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Fuzzy-DSM for Evaluating City-Forest Governance in Indonesia

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Abstract*: *City-forest is fruitful for human's life and health, particularly for people who living in Metropolitan. A decision support model (DSM) was established academically to evaluate five city-forests in Indonesia. Fuzzy-logic was functioned as a main method and model was designed in Android based application for easy to use. Five parameters were functioned in the model, they are land width, land type, tree number, tree type, and maintenance quantity. The constructed model is able to measure the quality of city-forest governance for five forests in Indonesia as a sample of the study.

***Keywords*: *Fuzzy logic, decision support model, city forest, human life, evaluating model, Indonesia, human life*.**

I. INTRODUCTION

This decision support model (DSM) focuses on evaluating city-forest management and governance. As, the good management and governance is going to affect the human life positively. Five Indonesia city-forests functioned as a sample in evaluation. They are Srengseng, Jakarta; Kota Gembira Loka, Yogyakarta; Malabar, Malang; Velodrom, Malang; and Bungkirit, Kuningan.

The study aims to develop a DSM that is able to evaluate the quality of city-forest governance in Indonesia. Also, it is able to propose the best city-forest prototype. The model constructed by using method fuzzy logic. The method operates a data as crisp input (CI) to be converted as crisp output (CO) thru fuzzification process. The fuzzified value is going to be functioned to define a decision (measurement result).

Five parameters that strongly interconnected to the issue are coming from several academic literatures. They are area width, land type, tree number, tree type number, and maintenance quality. Each parameter has different value type with specific unit.

Tree diagram operated to generate a number of fuzzy rules. They are 3,125 rules generated in the model. The rules are fundamental thinking to define a final decision.

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II. LITERATURE VIEW

[1] defined city-forest as a wood-vegetation and its association grow in around citizen's living, both in rural and metropolitan living. City-forest has benefit as a heart of city. It could eliminate a negative impact of pollution, avoid erosion, maintain waste, as city ventilation, as a provider of land-water, and recreation area [2].

Tree is a sub-parameter of city-forest. In this study, the tree is taken as thinking basis of the constructed model. The other sub-parameters of tree taken into account to develop model are tree and tree type number.

The definition of a tree according to the understanding of silviculture is woody stems with diameter at breast height (dbh) ≥ 20 cm. According to the Indonesian language dictionary (kamus besar bahasa Indonesia, KBBI), trees are plants that have hard and large trunk. Trees have benefits to reduce air pollution, can reduce temperature or temperature on hot roads, and can absorb lead [3]. Canopy cover is the most influential indicator in the fulfillment of city forest environmental services [4]. The number of trees is included in the parameters of city forest management because good city forests are city forests with many trees. The assessment scenario of the number of trees parameter is "more trees in the city forest is going to be making the city-forest better".

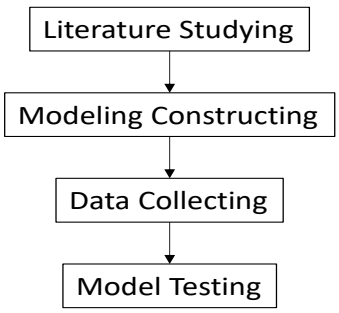

Fig. 1. Research Stages

III. RESEARCH METHODOLOGY

A. Research Stages

Four simple stages followed to perform the study (Fig. 1). The four stages are literature studying, model constructing, data collecting, and model testing. Firstly, several scientific literatures are collected and reviewed. Specific literature database (i.e. sciencedirect.com) functioned to find and then review them.

Furthermore, model is constructed. Here, fuzzy logic method [5] [6] operated to do so. Interconnection among parameters is analyzed. And model designing based on

Android device is developed. Moreover, collecting data via internet (secondary data) is done. The data is very useful to test the model (in the last stage of study).

B. Data Sources

All data used in the study are secondary data. They are coming from online documents or others. Table-I shows the raw-data operated in the model; parameter 1 until 5 respectively are land width, land type, tree number, tree type number, and maintenance quantity per annual.

Table-I: Raw Data Operated in the Study

City-Forest	Parameter	Value
Srengseng, Jakarta	1	15.3 Ha
	2	Aluvial (pH = 6)
	3	11,534
	4	65
	5	3
Gembira Loka, Yogyakarta	1	4.5 Ha
	2	Regosol (pH = 7)
	3	1,184
	4	44
	5	4
Malabar, Malang	1	1.6 Ha
	2	Aluvial (pH = 4.2)
	3	1,500
	4	81
	5	3
Velodrom, Malang	1	1.25 Ha
	2	Aluvial (pH = 5)
	3	1,040
	4	75
	5	1
Bungkirit, Kuningan	1	2 Ha
	2	Andasol (Ph = 6.5)
	3	1,059
	4	24
	5	2

IV. RESULT AND DISCUSSION

A. Model's Parameters

Parameter is a fundamental part in the model. It should be defined well and verified scientifically. Here, in constructing model, deep analysis to define the parameters considered was done. Then, five selected parameters were successfully explained; i.e. area width, land type, tree number, tree type number, and maintenance quantity per annual.

Area width is the total area on the surface of three-dimensional figures. According to [2], city development tends to minimize green open space. The area that is overgrown with trees is often converted into a commercial, residential, industrial, transportation network and other city facilities and infrastructure. The city environment develops economically, however decrease ecologically. This causes disruption of the balance of city ecosystems.

Efforts to eliminate the negative impacts of city development can be done by planting trees in accordance with PP No.63 of 2002 (Indonesian government rule). In Article 9 of Law No. 41 of 1999 concerning forestry stipulates that city forests have a percentage of land forest area of at least 10% (ten percent) from city areas and or adapted to local conditions or the area of city forest in one compact area is at least 0.25 (twenty-five percent). Land area can affect the quality of city forests because city forests that have extensive land can absorb lead from pollution caused by motorized conditions [7], therefore land area is used as a parameter of city forest governance. The scenario for assessing the parameters of land area is "more extensive land in the city forest, it will have the better the quality".

City forest vegetation is greatly influenced by the composition of trees planted in the forest area. Here trees mean woody plants that have the main trunk that stands upright supporting the tree canopy. In the city forest ecosystem, various kinds of trees will be found to house several birds and as a food source, so that it is going to create a city forest complex that is complex with all the vegetation in it that interacts with each other [8].

The types of tree that are often planted in city forests, specifically in Indonesia, are Mahogany, Red Dadap, Angsana, Bungur, Flamboyant, and other types of trees that have large trunks. According to [2], to support the development and development of city forests that are appropriate to their functions and uses, information is needed about potential tree species for their vegetation. If a tree species is not appropriate as vegetation in a type of city forest, then the benefits will be less than optimal or even will cause a problem for the surrounding environment.

Tree species from city forest vegetation have a role in life both directly and indirectly whether physical, aesthetic, and conservation. The number of tree species can also affect the quality of city-forests [2], so that they can be used as parameters for assessing city forest governance. An assessment scenario of the parameter for the number of tree species is "more number of tree species in a city-forest is giving the better quality value for the city-forest".

Land is defined by [9] as a material consisting of aggregates of solid minerals that are not cemented (chemically bound) to one another and from weathered organic matter (which has a solid particle) accompanied by liquid and gases which fill the space empty spaces between these solid particles. According to [2] good city forest is city forest that has a type of land that is suitable for the city zone. Examples of cities that are used as reference data in this case are Jakarta, Malang and Kuningan. The city zone is a plain zone so that good land types are land that has moderate to relatively high nutrient elements and has a moderate pH. For alluvial lands, the nutrients are moderate and somewhat acidic (pH = 4-5). Regosol for land types has very high nutrient content and is alkaline (pH = 6-7). And for the type of andosol land, has a high nutrient content and is neutral (pH = 5-6). Land type is included in the parameters of the assessment of city forest governance because land type is an important factor that can affect the quality of a city forest. The assessment scenario of the parameters of land type is "that more nutrients or the higher the pH of the land means the better land type being used by city-forests". The data for this land type is measured in pH. The definition of maintenance according to [10] is an activity to maintain and maintain existing facilities and improve.

Make adjustments or replacements needed to get a production operating conditions to fit the existing plan. Maintenance in city forests is an important thing to do, because city forests require special care so that the trees contained in city forests can function properly. The series of activities to maintain city forests include clearing damaged tree trunks, planting tree seedlings, transplanting trees, watering and fertilizing tree seedlings, trimming grass and wild plants, and repairing sidewalks found in city forests [11]. Maintenance is included in the parameters of the assessment of city forest governance because city forests can be said to be good if often done "maintenance". The assessment scenario of the maintenance parameter is that more often city forest is maintained (e.g. fertilizer on planted seeds and cleaned from rubbish), it is going to make city-forest better.

B. Fuzzification – De-fuzzification

In conducting the fuzzification process, the qualitative value of a parameter is determined or commonly referred to as a linguistic variable. In each parameter as in Table-II has its own qualitative value. In the land width parameter, the linguistic variable given is very narrow, narrow, medium, wide, very broad and the unit of measurement is hectares (Ha).

Table-II: Linguistic Variables and Qualitative Value

Linguistic Variable	Qualitative Value
Land width	very narrow, narrow, medium, wide, very wide
Land type	very low, low, medium, high, very high
Tree number	very few, few, medium, many, very many
Tree type number	very few, few, medium, many, very many
Maintenance quantity	very rare, rare, moderate, frequent, very frequent

The second parameter is land type. Its linguistic variables are very low, low, medium, high, and very high. The third one is parameter tree number. It has linguistic variables like very few, few, medium, many, very many. They are similar to the fourth parameter's (tree type number) linguistic variables. Then the last one is maintenance quantity. Its linguistic variables are very rare, rare, rare, moderate, frequent, and very frequent.

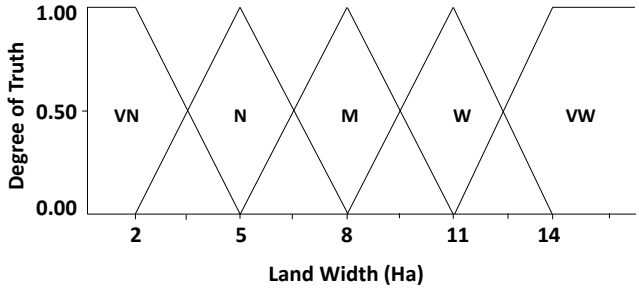

Fig. 2. Membership Function for parameter "Land Width"

In Fig. 2, the membership function of the land width is depicted in the form of a triangle, where the land area can be defined as having five linguistic variables. Each of which is depicted on a five-point scale, namely very narrow (VN), narrow (N), medium (M), wide (W), and very wide (VW); where respectively with a membership scale value (<2, 2, 5), (2, 5, 8), (5, 8, 11), (8, 1, 14), and (11, 14, >14).

In Fig. 3, membership function is depicted in the triangular form, where the type of land calculated by the pH unit can be defined as having five language variables very low (VL), low (L), medium (M), high (H), and very high (VH). Their scales are respectively (<2, 2, 5), (2, 5, 8), (5, 8, 11), (8, 11, 14), (11, 14, >14).

Furthermore, in Fig. 4, membership function of parameter tree number is depicted in the form of triangle, where the number of trees can be defined as having five language variables, each of which is depicted on a five-point scales very few (VF), few (F), medium (ME), many (M), and very many (VM). Their membership scale values are correspondingly (<400, 400, 1000), (400, 1000, 1600), (1000, 1600, 2200), (1600, 2200, 2800), (2200, 2800, >2800).

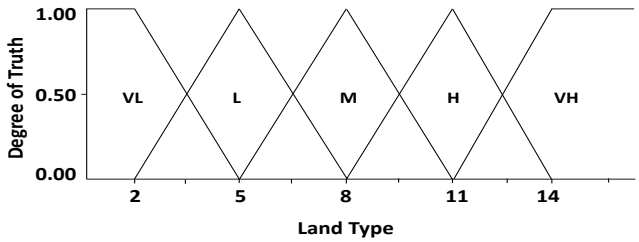

Fig. 3. Membership Function for Parameter "Land Type"

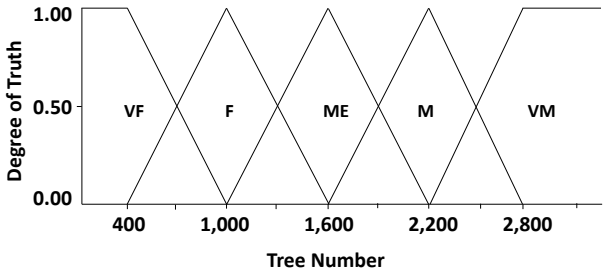

Fig. 4. Membership Function for Parameter "Tree Number"

Moreover, in Fig. 5, membership function for parameter tree type number is in triangular form also. The linguistic variable used are few (VF), few (F), medium (ME), many (M), and very many (VM). The five variable membership functions scale values are individually (<20, 20, 50), (20, 50, 80), (50, 80, 110), (80, 110, 140), and (110, 140, >140).

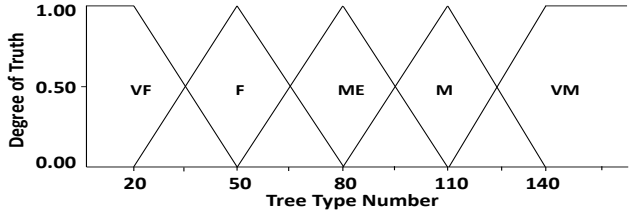

Fig. 5. Membership Function for Parameter "Tree Type Number"

Finally, the triangular membership function for parameter maintenance quantity is depicted in Fig. 6. The five maintenance quantity linguistic variables are very rare (VR) with membership scale value (<2, 2, 5), rare (R) with membership scale (2, 5, 8), moderate (M) with membership scale value (5, 8, 11), frequent (F) with membership scale value (8, 11, 14), and very frequent (VF) with value (11, 14, >14). And, finally, in Fig. 7, there is a useful decision value (DV) or assessment value function in the triangular form; where it is not good (NG) in less than 25 and good (G) is in worth above 75.

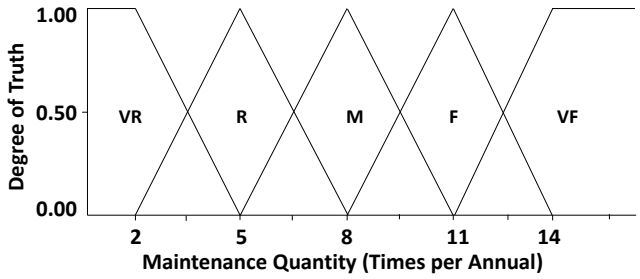

Fig. 6. Membership Function for Parameter "Maintenance Quantity"

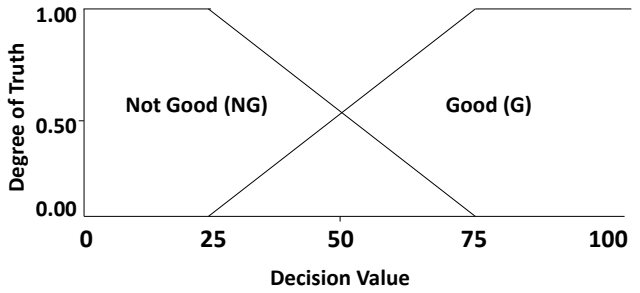

Fig. 7. Membership Function for Decision Value or Assessment Value

Then, by using these membership functions, a value (crisp input / CI) can be mapped into one (or more than one) fuzzy value (through the fuzzification process). This value is then converted into a definite value (crisp) again, through a process called the de-fuzzification process. In the de-fuzzification process using the interpolation formula. Furthermore, via operating this de-fuzzication process, crisp output (CO) values can be generated.

Table-III: Fuzzy Value for Each Parameter and Each City Forest

City-Forest	LW	LT	TN	TTN	MQ
Srengseng	1.00 VW	0.67 L	1.00 VM	0.50 AL	0.50 VR
		0.33 A		0.50 A	0.50 R
Gembira Loka	0.83 T	0.33 A	0.70 AL	0.20 AL	0.50 R
	0.17 VT	0.67 L	0.30 A	0.80 L	0.50 VR
Malabar	1.00 VT	0.27 L	0.17 AL	0.97 A	0.50 VR
		0.73 VL	0.83 A	0.03 M	0.50 R
Velodrom	1.00 VT	1.00 L	0.94 AL	0.17 A	1.00 VR
			0.06 A	0.83 AL	
Bungkirit	1.00 VT	0.50 L	0.91 AL	0.87 L	1.00 VR
		0.50 A	0.09 A	0.13 AL	

Fuzzy value for each parameter and each city forest can be shown in Table-III which has been calculated by the fuzzy logic method of the interpolation formula; where LW is land width, LT presents land type, TN means tree number, TTN is a tree type number, and MQ symbolizes a yearly management quantity. In making the rule base in this study we used the membership function of each parameter to be associated with the words "and". Then to compile 5 parameters with 5 linguistic variables, 3,125 rules are operated. The example of them are presented in RULE 01 (like ever operated by [12]).

RULE 01. Example of Fuzzy Rule

IF (LW is VW) AND (LT is VH) AND (TN is VM) AND (TTN is VM) AND (MQ is VO) THEN
DV is G
ELSE IF (LW is VW) AND (LT is VH) AND (TN is VM) AND (TTN is VM) AND (MQ is O) THEN
DV is G
ELSE IF …

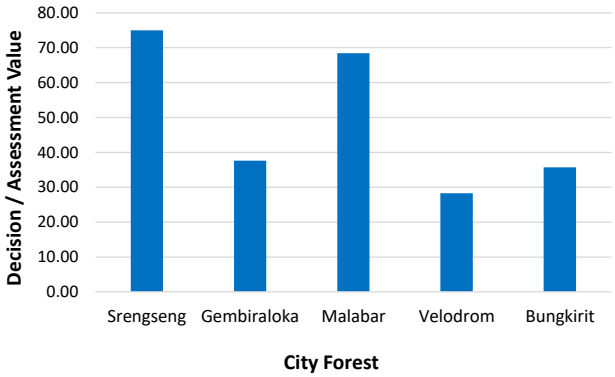

Fig. 8. Decision/Assessment Value for Each City Forest

In addition, rules were operated to get the final output or CO in the form of the value of each city forest in the form of a bar diagram as shown in Fig. 8. The picture explains each decision/assessment value of the city forest.

Then, the Android based dashboard was also created. It contains important information that found in the research of the DSM for evaluating city forest governance. Please see it in Fig. 9. It shows decision value of each city forest. Also, there is a choice to display the location of the city forest. Based on the dashboard, which city forests having the highest and lowest values can be presented.

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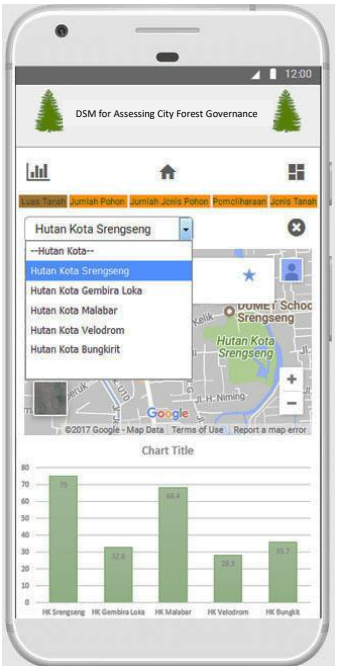

Fig. 9. Android based Dashboard of the Constructed Model

V. CONCLUSION AND FURTHER WORKS

Based on study, several points are able to be highlighted. The constructed model shows that the city forest Srengseng has the highest assessment value of municipal forest qualifies. It has been as a good city forest empirically. The number of trees greatly influences the quality of city forests. Thus, city forests that have a large number of trees have good value. Then, the concept of fuzzy logic is easy to understand in constructing the model and able to avoid bias value of parameters.

A more number of parameters would enrich the quality of model. It is still open as the big opportunity to do in next study. Also, other method use (e.g. optimization or computational intelligence method) is other chance to conduct for producing other novelty findings.

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