Classification of Rice Leaf using Fuzzy Logic and Hue Saturation Value (HSV) to Determine Fertilizer Dosage

by Yuslena Sari

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1st Yuslena Sari
Information Technology
Universitas Lambung Mangkurat
Banjarmasin, Indonesia
yuzlena@ulm.ac.id

2nd Muhammad Alkaff
Information Technology
Universitas Lambung Mangkurat
Banjarmasin, Indonesia
m.alkaff@ulm.ac.id

3rd Muti'a Maulida
Information Technology
Universitas Lambung Mangkurat
Banjarmasin, Indonesia
mutia.maulida@ulm.ac.id

***Abstract*—Rice is one of the food commodities that is most needed by the Indonesian people. Its condition requires farmers to maximize rice harvest as a rice-producing plant which one of them by providing fertilizer with the right dose. One of the methods used by rice farmers is to use a Leaf Color Chart to compare the color of rice leaves manually which might cause an error. Several research topics of classification based on plant image processing have been done to help the agriculture sector including rice. In this paper, the classification of rice leaves to determine the fertilizer dose by processing the rice leaf image using the HSV method is proposed. Results of rice leaf image processing are classified using fuzzy logic to calculate the right dose of fertilizer and developed as a mobile-based application. The proposed method achieved an accuracy value of 90% for the color of rice leaf and an accuracy value of 82.5% for the determination of fertilizer dose.**

Keywords—rice leaf, fuzzy logic, HSV, fertilizer

I. Introduction

As one of the rice consuming countries in the world, it has been recorded until 2017 that Indonesia's rice consumption per person in one year is 150 kilograms [1]. Rice produced comes from rice plants, which are the staple food of the Indonesian people [2]. To get satisfactory rice yields, the soil where the rice plants grow should be given additional nutrients through the provision of fertilizer [3]. Fertilization must be given regularly and in accordance with the dose required by the plant. To find out the fertilizer requirements needed by rice plants, farmers can see from the green color of the leaves of rice plants [4]. There are two tools that can be used to check the color of the leaves and determining fertilizer dose namely the Leaf Color Chart and Chlorophyll meters. Most farmers use Leaf Color Chart because the price is cheaper but all comparing processes must be done manually. For the manual process, it needs more processing time and a large amount of work [5]. Farmers' mistakes in comparing color of rice leaves can affect the dose of fertilizer given to the field.

Image processing techniques with various methods of feature extraction and classification have been carried out in several studies for various needs [6]. Each stage in image processing consists of image acquisition, pre-processing, segmentation, feature extraction processes, and the application of appropriate classification methods [7]. These stages can be performed only on the external appearance of plants which generally on leaf [8]. In determining fertilizer dose for rice plant can be known from leaves color which is divided into several categories. Inappropriate fertilizer dose application to rice fields may cause rice plant to fall easily and damage to soil chemical structure. To overcome this, a suitable technology for rice leaves color compared to the appropriate category for determining the right fertilizer dose is needed [9].

Hence this paper proposes a method for determining appropriate fertilizer dosage based on color processing of rice leaf images result. Our contributions in this work include: collecting several images of rice leaves from agricultural fields and preparing data sets. In pre-processing, background deletion and adjustment of the size of the rice image are done to be segmented. The HSV method is used to extract color features from rice images and is classified using fuzzy logic [10]. The structure of the rest paper is organized as follows: section 2 consists of a literature review related to rice leaves images classification. In section 3 comprises our proposed research methodology and section 4 explains the results of this research. Lastly, section 5 shows research conclusions.

II. Literature Review

Some recent research related to plant image processing has been done includes rice. Most of these research are used Leaf Color Chart (LCC) as a leaf color measuring tool as shown in Fig. 1. This researches will be explained below.

Based on the needs for an accurate and renewable tool besides Chlorophyll meter and Leaf Color Chart (LCC) that has been used for years, Tran Khac Duy et al. developed a prototype sensor to determine nitrogen levels from rice plants. They used AS7262 6- Channel Visible Spectral ID as the core device for a developed tool as a replacement for a leaf color chart. This device is used based on a very cheap price and easy to find. The results of experimental sensor prototypes in both the laboratory and environmental test are shows that it can read faster, more accurate, and consistent than the leaf color chart. They also concluded that there was no human intervention on the device because each process ran automatically and was easy to use [11].

Another research that discusses the use of leaf color charts was carried out by A.Nguy-Robertson et al to estimate chlorophyll canopy in corn (Zea mays). Two approaches were taken to estimate chlorophyll canopy content to measure leaf area index destructively (LAI) and leaf color with LCC. The method used to verify these two approaches is using canopy reflectance data collected from satellite imagery and four-band radiometers. Based on verification results it is shown that both estimation approaches have reasonable error values. Based on these results they stated that both leaves and chlorophyll canopy can be estimated cheaply without a newly developed tool such as a sensor [12].

Hendra Yufit Riskiawan et al. developed a device to measure the right amount of nitrogen fertilizer for maize per hectare. This microcontroller-based device has a TCS3200 color sensor that takes RGB values from the color of maize leaves. The results were compared with data from manual reading results of maize leaves with Leaf Color Chart (LCC) that has been processed in microcontroller [13]. Information on fertilizer dosage obtained from the processing of maize leaf color will be displayed on the screen of this device. Based on the test result it is shown that the sensor device can be categorized as quite well with an accuracy of 82%.

Overcoming problem of expensive leaf tissue analysis to evaluate the process of fertilization and detection of nutrient deficiencies in soybeans, Kestrilia et al. developed an automatic and non-destructive method based on soybean leaf color image for fertilizer dosages determination. Fuzzy logic is applied to get soybean leaf color gradation based on the color level obtained from Leaf Color Chart. Mobile application from previous research upgraded with fuzzy logic inference to determine fertilizer dose gradually and proportional to soybean leaf color level graduation. Results show from a field experiment that a new fuzzy logic algorithm implemented in the mobile application was performed with 100% accuracy to determine soybean leaves color gradation level [14].

Based on India's need for advanced technology in agriculture, Amandeep et al. propose an image processing technology to characterize plant leaf colors that can be compared to leaf color charts automatically. This characterization is needed to predict plant health status by applying an algorithm that has been developed on the MATLAB platform. The agriculture plant they used as data was the rice plant. This research uses HSV method as a color feature and converts it to a histogram before it is processed with the proposed algorithm [15]. The results of the study show that the new algorithm they propose is simple and accurate, can work in real environmental conditions and could be a new approach in agriculture especially for rice plants.

Fig. 1. Leaf Color Chart

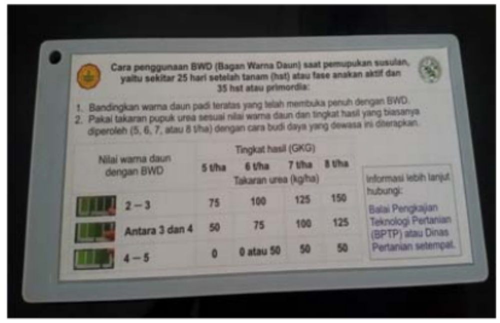

Fig. 2. LCC Fertilizer Dose Standard

III. Research Methodology

The result of this research is a mobile application that utilizes rice leaf image processing technique to determine fertilizer dose. This technique is developed through five stages include acquisition of rice leaf images, pre-processing, segmentation of rice leaf images, feature extraction of rice leaf images, and classification of rice leaf image features. Rice leaf images are collected from South Kalimantan Institute of Agricultural Technology at Banjarbaru, South Kalimantan using a high-resolution camera. Pre-processing stages will reduce the image dimension and remove the image background. The next stage is rice leaf image segmentation using edge detection to determine the location of rice leaf image edge. Color feature of segmented rice leaf image will be extracted using HSV method. In the last stage, the rice leaf image will be classify using logic fuzzy.

The flow of five stages of process for rice leaf image processing is shown in Fig. 3. After classification has been done, it will be applied in mobile applications and going through laboratory testing. The purpose of this test is to determine the accuracy level of rice leaf classification and fertilizer dose determination that has been produced by the system.

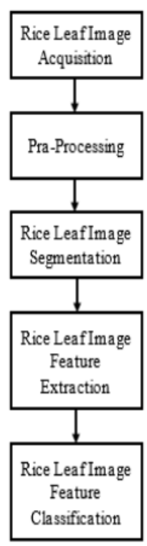

Fig. 3. Process Flow of Rice Leaf Image Processing

A. Rice Leaf Image Acquisition

The Rice leaf images collecting process in this research was carried out by taking rice leaf images from the farm field by using a high-resolution camera. This rice leaf image was brought to South Kalimantan Agricultural Technology Assessment Institute to be categorized using 4 panels Leaf Color Chart. Fertilizer dose application for each color category of rice leaves based on expert analysis is obtained. Total datasets prepared were 80 images which include 20 images for each color category. Some sample of rice leaves images used in this research are shown in Fig. 4.

B. Pra-Processing Image

After all rice leaf images have been collected and categorized based on Leaf Color Chart before image processing is pre-processing. The purpose of this step is to clarify the image taken, reduce or increase the size of the data, and eliminate noise. It also minimizes memory capacity and increases rice leaf image processing time. In this process, sampling is done on a particular part of the leaf image with dimensions of 128x128 pixels.

C. Rice Leaf Image Segmentation

Edge detection is used for the segmentation of rice leaf images. This technique is used to determine location of dots that represent edge of leaf image. Rice leaf images that have been resized are cropped to eliminate rice leaf image background. This process must be done to detect color values of rice leaf images and the detailed texture of rice.

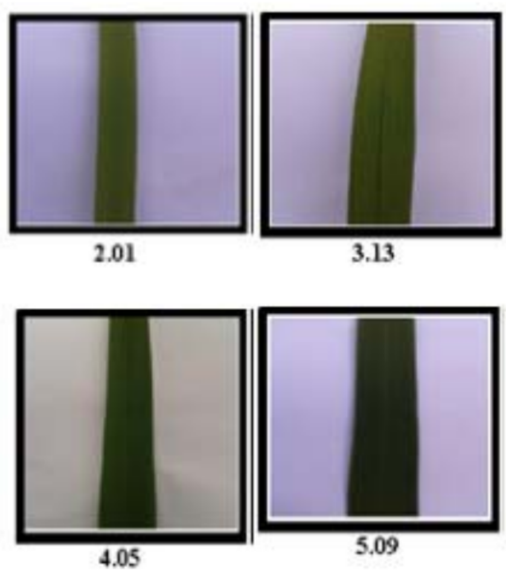

Fig. 4. Sample rice leaf image of each category

D. Rice Leaf Image Feature Extraction

After the segmentation process is completed, the process that will be executed next is feature extraction. For this research, the feature that will be extracted from rice leaf image is the color feature using Hue, Saturation, and Value method. First, RGB color values will be taken from rice leaf images using the Matlab application. RGB absolute value is obtained by calculating mean value of each pixels RGB value. The conversion process from RGB color to HSV will be using formula below (1).

$$R = \frac{R}{255}; G = \frac{G}{255}; B = \frac{B}{255}$$

$$V = max$$

$$S = \begin{cases} 0, if\ \Delta = 0 \\ \frac{\Delta}{max}, if\ \Delta <> 0 \end{cases}$$

$$H = \begin{cases} 60\frac{G-B}{\Delta}, if\ \mathrm{R} = max \\ 120 + 60\frac{B-R}{\Delta}, if\ \mathrm{G} = max \\ 240 + 60\frac{R-G}{\Delta}, if\ \mathrm{B} = max \end{cases}$$

$$H = H + 360, if\ H < 0 \quad (1)$$

Once the data are calculated, the range of HSV values obtained will be used to classify data. The range of values used for this research are shown in Table 1 below.

TABLE I. HSV RANGE VALUE

Variable	Table Column Head		
	Hue	*Saturation*	*Value*
Category 2	72-90	59-93	61-80
Category 3	88-105	48-68	50-61
Category 4	93-109	40-60	41-50
Category 5	98-128	30-56	22-41

E. Rice Leaf Image Classification

The last process from this research methodology is the classification of rice leaf images using fuzzy logic. Using this logic images dataset will be divide into several homogeneous regions based on specific similarity criteria by searching for the best hyperplane. A fuzzy system consists of several stages, namely input, fuzzification, inference, defuzzification, and output as shown in Fig. 5.

The data input into the fuzzy system is the HSV value of the image, while the output is in the form of fertilizer needs on rice plants (70kg, 50kg, 0kg). After variable determination for each range of HSV value as shown in Table 1, then a fuzzy set is created based on each membership schema as shown in Fig. 6, 7, and 8.

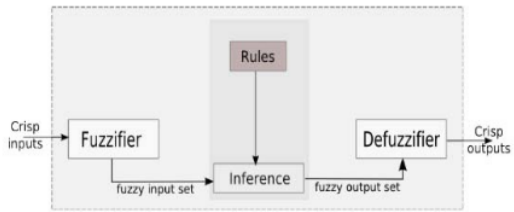

Fig. 5. Fuzzy Component

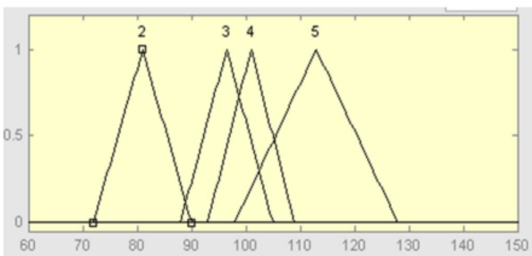

Fig. 6. Fuzzy Membership Function for Hue

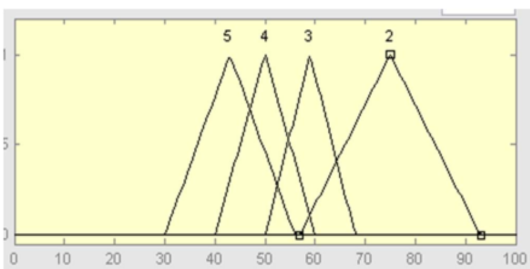

Fig. 7. Membership Function for Saturation

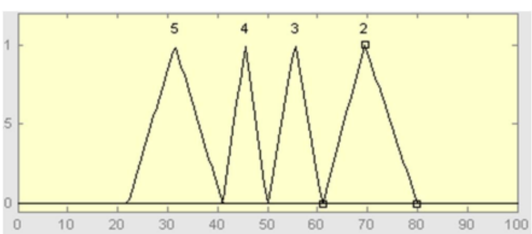

Fig. 8. Fuzzy Membership Function for Value

From the membership function that has been used, the formulation of the functions to be used is as follows:

$$\mu[x] = \begin{cases} 0; x \leq a\ OR\ x \geq c \\ \frac{x-a}{b-a}; a \leq x \leq b \\ \frac{c-x}{c-b}; b \leq x \leq c \end{cases} \tag{2}$$

In the formula, a is the first value, b is the middle value, and c is the last value in each category, while x is the image value of rice leaves. After calculating the function for each category membership, fuzzy rules for this research are determined in Table 2.

TABLE II. FUZZY RULES FOR FERTILIZER DOSE

Category			**Fertilizer Dose (kg/ha)**
Hue	***Saturation***	***Value***	
2	2 and 3	2 and 3	75
	2	4 and 5	50
	3	4	50
	3	5	0
	4 and 5	2	75
	4 and 5	3	50
	4 and 5	4 and 5	0
3	All	2	75
	3	3 and 4	50
	3	5	0
	4 and 5	3	50
	4 and 5	4 and 5	0
4	All	2	75
	2 and 3	3	50
	4 and 5	2 and 3	50
	4 and 5	4 and 5	0
5	All	4 and 5	0
	2,3,4	2	75
	2,3,4	3	50
	2	2	50

After determining fuzzy rules, the next step is to carry out the inference calculation process. Specifically this research use Sugeno method for fuzzy logic. The implication function that we use for this process is MIN. For inference calculations we use a formula as follow:

$$apredikat = \min(\mu Hue, \mu Saturation, \mu Value) \tag{3}$$

Furthermore, the value obtained from the inference calculation process will be used to carry out the defuzzification process. The input of the defuzzification process is a fuzzy set obtained from the composition of the fuzzy rules with the output result is a number in a fuzzy set domain. Defuzzification used in determining the dose for rice plant fertilizer is a weighted average method used by the equation for discrete domain.

IV. RESULT AND DISCUSSION

The focus of this research is to determine the fertilizer dose for rice plants based on rice leaf image processing. We implemented the result of rice leaf image classification as explained in the previous section into the Android mobile application. The performance of the proposed classification method is measured by comparing fertilizer dose and rice leaf color result from an android application and Leaf Color

Chart. Comparisons of both results are done using the rice leaf image category from 43% of total datasets.

Table 3 shows co of rice leaf image color classification using Leaf Color Chart and fuzzy logic implemented in android application. Implementation of fuzzy logic as a classification method has obtained an overall accuracy value which is 90%.

TABLE III. RICE LEAF CLASSIFICATION PERFORMANCE

Leaf Category	2	3	4	5
Accuracy	90	90	85	95
Precision	100	95	94	95
Recall	90	95	89	100
F1-Score	94,8	95	91,5	97,5

The confusion matrix obtained from rice leaf image classification using fuzzy logic is shown in Fig. 9. Based on the confusion matrix above, it shows the predicted value of True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN). Respectively for category 2 value of TP, TN, FP and FN are 18, 59, 1 and 2. The values of TP, TN, FP and FN for category 3 are 18, 57, 2 and 3 respectively. Furthermore, the value of TP, TN, FP and FN for category 4 are 17, 58, 2 and 3. At last, for category 5 the value of TP, TN, FP and FP are mentioned as follows 19, 58, 1 and 2.

Furthermore, the classification performance for fertilizer dose determination is also tested. The confusion matrix for fertilizer dose classification is shown in Fig. 10.

Android Application

Leaf Color Chart	Category 2	Category 3	Category 4	Category 5
Category 2	18	2	0	0
Category 3	1	18	1	0
Category 4	0	1	17	2
Category 5	0	0	1	19

Fig. 9. Confusion Matrix of Rice Leaf Classification

Android Application

Leaf Color Chart / Fertilizer Dose	0	50	75
0	16	3	1
50	0	17	3
75	0	7	33

Fig. 10. Confusion Matrix of Fertilizer Dose Classification

After calculation fertilizer dose classification reached 82,5% for its accuracy value. However, differences in the results of fertilizer dosage data show that fuzzy methods can be used to classify data, and also the results of the determination of fertilizer doses on Fuzzy systems are more flexible and not fixated on the dose values specified in the Leaf Color Chart.

V. CONCLUSION

From this research that has been done by looking at and observing the system and through the testing stages in the classification system, it can be concluded that the Fuzzy Logic Method can be applied to the classification of rice leaf images with more detailed results compared to fertilizer doses in the Leaf Color Chart table. Based on testing conducted by officers using the Leaf Color Chart that has been made, the accuracy of this system reaches 90% for the color classification of rice leaves. Fuzzy methods can be developed for subsequent applications to help farmers determine the dosage of fertilizer to be given to rice plants. However, light factors can provide different image results, if the image is taken at a bright light level or vice versa, it will affect the appearance of the greenish color of the leaves. Also, the picture of rice leaves taken in a hurry can result in the image of rice leaves not visible or blurred so that it can affect the classification results.

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