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An Intelligent System for Land Suitability Assessment of Tobacco

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***Abstract*—High level of tobacco exports value required step-up of tobacco productivity. Productivity needs is not comparable with land availability, so that required land optimization with assessing land suitability. In the current trend of suitability assessment techniques is use intelligent system. This paper presents a research on improvement accuracy of land suitability assessment for tobacco using intelligent system. Each sub-criteria assessment has result of standardization and weight values. Suitability index and land suitability class were obtained from calculation of the standardization results and the weights of each sub-criteria before being overlaid with spatial data to produce land suitability maps for tobacco. This map has been shows every land suitability class for tobacco cultivation. The result of system assessment was validated using yields of tobacco and compared with conventional method. The result assessment show intelligent assessment more accurate than conventional assessment system.**

Keywords-analytic hierarchical process; fuzzy set;intelligent system; land suitability assessment; tobacco; suitability index

I. Introduction

One important factor supporting the economic growth of a country is the availability of land that has capacity in terms of quality and quantity. Land is a medium for the development of several sectors in a country, including the agricultural sector, industry and infrastructure development [1]. But now the availability of land is decreasing, this is due to the increase in human population and infrastructure development that growing rapidly [2]. Based on conditions, it is required to optimize the land through assessing land suitability [3]. In addition to optimizing land use, land suitability assessment is useful to improve crop productivity. By cultivating crops on the appropriate land, it is expected to increase the potential for increased yields. One type of plant that needs to be cultivated because it has a high selling value and a source of state income through taxes is tobacco.

Technique of land suitability assessment can be reviewed in term of physical condition of the land, social and economic factors [4]. Physical condition of the land factor stable compared to social and economic factors because these factors are easily changed and controlled by human policies [5]. Therefore, this is the basis for land suitability assessment is generally based on the physical condition of the land. In terms of land physical factors, land suitability assessment should be able to represent data related with the condition of soil, topographic, and climatic elements in a region that affecting the growth of plants. Representation of the physical factors data of this land causes the land suitability assessment process to be complex and unstructured [6-7].

The selection of land suitability assessment techniques is needed to both current and future land use planning. Several land suitability assessment techniques have been applied in previous research. The approach in land suitability assessment techniques that has been generally used in previous research is the Boolean approach. This approach is applied to FAO method [8]. Based on previous research, the results of applying this approach resulted in poorly precise assessment results. The results of this assessment are due to the inaccuracy of the Boolean approach in dealing with land characteristics that are continuous and vaguely.

Land suitability assessment factors are multi-criteria. Each criterion has a variety of types and different levels of influence for plant growth. The condition of such criteria causes the assessment process to be complex and requires appropriate assessment techniques [9]. Therefore it is needed an estimation of weight to determine the effect of each factor on plant growth. AHP is an appropriate and effective method in weight estimation for each land suitability assessment criteria which is spatial data with multi-criteria data type [10, 11]. The value of priority scale of each factor resulted from AHP method calculation is determined based on expert opinion prepared in pairwise comparison [12]. Having obtained a comparison of values between the criteria of expert opinion, the next step is the determination of priority. A method of prioritizing a capable determines the priority estimation using the correlation coefficient between priorities is the CCMA method [13].

Mechanism for transforming numerical data with various magnitudes into land suitability classes in the standardization process require appropriate methods, because the result of standardization process indicates the potential of a factor for cultivation. Fuzzy set was developed to deal with this problem relating to the data is vaguely [14]. Compared with Boolean approach, implementation of fuzzy set method in land suitability assessment can produce more detailed and realistic output [15]. The output of standardization process will be result with values range from 0 to 1.

Implementation of fuzzy set and AHP methods in land suitability assessments have the potential to increase the effectiveness and accuracy of the assessment results. The results of this assessment are important for the sustainability of land use. The aim of this study is to improve accuracy of land suitability assessment for tobacco using intelligent system. This intelligent system integrates fuzzy set for standardization process and AHP method for weighting the assessment criteria. The result of this assessment is land suitability index that representing level of suitability for tobacco cultivation.

II. METHOD

A. Area of Study and Data Sets

The study was conducted in Wonogiri Regency which located in the southeastern part of Central Java Province in Indonesia. Total area in this area is 182.236,02 hectares. Data of climate, topography, and soil are used for system tested were collected from Indonesia's National Statistical Agency (BPS) sub-Central Java Province, weather station located at each of sub-districts and Assessment Institute for Agricultural Technology (BPTP) Central Java Province in the form of land resource database of Wonogiri Regency.

B. Identification of Criteria Assessment

Based on the previous work and considering actual situation in Wonogiri Regency, we preliminarily selected the following sub-criteria to evaluate the land suitability for tobacco production. The criteria and sub-criteria shows in Table I.

C. Fuzzy Set Method for Standardization Each Sub-criteria

Standardization process used for equalize the value of each sub-criteria assessment into comparable value. It is caused by sub-criteria has different magnitudes and value ranges.

Type membership function in the land suitability assessment includes trapezoid type, S-shaped, and Z-shaped type. The model of each membership function shows in Fig. 1, 2, and 3. The function of each membership function shows in function 1, 2, and 3.

$$\mu(x) = \begin{cases} 1.0 & ;\ x \in (b \le x \le c) \\ \frac{x-a}{b-a} & ;\ x \in (a \le x \le b) \\ \frac{d-x}{d-c} & ;\ x \in (c \le x \le d) \\ 0 & ;\ x \in (x \le a, x \ge d) \end{cases} \tag{1}$$

$$\mu(x) = \begin{cases} 0 & ;\ x \in (x < a) \\ 2\left[\left(\frac{x-a}{c-a}\right)^2\right] & ;\ x \in (a \le x \le b) \\ 1-2\left[\left(\frac{x-c}{c-a}\right)^2\right] & ;\ x \in (b \le x \le c) \\ 1 & ;\ x \in (x \ge c) \end{cases} \tag{2}$$

$$\mu(x) = \begin{cases} 1 & ;\ x \in (x < a) \\ 1-2\left[\left(\frac{x-a}{c-a}\right)^2\right] & ;\ x \in (a \le x \le b) \\ 2\left[\left(\frac{x-c}{c-a}\right)^2\right] & ;\ x \in (b \le x \le c) \\ 0 & ;\ x \in (x \ge c) \end{cases} \tag{3}$$

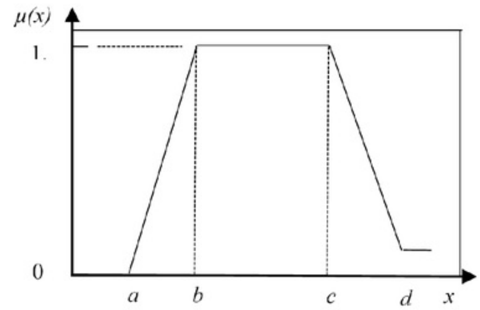

Fig. 1. Model of Trapezoid Function

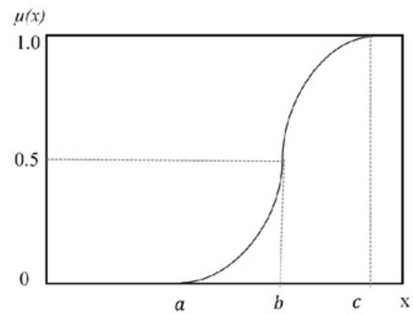

Fig. 2. Model of S-shape Function

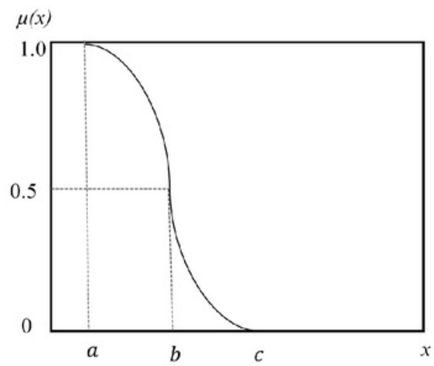

Fig. 3. Model of Z-Shape Function

where *u(x)* is a value of degree of membership result standardization process, *x* is a value of sub-criteria, , *a* is an lower limit in membership function, *b* is an optimal lower limit membership function, *c* is an optimal upper limit in membership function, and *d* is an upper limit in membership function.

TABLE I. SUITABILITY ASSESSMENT FACTORS, MEMBERSHIP FUNCTION (MF) TYPES AND THRESHOLD

Criteria	Sub-Criteria[a]	Mf type	Threshold for Fuzzy MF			
			LU[b]	*OLL*[c]	*OUL*[d]	*UL*[e]
Climate	Temp	Trapezoid	16	20	28	35
	Rainfall5	Trapezoid	20	50	100	150
	Rainfall6	Trapezoid	40	100	180	250
	Rainfall78	Trapezoid	30	80	150	250
	Sunshine	Trapezoid	200	400	600	800
Soil	pH	Trapezoid	4.5	5	6.5	7.5
	OM	S-shaped	0.4	0.6	1.6	2.5
	AN	S-shaped	30	40	80	100
	AP	Trapezoid	5	10	20	30
	AK	Trapezoid	80	120	240	350
	Ca	Trapezoid	4	8	20	25
	Mg	Trapezoid	0.8	1.6	3.2	5
Topography	Relief	Z-shaped	0.3			1
	Elevation	Trapezoid	60	150	800	1600
	Slope	Z-shaped	0			25

[a] Where Temp is the mean daily temperature (°C) during field growth (May-August); Rainfall5 is the mean of total rainfall (mm) during recovery stage (May); Rainfall6 is the mean of total rainfall (mm) during rapid growth (June); Rainfall78 is the mean of total rainfall (mm) during maturity stage (July-August); OM is soil organic matter content (%); AN is soil available N (mg kg^{-1}); AP is soil available P (mg kg^{-1}); AK is soil available K (mg kg^{-1}); Ca is soil available Ca (mg kg^{-1}); Mg is soil available Mg (mg kg^{-1});

[b] LU is lower limit;

[c] OLL is optimal lower limit;

[d] OUL is optimal upper limit;

[e] UL is upper limit;

D. AHP with Priority Estimation CCMA Method for Weighting Each Sub-Criteria

AHP is a method that appropriate in the spatial problem [10]. The first step in AHP method is the establishment of a hierarchical structure of problems. The model of hierarchical in this study shows in Fig. 4. The next step is to determine the degree of importance between sub-criteria assessment of land suitability based on Saaty's scale and compiled in pairwise comparison (PWC) matrix. Based on previous work mainly Zhang et al (2015) study the final pairwise comparison matrix in this study shows in Table II. The final step is to calculate the weight of each sub-criteria. The following step of weighting are normalizing the comparison matrix $A = (a_{ij})_{n\times n}$, calculating transformed weight w_i, determining the weight assignment coefficient β and computing the final priorities.

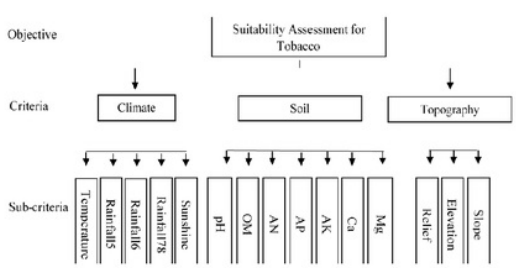

Fig. 4. Model of Hierarchical Structure Land Suitability for Tobacco

TABLE II. PWC SUB-CRITERIA

Climate	R6	R5	R78	Temp	Sunshine	Weight
R6	1	1	2	3	3	0.29
R5	1	1	1	3	3	0.26
R78	½	1	1	3	3	0.21
Temp	1/3	1/3	1/3	1	1	0.11
Sunshine	1/3	1/3	1/3	1	1	0.11

Soil	AK	AP	Ca	pH	OM	AN	Mg	Weight
AK	1	7	8	2	1	2	3	0.2676
AP	1/7	1	1/2	1/2	1/3	1/9	4	0.0484
Ca	1/8	2	1	1/4	1/5	1/8	1/3	0.2222
pH	1/2	2	4	1	1/2	1/4	2	0.0981
OM	1	3	5	2	1	1/2	5	0.1970
AN	1/2	9	8	4	2	1	8	0.3220
Mg	1/3	1/4	3	1/2	1/5	1/8	1	0.0444

Topography	Relief	Elevation	Slope	Weight
Relief	1	6	2	0.4933
Elevation	1/6	1	1/3	0.1934
Slope	1/2	3	1	0.3132

[f] Where R6 is the rainfall6; R5 is the rainfall5; Temp is the temperature;

E. Suitability Index Calculation

Formulation for computed land suitability index as follows:

$$SI = \sum_{i=1}^{n} W_i \cdot \mu_i \qquad (4)$$

where SI is suitability index, n is the number of sub-criteria, W is the weight of factor-i, μ_i is the result of standardization process. Classifying class suitability are divided into four suitability classes there is highly suitable, moderately suitable, marginally suitable, and not suitable.

F. Generating Land Suitability Map in GIS

Generating land suitability map for each suitability index in study area is performed using software ArcGIS 10.1. The map overlay result shows that suitability classes in this area.

III. RESULT AND DISCUSSION

Result of suitability index analysis and generated of map in GIS, show that all of the area study was marginally suitable for tobacco (Fig. 6). To manage data and application of these results, a system has been developed by using web and GIS technologies. The user can access these data and display value of suitability index for each land unit. The assessment of result of each land unit, can precisely provide a right guide to manage tobacco production and support decision of the land use planning.

The data used for testing system is tobacco productivity data in the some of the districts in the Wonogiri Regency. The result comparison of correlation value between of system with conventional method toward tobacco productivity levels shown in Fig. 5.

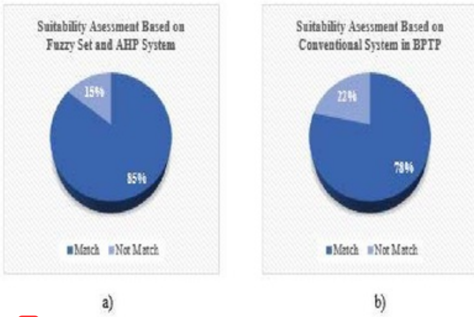

Fig. 5. Comparison of productivity correlation level of between the suitability assessments based on intelligent system (Fig. 6a) with suitability assessment based on conventional system (Fig. 6b)

Fig. 6. Land Suitability Map for Tobacco in Wonogiri Regency

The correlation result indicated that the intelligent system assessment had an 85% correlation rate to tobacco productivity, with an error rate of 15%. Whereas the correlation result of BPTP assessment had a correlation rate of 78% to tobacco productivity, with error rate of 22%. Based on result of correlation and comparison test between intelligent system with BPTP to tobacco productivity, it concluded intelligent system has a level of accuracy that is closer to real condition (productivity tobacco), than the method of BPTP. The result indicates that the intelligent system more significant in the known level of the influence of suitability index compliance with the crop yield in area study. The advantage of assessment tools based on intelligent system was carried out based on systematic calculation algorithm. Thus, the result of an assessment that is not too subjectively than the BPTP method which is based only on expert opinion without a certain calculation process.

IV. Conclusion

Assessment of land suitability for tobacco has been successfully created by intelligent system with case of study in Wonogiri Regency. Based on result of correlation and comparison test, it concluded assessment using intelligent system has a level of accuracy that is closer to real condition (productivity tobacco), than the BPTP method. This study demonstrates that assessment of land suitability using intelligent system provides an effective approach to increase the accuracy of land suitability assessment for tobacco production and manage the land use planning.

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