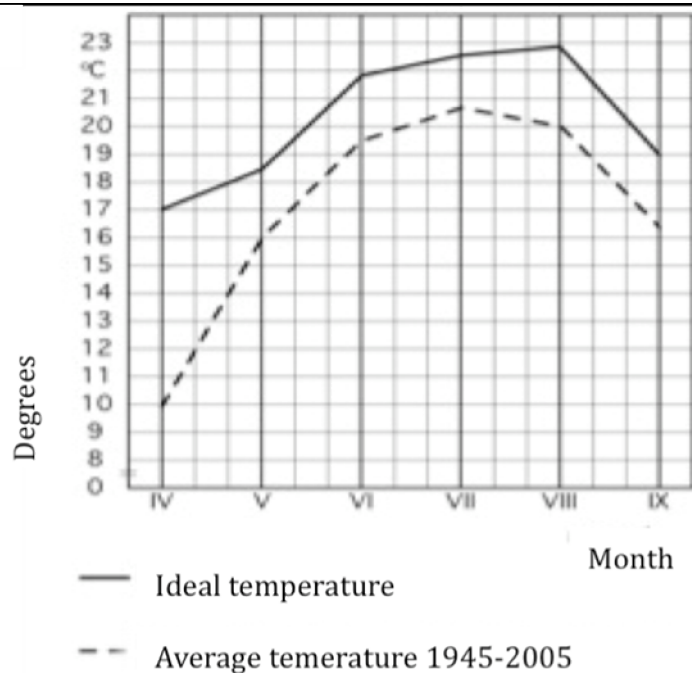
The heat is a form of energy that enables the generation and development of all living beings in nature. Together with other elements of light and climate, they enable the creation, development and

survival of plants, animals and people. Without specific soil temperature, air, water and lighting conditions, it is not possible to conduct a series of processes, starting from germination until the ripening of plants. There would be no nutrients in the soil, and the functioning of the osmotic pressure would be unthinkable.

In *Figure 1*, which is divided into boxes, are given a numeric value of temperature. At the base images are given months from April to September, and within each of these months there are three boxes (monthly decade). Full lines represent ideal temperature curve, while the average temperature curve is represented by dotted line. Among them is an area that fluctuates more or less from year to year.

Walas and Bressman have come to these values in 1937 by the thermogram, while the data on measurements of average temperature occurred in the period 1945 to 2005 (for the Northern Bachka region in Serbia). The thermogram of planting should be used as the selection of regions that match the characteristics of individual plant species, and to determine the planting or sowing date, as well as the choice of working days for other activities. However, annual variations in the data, the average temperature must be taken into account.

**Figure 1:**  
Thermogram  
of ideal and  
average  
temperatures  
from april to  
sept. in  
northern  
Bachka



Source: [www.weatherbase.com](http://www.weatherbase.com)

For all plants and animals, the most important state of the water is liquid. In a somewhat lesser extent, it is also important that water has a vapor-temperature, but below the boiling point. The water in the form of ice is the lowest importance for all forms of life on Earth. High temperatures usually cause low humidity. Extremely high humidity increased occurrence of plant diseases, disables the machine works, extending the ripening of fruit, and sometimes-causing germination of kernels per spike and beams.



Winds are known as slower or faster moving air masses. Winds greatly affect the distribution of weather conditions on the ground. Penetration of warm and cold air masses lead to large variations in temperature as well as in other elements of climate that would otherwise apply to certain seasons.

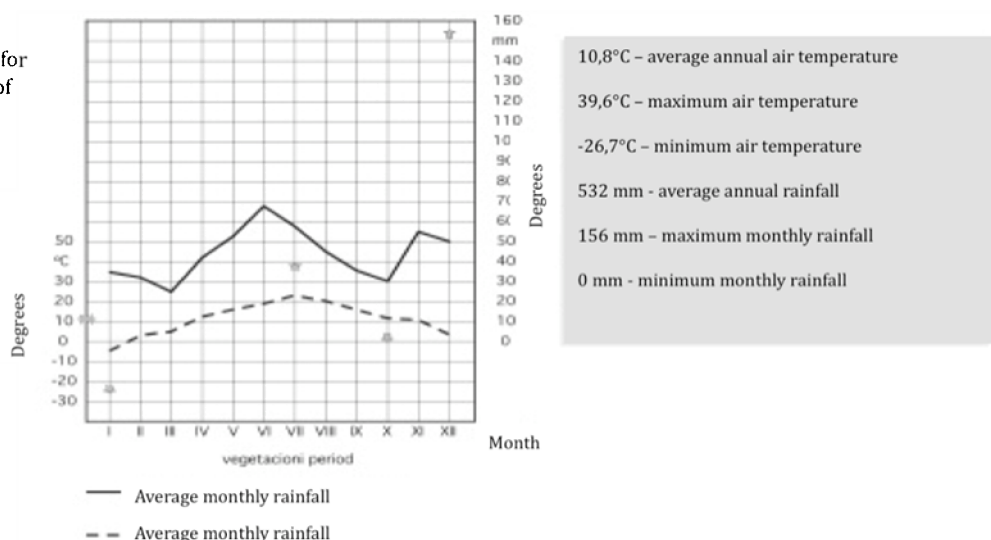
Winds may have a different speed, strength and direction of movement. They can be cold, hot, wet and dry. Depending on the type of winds and weather reporting, they can be more or less helpful. Damage of wind erosion is reflected across the land erosion and land drying, which in some cases may prove useful for facilitating and some agricultural work. Strong winds can relate the surface layer of soil along with it and seed, and in some cases, plants sprung.

Of all the five elements of climate, the most monitored data during the year are usually rainfall and air temperature. For this purpose we use a climagram (Hellmann, 1924), in which data are entered daily on the amount of rainfall and air temperature (Figure 2). Given the annual variability of climate, those data are not sufficiently reliable for agricultural production. Therefore, the annual data (within climagram that includes at least twenty years) are compared with each other to get the average sizes that are used as information in agricultural one-year production.

In the climagram bellow are given the average sizes of the temperature and precipitation for the last 40 years in the field of the region of Subotica in northern Bachka (45°54'34.97"N; 19°47'15.83"E), represented by two curves. Dashed curve represents the mean monthly air temperature (°C) and the second monthly quantity of rainfall (mm). If the field between the two curves is higher, precipitation is less and *vice versa*.

For example, if two curves are at the same position, rainfall is sufficient. If however, such contact is shown to often, the rainfall is exceeding the needs of plant production. There are several points on the climagram that are above-average size, compared to other data. In the text explication, they are related to data that bear the names of *absolute* and *total*.

**Figure 2:**  
Climagram for  
the region of  
Subotica



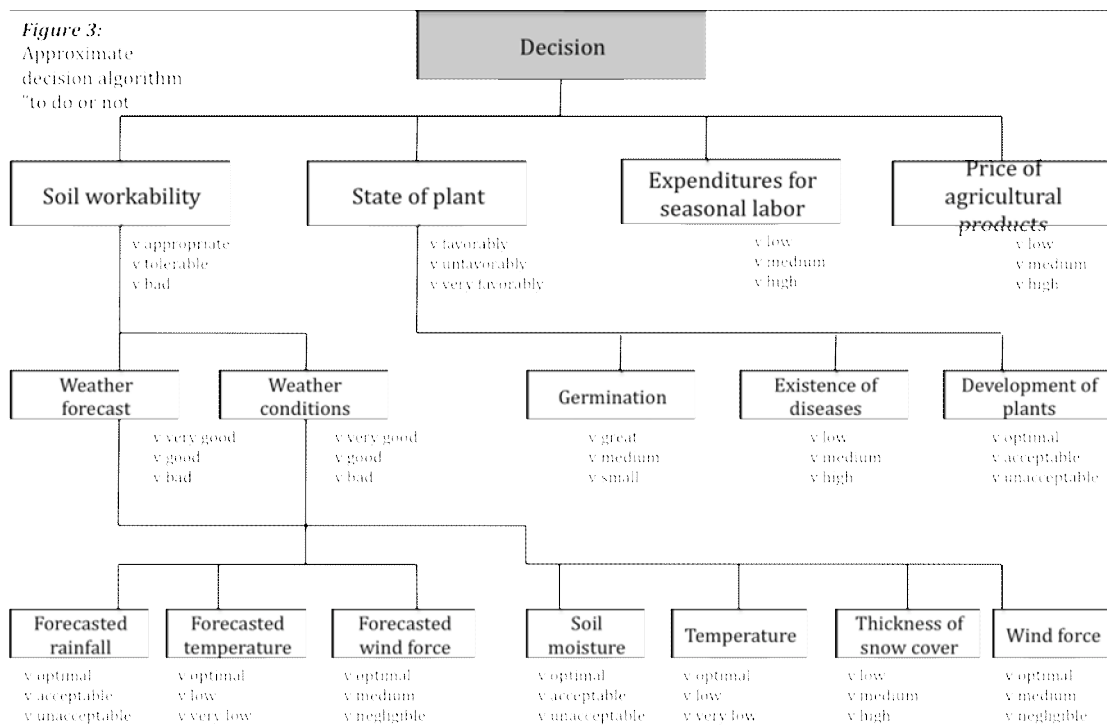
Source: [www.weatherbase.com](http://www.weatherbase.com)

For example, it is expected to be a rainy day, but at the time of observation, soil is wet to 0.5 cm, the wind is up to 15 km/h, and the temperature 14° C. Therefore, workability of the soil is adequate. We know that the existence of snow cover significantly reduces the workability of soil. Because a significant number of previously mentioned factors influence the decision (to work or not), a prototype expert system is developed.

#### 4. Results and discussion

Decision-maker communicates with the expert system in such a manner that he brings values to the attributes of the last leaf of decision tree. On the basis of these data, expert system provides the draft decision. Thus, the risk of making wrong decisions is reduced for a several times, which was the main goal of the expert system.

The character of the other enumerated factors also justifies the application of the theory of fuzzy sets. Decision tree, set in the *Figure 3*, can serve as an algorithm for the decision-making process. If necessary, it is possible to develop this model an even larger number of levels or narrowed to a smaller number of levels, depending on the crops or types of operations that we want to do.



Input variables occur in the first, second and third level. The second level already has five functions of three or four arguments. The third level includes four functions with two or three arguments, with some arguments on the previous level of defined functions (it is a complex function). The fourth level is a function of four arguments, which are defined at the third level. This function is a complex manifold, and its value represents the solution of the model.

However, we can not talk about the functions and their arguments in terms of classical mathematics sense. Input variables (arguments) are so-called linguistic variables ("adequate rainfall", "low level

affected by the disease", "high price of seasonal labor ", etc.). These are also the output size, which until the last level represent the input size for complex functions, such as meteorological conditions, soil workability, the state of the plant. This nature of input and output size (domain values for which there is no possibility to accurate quantification) is very suitable for the fuzzy sets theory, or for solving the above problems.

For modeling problems in which the interdependence between different variables are very complicated, we can easily apply fuzzy logic. Input and output sizes are defined as different fuzzy sets, i.e. all possible values are associated with the corresponding degree of belonging. Finally, it is necessary to define the rules of reasoning, which contain the logical implications of the operations with input conjunction and/or disjunctions. After considering the degree of belonging for each rule, output values of variables should be selected, with a minimum but certainly guaranteed levels of belonging (taking into account all inputs).

In all points, depending on the number of rules, observed output size has different values with different degrees of belonging. The next step is to choose those values (points) that have the output belonging degrees at maximum. In this way, we are getting the output variable that can be defuzzified by using the *center of gravity* method. This point is determined by a specific numerical value, which is either a variable input to the next higher level, either a decision (solution) at the last level.

Thus, applying a large number of steps leads to a final decision, taking into account all possible circumstances, and all possible values appearing in it. Such a complete overview and analysis of the problem relying only on knowledge, experience and intuition of experts would have been impossible without the Fuzzy logic.

Fuzzy variables with domains of possible values can be found in *Figure 3*. According to the function of belonging, fuzzy variables in the given problem have the following characteristics:

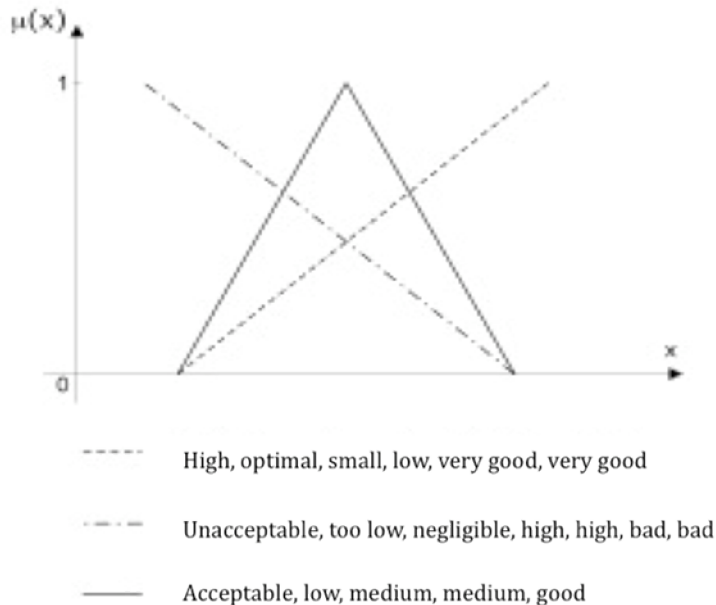
1. Interval values (a, b) have to be determined for variables like: forecasted rainfall (l/m<sup>2</sup>), forecasted temperature and temperature (° C), forecasted wind force and the wind (km / h), the thickness of snow cover (cm), weather forecasting and meteorological conditions, soil workability (degree of workability). Those values vary depending on the type of agricultural activities that has to be done;
2. Interval values (a, b) have to be determined for variables like: grounding, existence of disease, development of plants, the state of the plant, and vary depending on the type of crops and types of jobs. They are measured in percentages;
3. Interval values (a, b) have to be determined for variables like: expenditures for the seasonal workforce, certain agricultural prices, and vary depending on the date, the season when the decision is made and the agricultural crops. They are measured in monetary units.
4.  $\alpha$  and  $\beta$  factors are the median, where  $0 < \alpha, \beta < 1$ , and usually  $\alpha < \beta$ . Experts often determine their value. Those factors exist to make the influence of the variable cost of labor and agricultural products on the decision "to work or not" less important.

Fuzzy variables with domains of possible values:

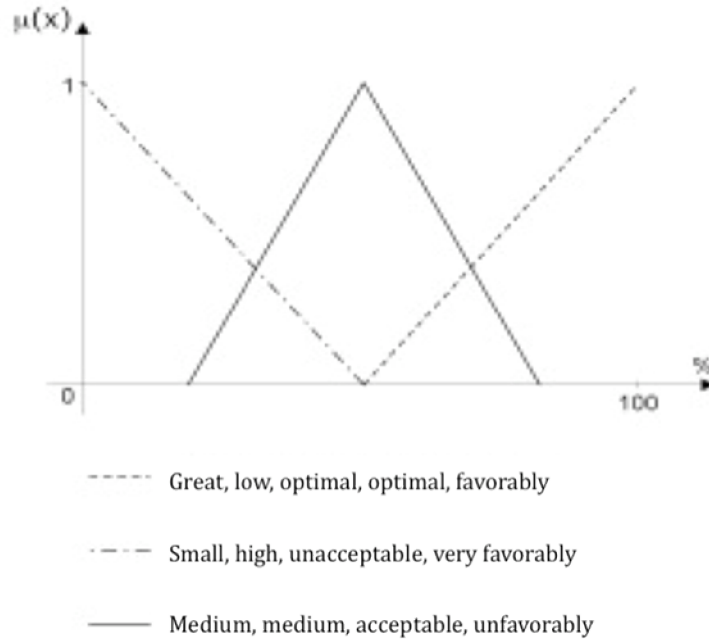
<b>Decision:</b>	to work: yes or no
<b>Soil workability:</b>	appropriate, tolerable, bad
<b>State of plant:</b>	favorably, unfavorably, very favorably
<b>Expenditures for seasonal labor:</b>	low, medium, high
<b>Price of agricultural products:</b>	low, medium, high
<b>Weather forecast:</b>	very good, good, bad
<b>Weather conditions:</b>	very good, good, bad
<b>Germination:</b>	great, medium, small
<b>Existence of diseases:</b>	low, medium, high
<b>Development of plants:</b>	optimal, acceptable, unacceptable
<b>Forecasted rainfall:</b>	optimal, acceptable, unacceptable
<b>Forecasted temperature:</b>	optimal, low, very low
<b>Forecasted wind force:</b>	optimal, medium, negligible
<b>Soil moisture:</b>	optimal, acceptable, unacceptable
<b>Temperature:</b>	optimal, low, very low
<b>Thickness of snow cover:</b>	low, medium, high
<b>Wind force:</b>	optimal, medium, negligible

According to the function of belonging, fuzzy variables in the given problem can be distinguished as follows: Group I (*Figure 4a*), the second group (*Figure 4b*).

**Figure 4a:**  
forecasted rainfall,  
forecasted temperature,  
forecasted wind force, humidity,  
temperature,  
thickness of snow cover,  
wind force,  
expenditure of labor, weather forecasting and meteorological conditions



**Figure 4b:**  
Germination,  
existence of  
disease,  
development of  
plants, state of  
plant



Approximate reasoning algorithm which decides "to work or not", contains three basic steps. Each one is divided into several steps, which are not connected. All steps contain logical deduction rules, defined by experts.

**Step 1:**

a)

Forecasted rainfall	^	Forecasted temperature	^	Forecasted wind force	=>	Weather forecast
optimal	^	optimal	^	optimal	=>	very good
optimal	^	low	^	optimal	=>	very good
optimal	^	low	^	medium	=>	good
optimal	^	very low	^	negligible	=>	bad
acceptable	^	optimal	^	optimal	=>	very good
acceptable	^	optimal	^	srednja	=>	good
acceptable	^	low	^	srednja	=>	bad
acceptable	^	low	^	optimal	=>	bad
unacceptable	^	1	^	*	=>	bad

b)

Soil moisture	^	Teperature	^	Snow cover	^	Wind force	=>	Weather conditions
optimal	^	optimal	^	low	^	optimal	=>	very good
optimal	^	low	^	low	^	optimal	=>	very good
optimal	^	<low	^	low	^	<optimal	=>	good
optimal	^	<low	^	<low	^	<optimal	=>	bad
acceptable	^	optimal	^	low	^	optimal	=>	very good
acceptable	^	low	^	low	^	<optimal	=>	good
acceptable	^	low	^	>low	^	<optimal	=>	bad
acceptable	^	very low	^	low	^	<optimal	=>	bad
acceptable	^	very low	^	>low	^	<optimal	=>	bad
unacceptable	^	optimal	^	low	^	optimal	=>	bad
unacceptable	^	<optimal	^	<low	^	<optimal	=>	bad

<sup>1</sup> Sign \* indicates that the attribute can take any value from the domain of the rule

## Step 2:

a)

Weather forecast	^	Weather conditions	=>	Soil workability
very good	^	very good	=>	appropriate
very good	^	<good	=>	tolerable
very good	^	bad	=>	bad
good	^	very good	=>	appropriate
good	^	good	=>	appropriate
good	^	bad	=>	bad
bad	^	very good	=>	appropriate
bad	^	good	=>	tolerable
bad	^	bad	=>	bad

b)

Germination	^	Existence of diseases	^	Development of plants	=>	State of plants
great	^	low	^	optimal	=>	favorably
great	^	>low	^	<optimal	=>	favorably
medium	^	low	^	optimal	=>	favorably
medium	^	>low	^	optimal	=>	favorably
small	^	low	^	optimal	=>	favorably
small	^	>low	^	acceptable	=>	unfavorably
small	^	>low	^	unacceptable	=>	very unfavorably

## Step 3:

Germination	^	State of plants	^	$\alpha$ /Expenditures for seasonal labor	^	$\beta$ /Price of agricultural products	=>	Decision – to work
great	^	favorably	^	*	^	*	=>	Yes
great	^	unfavorably	^	low	^	high	=>	Yes
great	^	unfavorably	^	>low	^	<high	=>	No
great	^	very unfavorably	^	low	^	high	=>	No
great	^	very unfavorably	^	>low	^	<high	=>	No
medium	^	unfavorably	^	*	^	*	=>	Yes
medium	^	very unfavorably	^	*	^	*	=>	No
medium	^	favorably	^	*	^	*	=>	No
small	^	favorably	^	low	^	high	=>	Yes
small	^	*	^	*	^	*	=>	No

Experts estimate logic rules, based on experience, previous knowledge, and depending on the location, climate, agricultural and technological equipment, as well as the development of national agriculture (its place and role in the economy of the country). Numeric values are directly entered. Variables are: anticipated rainfall, provided temperature, provided wind, soil moisture, temperature, thickness of snow cover, the wind, growing, existence of disease, development of plants, costs for labor and price of crops. After entering the data listed above, defined algorithm has to be activated, where defuzzification is made by the known formula for determining center of gravity.

## **Concluding remarks**

The processing of production land holds an important place in agriculture. The Earth Population is continuously growing, while the number of hectares of arable land is stagnating or declining. We come to the conclusion that production per unit of arable land has to grow. Without adequate treatment of land, many surfaces will retain the characteristics of non-agricultural land.

Scientists, technologists and skilled work force explore and apply their discoveries to increase production through the cultivation of all efficient manner. As part of agricultural science, centers that

have the focus of work on the land and its treatment are formed. Large manufacturers of agricultural machinery are working tirelessly on the production and use of machines for processing of land in order to obtain from it as much as possible.

This decision-algorithm does not depend on the type of performed agricultural activity, the type of cultivated crops, or the geographical position of agricultural farms. Fuzzy sets for variables that influence the decision depend on the above-mentioned factors. The nature of the problem is such that it possesses the characteristics of uncertainty, and a large number of input data for the subjective evaluation.

The results of this study have shown how to use fuzzy logic control in the agricultural machines management and decision-making processes. The theory of fuzzy sets (using fuzzy logic) in decision-making provides treatment, a complete review and analysis of the given problem. There is no possibility of "fixing" desirable decision by changing the inputs, and the risk of making wrong decisions is reduced (more harm than good of a job).

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