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FUZZY MULTI-CRITERIA DECISION MAKING TO CLASSIFY LAND CAPABILITY AND SUITABILITY

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Abstract. The land capability and suitability classification is a difficult thing to do. The problem formulated in this study is how to use fuzzy multi-criteria decision making to determine the classification of land suitability and suitability. In fuzzy logic shows the extent to which the value is true and the extent to which the value is false. Multi-Criteria Decision Making is a method of decision making to determine the best alternative based on certain criteria. The purpose of this study is to create a system that can facilitate the classification of land suitability and suitability by using fuzzy multi-criteria decision making. This research was conducted with three stages, namely: 1. The problem representation stage (including determining decision objectives, identifying alternatives, identifying criteria, and establishing a decision hierarchy structure), 2. Evaluating the fuzzy set of alternative decisions (including establishing linguistic variables) and membership functions, determine branches for each criterion, and calculate the fuzzy suitability index for each alternative), 3. Defuzzy stage to find an optimal alternative value. The expected output or outcome at the end of this research is the creation of a system of land capability and suitability classification using fuzzy multi-criteria decision making.

Keywords: Classification, Fuzzy, Fuzzy Logic, Land Capability, Land Suitability, MCDM

1. INTRODUCTION

Land capability classification is land classification carried out by the inhibiting factor method. With this method, each land quality or land characteristic is sorted from best to worst or from the smallest obstacles or threats to the largest. Then the criteria table is arranged for each class; the smallest barrier for the best class and sequentially the greater the obstacle the lower the class.

The results of classification are often wrong because the grouping of land in eight classes is done using strict logic (crisp). Thinking using a crisp set is simpler because it is only done by seeing whether something can be a member of a crisp set or not. Using the crisp set to state classification is very unfair, a small change in value results in quite significant differences in categories. For example in determining the magnitude of the slope, a difference of one degree will cause the difference in the determination of land classes. Therefore used a fuzzy set to anticipate this. Fuzzy logic is a logic that has a blurring value or fuzziness between right or wrong. Membership levels in fuzzy logic are in the range of 0 to 1. A linguistic expression will be translated by fuzzy logic, for example, the magnitude of the slope is expressed flatly, rather steeply, steeply, and very steep.

Multi-Criteria Decision Making (MCDM) is one of the most widely used methods in decision-making areas. The MCDM aims to choose the best alternative from several mutually exclusive alternatives based on general performance under various criteria (or attributes) determined by the decision-maker (Kusumadewi et. Al., 2006: 69). The problem that can be formulated is how to use Fuzzy Multi-Criteria Decision Making to determine the classification of land suitability and suitability.

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The specific purpose of this study is to create a system that can facilitate the classification of land capability and suitability using Fuzzy Multi-Criteria Decision Making.

2. REVIEW OF RELATED LITERATURE

2.1. Definition of Fuzzy Logic

By using Fuzzy Logic the input spaces will be mapped into appropriate output spaces. There are many ways to map the input space to this output, such as with linear systems, neural networks, and differential equations. Although there are many ways besides Fuzzy, Fuzzy is considered to provide the best solution because using Fuzzy will be faster and cheaper (Kusumadewi S., 2010)

In a strict set (Crisp), the membership value of item x in set A, written as μA (x), will have one of two possible values, namely (Kusumadewi S. et al., 2004):

a. will have a value of one (1), if an item becomes a member in a set, or
b. will have a value of zero (0), if an item does not become a member in a set.

In understanding the Fuzzy system, we need to understand several things as follows (Muzayyanah, I, Mahmudy, WF, and Cholissodin I, 2014):

1. Fuzzy variables, namely variables that will be discussed in a Fuzzy system.
2. Fuzzy set, which is a group that represents a condition or state in a Fuzzy variable.
3. The Universe of Speech, which is the whole value that can be operated in a Fuzzy variable. The universe of speech is a set of real numbers whose values always increase monotone from left to right. The universe of speech values can be either positive or negative numbers. Sometimes the value of the universe of speech is unlimited.
4. Fuzzy set domain, which is the whole value that is allowed in the universe of speech and may be operated in a Fuzzy set. As the universe of speech, a domain is a set of real numbers that increase from left to right. Domain values can be either positive or negative numbers.

Some of the advantages of fuzzy logic are as follows:

a. Fuzzy logic has a very simple concept.
b. Fuzzy logic can adapt to changes and uncertainties because of its flexibility.
c. Fuzzy logic can tolerate incorrect data.
d. Fuzzy logic can solve very complex non-linear functions.
e. Fuzzy logic can represent experience or knowledge from experts.
f. Fuzzy logic can work with conventional control techniques.
g. Fuzzy logic is based on colloquial language so it's easy to understand.

2.2. Membership Function

The membership function is a function that maps elements of a set to membership values at intervals [0,1]. A membership function that distinguishes fuzzy sets from explicit sets. Membership functions can be represented in various ways, but the most common and widely used in systems that are based on fuzzy logic is analytic representations. 10 Appropriate modeling is needed because the fuzzy model is sensitive to the type of fuzzy set description. There are various types of fuzzy set descriptions, but the membership function used in the author's research is linear, triangular and trapezoidal representations.

2.3. Fuzzy-Rule Based Systems

The steps taken in the fuzzy rule-based system are:

a. Fuzzification, i.e establish membership functions that are defined in the domain of the input and output data. Perform fuzzification for input and output data based on defined membership functions.
b. b. Inference, whose duty is to do reasoning using fuzzy input and Fuzzy rule that has been determined to produce Fuzzy output.
c. Defuzzification, this stage changes fuzzy output into crisp value again based on the predetermined membership function.

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2.4. Multi-Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) is one of the decisions making methods to determine the best alternative from several alternatives based on certain criteria. Criteria are usually in the form of criteria for rules or standards used in decision making. In general, it can be said that MCDM selects the best alternative from several alternatives. (Kusumadewi et al, 2006).

3. RESEARCH METHOD

The method applied in this research is fuzzy decision making. The steps in this method are:

3.1. Representation of problems

There are 3 activities carried out namely:

a. Identify the goals and alternative sets of decisions. Decision objectives can be represented by using natural language or numerical values according to the problem.
b. Identify a set of criteria
c. Build a hierarchical structure of the problem based on certain considerations

3.2 Evaluate the fuzzy set

In this step there are 3 activities carried out namely:

a. Select the set of branches for the criteria weights and the degree of compatibility of each alternative with the criteria. After determining the set of branches it must determine the membership function for each rating. Usually, a triangle function is used
b. Evaluate the criteria weights and the degree of compatibility of each alternative with the criteria
c. Aggregate the criteria weights and the degree of compatibility of each alternative with the criteria using the mean operator, F_i, formulated as follows :

$$F_i = (\frac{1}{k}) [(S_{it}\ W_1)\ (S_{it} W_2),\ldots\ (S_{it}\ W_i)$$
$$S_{it} = (o_{it}, p_{it}, q_{it})$$
$$W_i = (a_i, b_i, c_i)$$

By substituting S_{it} and W_i with triangular fuzzy numbers :

$$F_i = (Y_i, Q_i, Z_i)$$
$$Y_i = (\frac{1}{k}) \sum_{i=1}^{k} (o_{it}\ a_i)$$
$$Q_i = (\frac{1}{k}) \sum_{i=1}^{k} (p_{it}\ b_i)$$
$$Z_i = (\frac{1}{k}) \sum_{i=1}^{k} (q_{it}\ c_i)$$

3.3. Optimal alternative selection

There are 2 activities at this stage, namely:

a. Prioritize alternative decisions based on aggregation results

$$I_T^a(\mathrm{F}) = (\frac{1}{2})\ (\mathrm{ac} + \mathrm{b} + (1\text{-a})\mathrm{a})$$

b. Choosing alternative decisions with the highest priority as optimal alternatives. The greater the value of F_i, the biggest match of alternative decisions for this criterion

4. RESULT AND DISCUSSION

4.1. Analysis of alternative data and criteria

The Linguistic Value in this study is shown in Table 1.

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Table 1. Linguistic Value

Class Land	Criteria					
	Slope	**Drainage**	**Rate Of Erosion**	**Rainfall**	**Soil pH**	**Land Depth**
I	Flat	Good	Very Slight	Very Dry	Neutral	Deep
II	Flat	Reasonably Good	Moderate	Moderate	Rather Alkaline	Moderate
III	Sloping	Reasonably Bad	Moderate	Very Wet	Acid	Shallow
IV	Steep	Bad	Weight	Wet	Alkaline	Deep
V	Flat	Good	Slight	Moderate	Alkaline	Rather Shallow
VI	A Bit Steep	Moderate	Weight	Very Wet	Alkaline	Shallow
VII	Steep	Bad	Very Weight	Dry	Rather Acid	Rather Deep
VIII	Very Steep	Bad	Very Weight	Wet	Neutral	Moderate

In this study, Land is grouped into eight classes marked with Roman letters from I to VIII. Land classes ranging from classes I to VII are used to determine the appropriate type of plant to be planted on the land. While the land in Class VIII should be left in a natural state. The criteria used for land grouping are Slope, Drainage, Erosion Rate, Rainfall, Soil pH and Soil Depth.
Based on the above data obtained membership values for the degree of compatibility of the criteria with alternatives as shown in Tabel 2.

Table 2. Degree of Match Criteria

Degree Of Match	Membership Function Value		
	Y	**Q**	**Z**
Very Suitable	50	80	100
Suitable	25	50	80
Rather Suitable	0	25	50
Not Suitable	0	0	25

4.2. The result of aggregating the criteria weights
After obtaining the degree of membership it can be evaluated with criteria weights. To evaluate the importance of each criterion and the degree of compatibility of each alternative with the criteria, it can be done by aggregating the criteria weights to determine the values of Y, Q, and Z. To obtain the aggregation values as shown in Table 3.

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Table 3. Aggregation Result

Land Group	Y	Q	Z
I	6,272	14,722	847,752
II	52,728	734,088	6696,52
III	45	728,2	6567,712
IV	194,912	2202,33	17551,12
V	8,512	195,93	2287,32
VI	191,712	2186,93	17414,72
VII	546,4	5799,328	17776,688
VIII	561,472	5857,722	17684,752

From the results of these aggregations then prioritize alternative decisions based on aggregation results with the equation. so we get the calculation results for each alternative classification of land. Resulting in the following recommendations:

Table 4. Recommendation Result

Land Group	Recommendtion Result
I	10,6232
II	394,405
III	387,578
IV	1201,22
V	102,563
VI	1191,9
VII	3175,45
VIII	3212,17

From the recommendations, it can be concluded that the highest F_i value is in class VIII land and the lowest value is in class I land.

5. Conclusion

This study concludes that the use of the Fuzzy Multi-Criteria Decision Making (FMCDM) model can handle the problem of land classification and suitability with many criteria that must be considered as a selection parameter. FMCDM can objectively calculate selection weight values to produce numerical data values that represent land suitability accurately and relatively quickly.

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