Fuzzy Logic Methods to Identify Potential Area Mapping for Mangrove Forests in Kendari using Landsat Image

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Abstract. Indonesia is an archipelago country with widest mangrove areas in the world. This potential is supported by length the coastline reaches ± 81,000 km. As one of city in Indonesia, Kendari surrounded by the bay with temperatures reaching 22-31°C makes it potential to has mangrove forests. But the mangrove areas in Kendari decrease by 30% in recent year. This study aims to determine the level of mangrove fertility so we hope in future we could identify potential area Mapping for Mangrove in Kendari to increase more mangrove area. To analyze the quality of mangroves area through remote sensing data can be used Normalized Difference Vegetation Index (NDVI) method. By utilizing Landsat 7.0 ETM + image can make it easier to get information without touching the object of research. This experiment used fuzzy logic method (Fuzzy Mamdani) to get fertility rate of land soil. The result showed the highest fertility rate of mangrove area is 58,2034 which categorized as Very Good and the lowest score is 36,991 which categorized as Average.

1. Introduction
One of the most important parts of Indonesia's geographical condition as an archipelago is a fairly large coastal area with a coastline reaching 95,181 km [1]. This number makes Indonesia a country with the fourth longest coastline in the world, in harmony with its vast coastal area. Indonesia has tremendous potential for coastal natural resources with a diversity of ecosystems [2]. Indonesia is an archipelago country with the largest mangrove area in the world. This potential is supported by the length of the coastline which reaches ± 81,000 km and makes Indonesia a country with the second longest coastline in the world after Canada [3].
Kendari Region is also the capital city of Southeast Sulawesi Province, geographically located with coordinates of 3°54'30"- 4°3'11" S and 122°23'-122°39' E, and the location of the region stretching around Kendari bay [4]. While the average air temperature in Kendari city ranges between 22 °C - 31 °C [4] where the surface temperature is very important for the development of mangroves which acts as a parameter that is sensitive to the existence and the type of vegetation that covers the object of study, as well as air humidity and surface moisture. These parameters will affect temperature variations both temporal and spatial of a surface. Basically, the estimation of surface temperature using satellite imagery utilizes the concept of electromagnetic wave emission of objects that are unique based on surface temperature. Objects with different temperatures will emit maximum electromagnetic waves at different wavelength ranges [5].
Mangrove trees are no stranger to our lives. The benefits are so many, especially for the balance of the aquatic environment. So, it is only natural that Kendari city, Southeast Sulawesi, is participating in preserving the 'Green Belt' plant as an environmental defense because the area of mangrove forest in the coastal city of Kendari is shrinking. Data obtained from the Southeast Sulawesi Provincial Forestry Service stated that the area of mangrove forests in Kendari bay in 1960 was 542.58 ha, but experienced a drastic decline in 1995, leaving with only 69.85 ha. of total area [4].

The purpose of this paper is to get information about the level of mangrove fertility in Kendari City where mangroves play an important role in the stabilization of shoreline, can prevent erosion as a result of waves and also play a role in the addition of coastal land.

The method in this study uses the Mamdani method which is part of fuzzy logic. The Mamdani method itself, both input variables and output variables are divided into one or more fuzzy sets. The stages are data collection and data processing. Data retrieval consists of NDVI data, surface density and temperature. Data processing uses Fuzzy Logic decision making to determine the value and status of mangrove fertility levels.

2. Research Methods

The Mamdani method is often also known as the Max-Min Method. Some defuzzification methods on Mamdani's composition rules are [6]:

a. Centroid Method (Composite Moment). In this method, the crisp solution is obtained by taking the center point \(z^*\) of the fuzzy region, which is generally formulated:

\[
z^* = \frac{\sum_{i=1}^{n} z_i \mu(z_i)}{\sum_{i=1}^{n} \mu(z_i)} \tag{1}
\]

b. Bisector Method. In this method, the crisp solution is obtained by taking values in the fuzzy domain that has a membership value of half of the total membership value in the fuzzy area, which is generally written:

\[
z_p \text{ so that } \int_{R_1}^{R_p} \mu(z) \, dz = \int_{R_p}^{R_n} \mu(z) \, dz \tag{2}
\]

c. Mean of Maximum Method (MOM). In this method, the crisp solution is obtained by taking the average value of the domain that has the maximum membership value.

d. Largest of Maximum Method (LOM). In this method, the crisp solution is obtained by taking the largest value from the domain that has the maximum membership value.

e. Smallest of Maximum (SOM) method. In this method, the crisp solution is obtained by taking the smallest value from the domain that has the maximum membership value.

This study was done by collecting data from previous research. Data retrieval is needed as a reference for further analysis and calculation using fuzzy logic so the value of the mangrove fertility level in Kendari city can be known. In the fuzzy logic control system, there are several operational stages including:

2.1 Fuzzification

The fuzzification process is done by converting non-fuzzy variable data (numeric variables) into fuzzy variables (linguistic variables). Since fuzzy inference systems work with fuzzy rules and inputs, the first step is to change the firm input received, into a fuzzy input.

| Function | Variable Name | Range |
|----------|---------------|-------|
| Input    | NDVI          | 0 - 1 |
|          | Density Level | 0% - 100% |
|          | Surface Temperature | 0°C - 40°C |
| Output   | Fertility Status | 0 - 90 |
For each input variable, a fuzzification function is used to change the crisp input variable (the usual expressed in real numbers) becomes the value of the fuzzy approach.

The NDVI input variable has three forms of fuzzy set, namely: Low \([0 \ 0.18 \ 0.32]\), Medium \([0.3 \ 0.4 \ 0.47]\), and High \([0.42 \ 0.7 \ 1]\). The Density Level input variable has three forms of fuzzy sets, namely: Sparse \([0 \ 10 \ 21.4]\), Intermediate \([20 \ 42 \ 61.8]\), and Dense \([60 \ 80 \ 100 \ 100]\).

Surface temperature’s input variables has three forms of fuzzy sets, namely: Cold \([0 \ 10 \ 20]\), Warm \([18 \ 25 \ 33]\), and Hot \([32 \ 35 \ 40 \ 40]\). While the Fertility Status input variable has three forms of fuzzy sets, namely: Not Fertile \([0 \ 15 \ 25]\), Medium Fertility \([20 \ 35 \ 55]\), and High Fertility \([50 \ 70 \ 90 \ 90]\).

### 2.2 Fuzzy Knowledge Base

The knowledge base of a fuzzy inference system consists of a database and a rule base. Database is a set of membership functions from fuzzy sets that are related to linguistic values of variables involved in the system. The rule base is the set of fuzzy implications that apply as rules in the “If ...and ...then...” system. In this paper there are 27 rules used by the author to get the value of Mangrove fertility in Kendari City. The rules are:

| No | Rules |
|----|-------|
| R1 | If (NDVI is Low) and (Density Level is Sparse) and (Surface Temperature is Hot) then (Fertility Status is Unfertile) |
| R2 | If (NDVI is Low) and (Density Level is Sparse) and (Surface Temperature is Warm) then (Fertility Status is Unfertile) |
| No | Rules |
|----|-------|
| R3 | If (NDVI is Low) and (Density Level is Sparse) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R4 | If (NDVI is Low) and (Density Level is Intermediate) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R5 | If (NDVI is Low) and (Density Level is Intermediate) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R6 | If (NDVI is Low) and (Density Level is Intermediate) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R7 | If (NDVI is Low) and (Density Level is Dense) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R8 | If (NDVI is Low) and (Density Level is Dense) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R9 | If (NDVI is Low) and (Density Level is Dense) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R10 | If (NDVI is Sedang) and (Density Level is Sparse) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R11 | If (NDVI is Medium) and (Density Level is Sparse) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R12 | If (NDVI is Medium) and (Density Level is Sparse) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R13 | If (NDVI is Medium) and (Density Level is Intermediate) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R14 | If (NDVI is Medium) and (Density Level is Intermediate) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R15 | If (NDVI is Medium) and (Density Level is Intermediate) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R16 | If (NDVI is Medium) and (Density Level is Dense) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R17 | If (NDVI is Medium) and (Density Level is Dense) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R18 | If (NDVI is Medium) and (Density Level is Dense) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R19 | If (NDVI is High) and (Density Level is Sparse) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R20 | If (NDVI is High) and (Density Level is Sparse) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R21 | If (NDVI is High) and (Density Level is Sparse) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R22 | If (NDVI is High) and (Density Level is Intermediate) and (Surface Temperature is Cold) then (Fertility Status is Unfertile) |
| R23 | If (NDVI is High) and (Density Level is Intermediate) and (Surface Temperature is Warm) then (Fertility Status is Medium Fertility) |
| R24 | If (NDVI is High) and (Density Level is Intermediate) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R25 | If (NDVI is High) and (Density Level is Dense) and (Surface Temperature is Warm) then (Fertility Status is High Fertility) |
| R26 | If (NDVI is High) and (Density Level is Dense) and (Surface Temperature is Hot) then (Fertility Status is Medium Fertility) |
| R27 | If (NDVI is High) and (Density Level is Dense) and (Surface Temperature is Hot) then (Fertility Status is High Fertility) |
2.3 Defuzzification
Defuzzification is the process of mapping fuzzy sets to a strict set (crisp). This process is the opposite of the fuzzification process.

Figure 5. Defuzzication Process with Mamdani Method

3. Results and Discussion
To analyse the quality of mangroves through remote sensing data, vegetation index method normalized NDVI (Normalized Difference Vegetation Index) can be used. This calculation method will divide the mangrove health level based on the canopy density value, which are:
1) <=20% (Very Sparse), the range of NDVI values > 0.01 to 0.18
2) 21.40% (Sparse), the range of NDVI values is 0.18 to 0.32
3) 41.60% (Medium), the range of NDVI values is 0.32 to 0.42
4) 61.80% (Heavy), the range of NDVI values from 0.42 to 0.47
5) >=80% (Very Heavy), the range of NDVI values > = 0.47

Determination of mangrove fertility status using the Mamdani method of Fuzzy Logic. Based on the regional data of Kendari city in 2014 (NDVI values, Density and Temperature), the results obtained for the calculation for fertility status of mangroves are as shown in Table 3 below.

| No | NDVI Value | Density (%) | Temperature (°C) | Fertility Value | Fertility Status  |
|----|------------|-------------|------------------|----------------|------------------|
| 1  | 0.256      | 26.0818     | 21.7372          | 37.1731        | Medium Fertility |
| 2  | 0.430      | 66.3110     | 21.8944          | 41.4167        | Medium Fertility |
| 3  | 0.874      | 68.0142     | 22.3661          | 56.951         | High Fertility   |
| 4  | 0.345      | 48.4718     | 21.7372          | 36.991         | Medium Fertility |
| 5  | 0.808      | 80.2783     | 21.7372          | 57.6743        | High Fertility   |
| 6  | 0.202      | 11.0731     | 21.5800          | 11.0481        | Unfertile        |
| 7  | 0.519      | 80.2910     | 21.8944          | 56.714         | High Fertility   |
| 8  | 0.510      | 79.1245     | 21.7372          | 56.5603        | High Fertility   |
| 9  | 0.824      | 77.7830     | 22.3661          | 58.2034        | High Fertility   |
| 10 | 0.414      | 63.2599     | 21.7372          | 37.2844        | Medium Fertility |

Based on these data, mangroves that have the highest fertility value is 58.2031 with their Mangrove Fertility Status is in "High Fertility", this is because the environment in which mangroves grow is very suitable for mangroves to live. The area is dominated by mangroves because it has not been touched by development for human settlements or fishponds. The place was also protected by the government. Besides that, fresh water supply, and groundwater salinity are the most influential factors on mangrove growth in this region. Its location close to the sea (salt water) that also influences its growth. With the influence of sea water, if mangroves are not able to adapt to existing environmental conditions it can cause growth ability to be slightly inhibited.
Whereas mangroves that have lowest fertility value are 11.0481 with the Fertility Status mangroves "Unfertile" which is on the coast of Kendari city. The main cause besides low's density is due to its ability to adapt to existing environmental conditions. The utilization pattern is one of the factors that greatly affect the presence of mangroves in this place. With the increasingly high rate of exploitation, the mangroves here are very vulnerable to damage because many are used as a material for consumption by the community. Its use as firewood and other household necessities by the surrounding population is a major factor in the reduction of mangroves population in this place.

For the condition of density of mangroves tree in the Bay of Kendari as a whole is still categorized as "Dense" where the value of density reaches 80.2910 because the location of mangrove growth in this place gets sufficient water supply. In addition, because mangroves in this place grow along beaches that are protected from large wave activity and strong tidal currents, the substrate needed for mangrove growth is very suitable so that this area is highly recommended for Mangrove cultivation. Given the type of substrate in the form of sandy mud and peat soil, this type requires special adaptation, namely in the roots. Also due to regeneration factors that are often limited.

4. Conclusion
Based on the experiment results it can be seen that the level of fertility of mangroves is very high. The highest fertility value is 58,2034. The recommended area for Mangrove cultivation is the Bay of Kendari city because the density of mangroves in the area reaches 80.2910. The role of the community and government is needed to conserve mangrove ecosystems as an effort to maintain the existence of mangrove ecosystems.

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