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USING OF FUZZY LOGIC FOR DETERMINING THE APPROPRIATENESS OF PLANTING DIFFERENT AGRICULTURAL CROPS

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ABSTRACT

Selection of a particular agricultural crop for the food production is a complex problem. This is usually conditioned not only by the financial claims, but also other requirements should be taken into the account, i.e. environmental criteria, sustainability, etc. Fuzzy Logicis one of the many appropriate tools/procedures for solving such task(s).Such a procedure will be implemented within decision-making algorithm for the selection of an appropriate agricultural crop. The paper deals with the implementation of the mentioned tool/procedure for selection and ranking of the particular sort of crops, regarding different decision-making structures. Within this, there is an intention to reduce all possible biases and subjectivities to minimum by using Fuzzy Logic. This will be applied with input parameters, which are extracted and correlated with real requirements and conditions regarding actual needs of the market and farmers. Along with the offered agricultural crops and possibility of their selection, final ranking and selection of the most appropriate crop can be supported for different possible scenarios (dry or wet period of the year, accents on the financial, environmental of other criteria, available financial resources, market availability, etc.). Presented methodology will contribute to the final goal, which is systematic agricultural planting and sustainability of the food production.

Keywords: *fuzzy logic, agricultural crop, decision making, criteria, sustainability.*

INTRODUCTION

All around the world, food production is one of the importanthuman activities. Particular agricultural crops are still widely and massively planted on almost every continent. Today croplands occupy nearly 18 million km^2 (an area roughly the size of South America), which is approximately 12% of the land surface.The most abundant agricultural crops worldwide are corn, wheat, rice, rye, potatoes, sugar beets, sugar cane, pulses, soybeans, sunflower and oil palm fruit (Leff, B. et al., 2004).

In the past, a profit from production of agricultural cropswas (and still is in most of the cases, but this is changing) main factor for selection of the particular sort of the agricultural crop. Nowadays, social and especially ecological factors must be includedinto the selection analysis, i.e. crop management procedure. This implies the use of the multi-objective decision making. Paper presents asimplified methodology for the final choice between particular agricultural crops, in this case wheat and corn, which are also the most planted crops in Croatia. Wheat and corn were planned to sow on the selected location near Varaždin, Croatia. In this analysis, CALiforniaGOSym model, i.e.CALGOS model (Jones&Barnes, 2000) will be used, with modification regarding real conditions and requirements. Within this, Fuzzy Logic, i.e. Fuzzy Composite Programming will be used. Within CALGOS, such methodology was used in for three irrigation management alternatives (‘’normal/usual irrigation’’, ‘’linear move irrigation’’ and ‘’not to do irrigation’’, which were developed for each of the two soil type; sandy loam and clay loam.

MATERIALS AND METHODS

The CALGOS model was selected because this model is a modified form of a cotton crop simulation model (GOSSYM), which was presented by Baker et al., 1983 for semi-arid conditions (Marani et al., 1992), which can also be applied for the analyzed situation in Croatia. Model can provide prediction of cotton growth and development in response to variation in meteorological, soil water, and soil nitrogen conditions. Management practices in the CALGOS model (i.e. tillage, planting, irrigation, fertilizer applications) were determined from farm records and input to the crop model for the 1994 growing season(Jones & Barnes, 2000).

The aim of this paper was to provide model for selection of the optimum agriculture crop between wheat and corn for the certain soil type (a combination of sandy clay and humus). It should be noted that CALGOS model was developed for the semi arid climate and cotton crop. Despite this,CALGOS will be applied with Fuzzy Composite Programming.After this, next step in the research would be to test mentionedmethodology on real case study.

Composite programming is a normalized multi-level based methodology that deals with problems of a hierarchical nature, i.e., when certain criteria contain a number of sub-criteria. It was developed by Bardossy et al. (1985) from compromise programming. This technique, first developed by Zeleny (1973), is a mathematical programming technique that employs single level non-normalized distance based methodology to rank a discrete set of solution according to their distance from an ideal solution.

Composite programming applies Equation (1) to each sub-criterion within the same group, and then combines the compromise distance metrics of each sub-criterion to form a single composite distance metric. Then the process iterates with the successive level until final level composite distance metric is reached (one composite distance metric for each alternative)(Jones & Barnes, 2000).

$$L_j^{'} = \left[\sum_{i=1}^{n_j} (w)_{i,j} \times (S_j^{'}) p_j \right]^{1/p_j} \quad (1)$$

$L_j^{'}$ iscomposite distance for group*j* of the indicators, $S_{i,j}^{'}$ is normalized fuzzy value of the input element indicator*i* in group*j*; $(w)_{i,j}$ areweights expressing the relative importance of indicators in group *j*such that their sum is 1;$p_j$is balancing factors among indicators for group *j*, and n_j is number of indicators in group *j*. In this example$j = 1$, since there is only one group, as is shown in Table1. There are two indicators (Profitability and environment) in this group, sotherefore $n_j = n_i = 2$.

The addition of fuzzy set theory (Zadeh, 1965) to compromise programming to represent uncertainties of indicator forms fuzzy compromise programming. Similar to normalization, multilevel composite programming, fuzzy compromise programming can also be extended to normalized multi-level distance based methodology to account for uncertainties,(Jones & Barnes, 2000).

The uncertainties inherent in the indicators wereaccounted for with the use of possibilities approach. Fuzzy compromise programming is extended to a normalized multi-level distance based methodology with the use of best and worst first-level indicator values (Bogardi, 1992; Hagemeister et al., 1996), equation (2).

$$S_i^{'} = \frac{Z_i^{'} - Z\min_i}{Z\max_i - Z\min_i}, \text{ when } Z\max_i \text{ is best, or}$$

(2)

$$S_i^{'} = \frac{Z\max_i - Z_i}{Z\max - Z\min_i}, \text{ when } Z\min_i \text{ is best}$$

Where $S_i^{'}$ is normalized *i*-th fuzzy indicator; $Z_i^{'}$ is value of the *i*-th fuzzy indicator; $Z\max_i$ is maximum possible value of the *i*-th indicator; and $Z\min_i$ is minimum possible value for the *i*-th indicator.

The normalization formula presentedabove can have different form,which depend on whether the maximum is the “best” or “worst” value.It should be noted that this normalization process will result in the coordinate (1, 1) to be the ideal (best) point. Prior to examining alternatives, the decision maker (DM) must assign weights to indicate their preferences to the relative importance of indicators in the same group. The method of assigning weights to indicator is not typically defined or thoroughly documented. It usually depends on the judgement and experience of the expert group which is involved in procedure of the decision making. Most of the applications of FCP method, mentioned above, use crisp numbers to express weights according to the judgment of DM, except that of Lee et al. 1991 andLee et al. 1992, who used the Analytic Hierarchy Process (AHP) (Maksimović et al., 2004).

The DM is also required to determine balance factors in order to evaluate alternatives using FCP. Balance factor determine the degree of compromise between indicators of the same group. Low balance factors are used for a high level of allowable compromise among indicators of the same group. Balance factor of 1 suggests that there is a perfect compromise between indicators of the group. If the level of compromise between indicators is moderate, a balance factor of 2 will be sufficient. A balance factor of 3 or higher indicates that there is minimal compromise between indicators (Jones & Barnes, 2000).

RESULTS AND DISCUSSION

Analyzed location wasarea of 5 hectares, usually planted with wheat or corn, and it is located near Varaždin, Croatia.Soil type is sandy loam soil. Considering mentioned agriculture crops, profit and required amount of the fertilizers with regards to the recommendations from CALGOS model, Table 1 presents assignment of weights and balancing factor for decision model, which were obtained by the expert group, i.e. authors of the paper during communication with the potential users of the presented methodology.

Table 1. Assignment of weights and balancing factors

Balancing factor	**Group**	**Weights**
3	Profitability	$w_1 = 0,5$
	Environment	$w_2 = 0,5$

This analysis will take into account two criteria, i.e. contributing/competing factors, which are Profitability and Environment. Both of them will be described by crisp values. Profitability is described with final profit, which is made of investment and selling price, expressed in Euros per hectare, while environment is described with amount of the fertilizer per hectare. With regards to the actual prices and data (AgroKlub,2011;AgroKlub, 2013; AgroKlub, 2017; Pioneer, 2003; Pinova, 2014; TISUP, 2017), all required input values are shown in Figure 1.

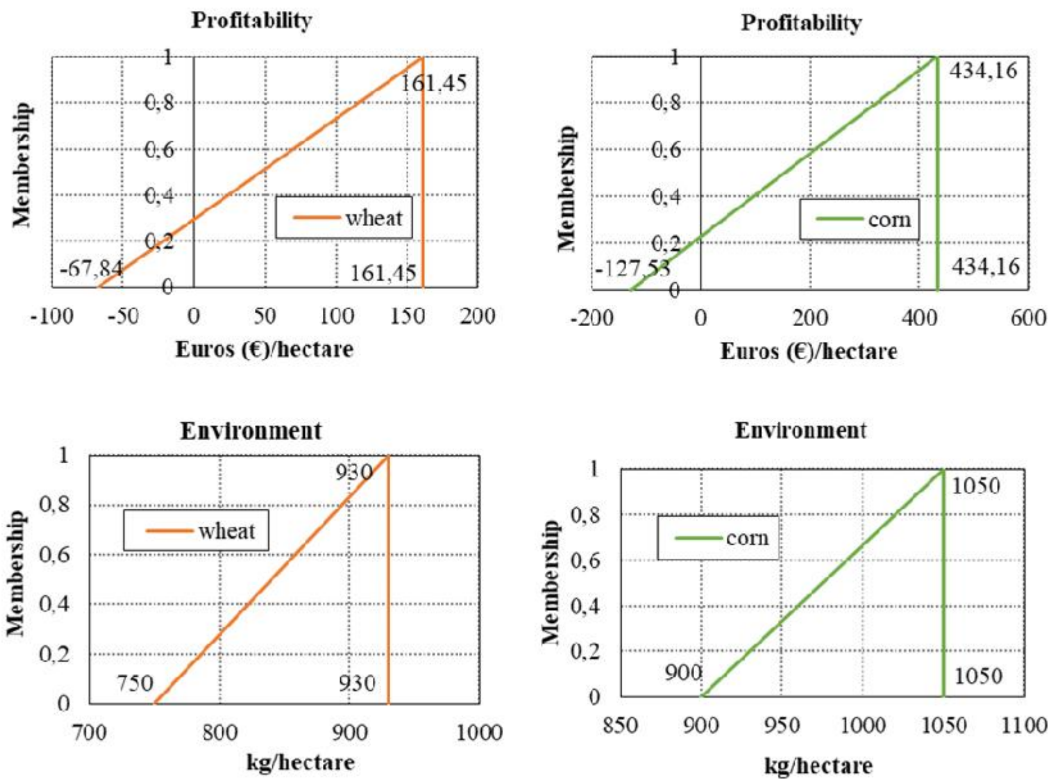

Figure 1. Description of contributors for wheat and corn

For the purpose of the calculation, computational algorithms require normalized values; therefore, ‘‘Worst’’ and ‘’Best’’ values for each contributor must be defined, table 2.

Table 2.Worst and best values for each contributor

Contributors	Worst	Best
Profitability	-127,53€/ha	434,16 €/ha
Environmental	1050 kg/ha	750 kg/ha

By using data from Figure 1 and Table 2, and by using of equations 1-2, obtained results can be seen on Figure 2. It should be noted that sensitivity analysis was also done with changes of the weights with regards to the importance of each contributor. Weightsw_1 and $w_2$were changed by ± 10 % (0.1) to see how this change affects final ranking of the variants (wheat and corn).

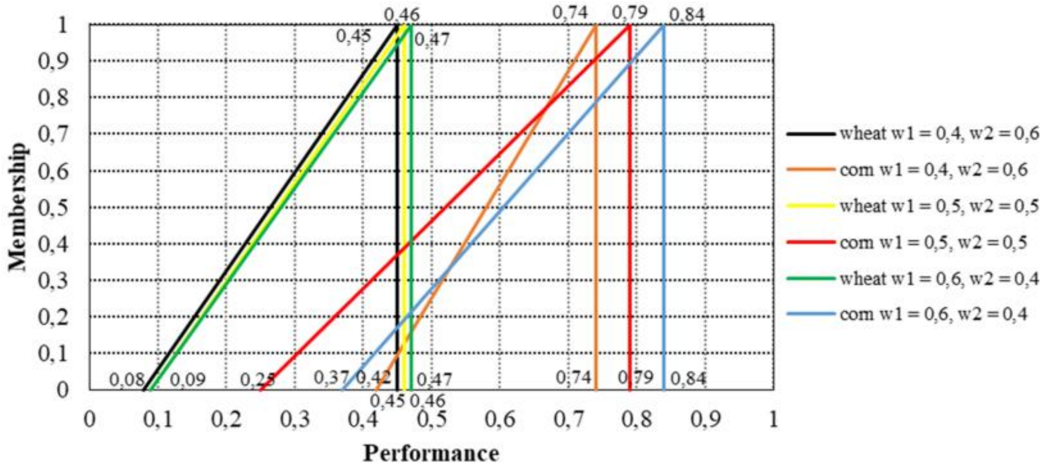

Figure 2. Fuzzy performance and rankings of the obtained variants (wheat and corn)

It can be seen that corn is better ranked crop compared with wheat, regarding all contributors and weights. Variants, which have bigger weights regarding profitability, are closest to the ideal point (1, 1). In this case, ranking i.e. ‘’defuzzyfication’’ is very obvious, due to un-ambiguity and visibilityof the shape (triangle) of each variant.

CONCLUSION

Presented methodology, although simplified, has shown that doubts of selection between particular agriculture crops can be eliminated by using Fuzzy Logic. Such procedure makes it easier to choose the optimum agriculture crop for cultivation. On first sight uncorrelated contributors (Profitability and Environment) were connected and involved into the methodology which reduces subjectivity of selection to a lesser extent, due to the preferences of the expert group.Further development of this research implies extending of the contributors, more detailed sensitivity analysis, consideration of the different soil types and extension of the analysis with regards of the other agriculture crops, which commonly growin analysed area.

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