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Application of digital image processing to the measurement of Leaf Area Index (LAI) of rice plants (Oryza Sativa L.)

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Abstract

Indonesia's main staple food, rice, is by far the largest commodity. In improving food security through the productivity of this local staple crop, care is needed from planting to harvesting. One of the physiological parameters that can determine biomass production and photosynthesis in rice is the leaf. We can measure this part of the plant through various methods ranging from conventional techniques to computer image processing techniques such as canny edge detection and ImageJ software. Through the comparison of these two methods, it is found that canny edge detection has a smaller average error value when compared to ImageJ, which is 3.76% and 4.53% respectively. With this final value, it is proven that canny edge detection can be an alternative technique to measure the value of LAI (Leaf Area Index) in rice plants.

Keywords: *Canny, ImageJ, Image Processing, Leaf Width, Rice*

1 INTRODUCTION

Rice is one of the food crops in Indonesia that is still maintained as a staple food commodity until now. Efforts to increase the productivity of local rice plants in Indonesia are still ongoing in order to support food self-sufficiency [1]. Rice productivity is highly dependent on accurate monitoring of plant growth. Leaf Area Index (LAI) is one of the important physiological parameters related to photosynthesis, transpiration, and biomass production. Leaf area index (LAI) is a variable that describes the relationship between leaf area and the surface area it covers. Changes in LAI values are strongly influenced by the quality of metabolism during the plant growth process [2]. Therefore, LAI is often used as an indicator of plant growth, namely as one of the variables to measure the intensity of radiation absorbed by the leaves, making it possible to estimate the amount of biomass produced.

Conventionally, the determination of LAI value is done by measuring and accumulating the amount of leaf area in a particular field using millimeter block paper. In order to optimally and reduce time, methods such as digital image processing are needed. This method has generally been widely used [3], such as manipulating and analyzing images [4], [5]. The utilization of image processing technology is a promising approach in accelerating plant growth data acquisition, thereby improving agronomic management and crop yield prediction.

Research conducted by Shen et al proves that edge accuracy detection through the canny method can detect edges and filter noise better than using block image processing. However, the results displayed are only up to edge segmentation without providing the results of the leaf area through the processed image [6]. ImageJ was also used in the research used by Koyama [7]. The results shown by both studies prove that ImageJ is able to produce a final value of area in the leaf area calculation process that is suitable for leaf types (monocots and dicots). The enhanced canny method by Zhang et al focusing on bilateral filtering and adaptive histogram equalization gives high edge precision results especially on low contrast objects [8]. However, the results given also do not display the broad results of the processed image object. Through some of the above research, this study will compare and compare the results of measuring leaf area from ImageJ and canny to prove the superiority and precision of the results of the two methods when compared to using the conventional method of measuring through millimeter block paper.

The object of this research is to measure the Leaf Area Index because through this LAI value, researchers will have many practical benefits in agronomy. In addition to LAI as a direct indicator of plant growth, LAI data can also be used as a plant stress detection factor, nutrient deficiencies, to estimate irrigation and fertilization needs [9]. Accurate and precise LAI estimation can help contribute to crop production modeling, harvest planning, and support the selection of superior varieties in plant breeding programs including rice [10]. This research contributes to measuring one of the physiological parameters of plants through the comparison of the canny method and ImageJ software as a method based on image processing techniques to estimate the value of LAI in rice plants. Through the results of the canny method that detects image-based LAI, this will be a practical solution to support the monitoring and resilience of rice as a major food commodity.

2 LITERATURE REVIEW

The following are the literature and references used in this research. The image processing process consisting of two methods, namely ImageJ software and canny edge detection, is explained in this section. The basic calculation of the Leaf Area Index (LAI) is also explained in this section.

2.1 IMAGEJ SOFTWARE

ImageJ is an open-source image processing software that is widely used in scientific research for quantitative image analysis, including non-destructive measurement of plant leaf area. Figure 1 is a GUI view of the ImageJ software. The use of this software has a role in agronomy because users can convert digital images into numerical data about leaf surface area, which is an indicator of plant growth, photosynthesis, and plant health.

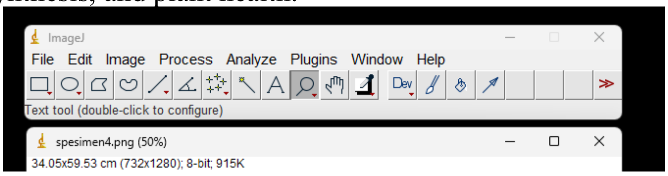


Figure 1. ImageJ Software

In order to determine the LAI value, the leaf image can be uploaded to the work window in this software. Furthermore, the image is calibrated based on a known scale (set scale), the next step is to segment and count pixels on the object to be measured, the ImageJ conversion results can be set which in this case the researcher uses a centimeter (cm) scale. The measurement results through this method have high accuracy when compared to the measurement method using the LI-COR leaf area meter tool. In a study conducted by Martin et al, ImageJ used for leaf area measurement in rye and white wheat showed very similar results to the LI-3100 leaf area meter, with no significant difference in the final LAI value [11].

2.2 MEASURED LEAF AREA (MLA)

Measured Leaf Area (MLA) is a non-destructive method used to assess leaf surface area. This method can be used to non-destructively observe leaf area index based on leaf morphometric parameters, namely length (L) and width (W). The estimated leaf area index in this method is calculated by a mathematical equation of the basic leaf size with a correction factor. MLA is an alternative method in calculating Leaf Area Index (LAI) that is more efficient and effective without the need to damage plant tissue.

Equation (1) is the general formula used to calculate MLA:

$$MLA = L \times W \times CF \quad (1)$$

Description:

L = Leaf Length
W = Leaf Width
CF = Correction Factor (adjusting for plant species)

The CF value is obtained from the regression analysis between the actual leaf area (scanned) and the estimated area using the leaf length and width, thus minimizing the measurement error [12]. In rice, the CF value is between 0.6 and 0.75, depending on the leaf shape. For example, Öner and Odabaş used multiple regression models to estimate the leaf area of different rice varieties [13], resulting in the complex shape formula in equation (2):

$$LA = a + (b \times L) + (c \times W) + (d \times L^2) + (e \times (L \times W)) \quad (2)$$

Description:
LA = Leaf Area
a, b, c, d, e = Coefficient Value
L = Leaf Length
W = Leaf Width

The above formula indicates a non-linear relationship between leaf dimensions and actual area. Leaf Area Index observations using the MLA method can be done more effectively and efficiently while providing fairly accurate results. Leaf Area Index is an important parameter in agronomy to observe the growth to morphophysiological characters of plants, plant stress analysis, and crop yield prediction [14]. This method is a non-destructive observation method so that it can be applied repeatedly to the same plant throughout the maximum vegetative phase without having to damage plant tissues and organs.

2.3 CANNY *EDGE DETECTION*

Canny edge detection is an edge detection method applied to produce optimal detection with minimal noise level and localization error. The process includes four main stages: noise suppression using a Gaussian filter, intensity gradient calculation, edge thinning through non-maximum suppression, and the application of double thresholding to identify edges. Mathematically, the first operation in Canny edge detection is the convolution of the image $I(x, y)$ with the Gaussian function $G(x, y)$, given by equation (3):

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (3)$$

In the above equation, σ controls the level of smoothing. The next step is to calculate the image gradient using Sobel in the x and y directions, which is formulated through the following equation (4):

$$G_x = \frac{\partial I}{\partial x}, G_y = \frac{\partial I}{\partial y} \quad (4)$$

In order to calculate the gradient magnitude and gradient direction through equations (5) and (6):

$$G = \sqrt{G_x^2 + G_y^2} \quad (5)$$

$$\theta = \arctan\left(\frac{G_y}{G_x}\right) \quad (6)$$

Non-maximum suppression is applied to attenuate the edges in the gradient direction, followed by double thresholding that classifies the edges into strong, weak, or ignored. This process is followed by hysteresis thresholding to connect the integrated weak edges with the strong edges [15]. In rice leaf area measurement, the Canny edge detection method is effective in extracting leaf boundaries in digital images. This edge detection segmentation enables accurate calculation of leaf area, thus supporting the estimation of agronomic parameters such as Measured Leaf Area (MLA).

Research by Brenda et al. showed that the application of canny edge detection for leaf extraction in Pak Choy plants achieved leaf width measurement accuracy of up to 95% [16]. This finding reinforces the reliability of the Canny method as an image processing-based approach. With precise edge segmentation, leaf area can be calculated through pixel counting method or conversion of pixel ratio to actual physical size, thus supporting non-destructive and efficient monitoring of plant growth [17].

3 RESEARCH METHOD

The whole method used in this research consists of taking photos to become basic data, then processed through two image processing methods, namely canny edge detection and ImageJ software. Next is analyzing and comparing the results of the two methods. Comparison of results is done by comparing the results with manual calculations, which is a calculation using millimeter block paper. From all these results, data analysis will be carried out to compare all the results of the method with the results of the manual method carried out. The research process flow is visualized in Figure 2 below.

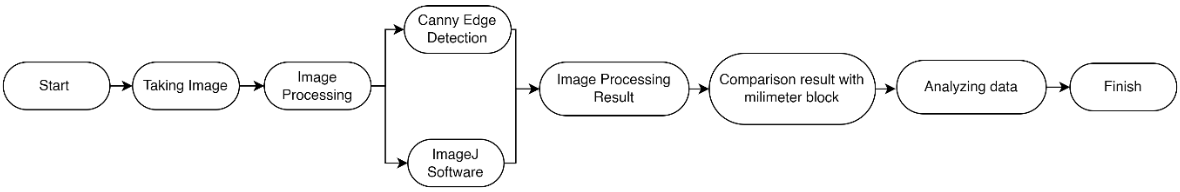


Figure 2. Research process flow

Through the outline in Figure 3, Canny has a total of six processes. The first process, grayscale, is to make the image into black and white values that were originally Red Green Blue (RGB). Gaussian blur is used to give the image a matrix value that has a specific standard deviation value. In order to calculate the gradient value of the image, a gradient process is performed using the Sobel operator. To eliminate unnecessary values in the image, the non-maximum suppresion operation is used at this stage. After knowing the predetermined value, the thresholding process makes the image black (OOOOO) and white (FFFFFFF). Edge tracking or edge detection is the last process in canny detection. The end result of this flow is an image that has a contour box around the leaf that has been detected. In conducting this research, Figure 3 is an outline of what will be done in canny edge detection..

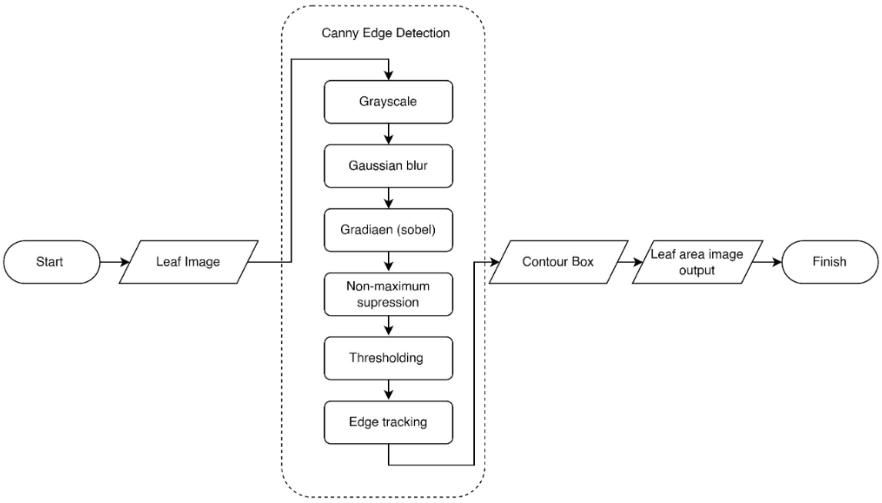
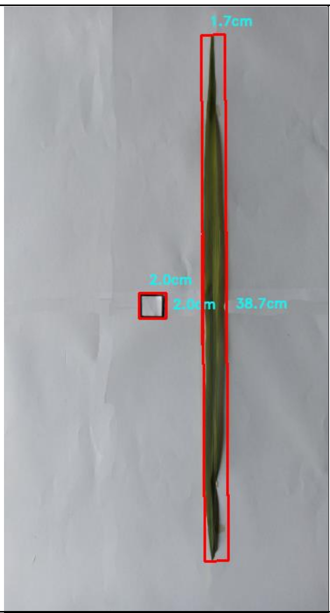
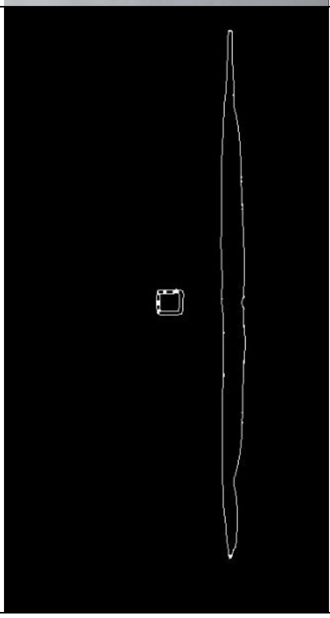
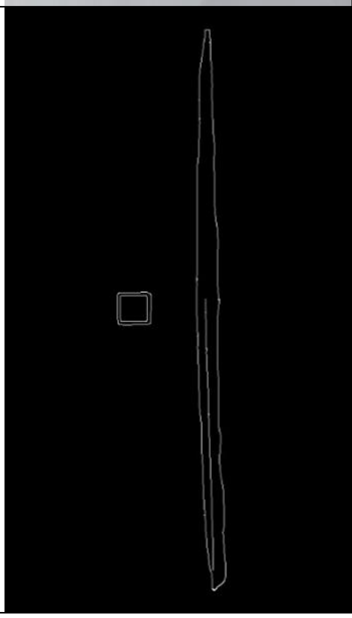
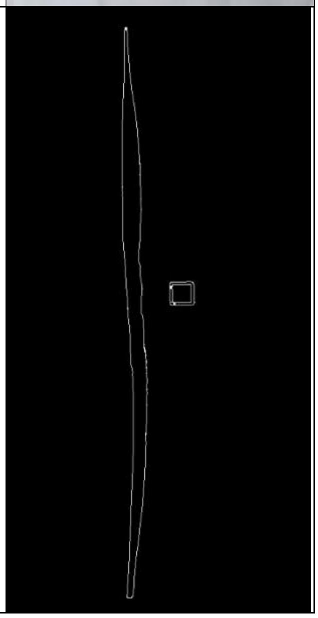


Figure 3. Flow of research process using canny edge detection

4 RESULT AND DISCUSSION

In taking the results, the researcher conducted three measurement methods. Canny edge detection as an image method with python language base, ImageJ software version 1.65g with java programming base. To compare the accuracy of the two methods, we used the third method, namely the conventional method through measurement using millimeter block paper. In the results listed in Table1, the smallest value of LAI produced by the canny method is 44.33 cm^2 while the largest LAI value is 101.80 cm^2. The use of various sizes of leaves to help give validity to the accuracy of the two methods used, canny and ImageJ. While the largest LAI size when using millimeter blocks is 102.9 cm^2 and the smallest LAI size is 47.4 cm^2. For differences in images visualized through canny edge detection can be seen through Table 1.

Table 1. Edge tracking with canny

RGB image with contour box			
Image edge tracking with canny			

Through the process in the figure in the research method, Table 1 is two results of the same image but at different stages of the process. In the first row, there is the result of the RGB image with the contour box and the result of the measurement through the canny edge detection method. The contour box used is red in color to contrast with the white background. In each experiment there is an auxiliary object, namely a box with a black border measuring 2 cm x 2 cm. This black box is used to help measure the overall object detected by the canny method. Through this 2 cm black box, the contour box will perform scale/pixel-based measurements so that the final result of the LAI measurement of the rice plant object can be found. While in the second row there are results that are still in the edge tracking stage, the final stage of the canny method has gone through the grayscale stage to thresholding. This process causes the white image to be only the edge of the object in the image.

To make a comparison of the canny method, researchers used ImageJ as software that is generally used to measure the area of an object including measuring the LAI of plants. In Figure 4, there is one of the measurement results through ImageJ, the difference that can be seen through the final result image is a binary image of an object whose color is different from the overall background. In the process of detecting an object area, ImageJ will make a value of.

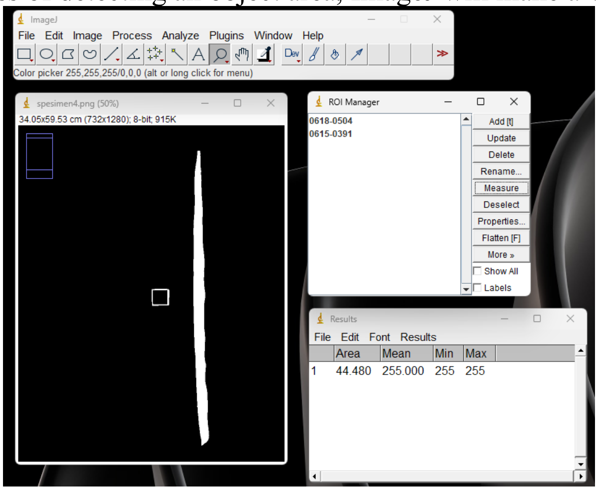


Figure 4. Use of ImageJ application for comparison

In measuring LAI, researchers used three measurements, namely the canny edge detection method, ImageJ software, and manual measurement through millimeter blocks. To find out the error of the two measurements (canny and ImageJ) against the millimeter block listed in Table 2. the error acquisition formula is used through the following equation (7):

$$error = \frac{manual\ measurement - method\ measurement}{manual\ measurement} \times 100\ \% \quad (7)$$

The size used as an LAI measurement object has many variations, through conventional measurements the smallest size is 47.4 cm^2 and the largest size is 102.9 cm^2. In order to take pictures, light is needed, the light value obtained is 18k to 20k lux. The smallest error obtained from the canny method measurement against the manual is 1.10%, while the largest is 6.68%. Through ImageJ software, the smallest error result is 2.92% while the largest is 8.71%. Table 2 lists the overall results through the experiment either through Image J software or canny edge detection.

Table 2. Overall experiment

Lux	**Measurement (cm)**			**Error**	**Error**
	Canny (C)	**ImageJ (I)**	**Manual (M)**	**(C-M)**	**(I-M)**
20k	101.8	99.23	102.9	1.10%	3.67%
19k	44.33	44.48	47.4	3.07%	2.92%
20k	75.54	75.17	78.1	2.56%	2.93%
18k	53.85	53.13	57.8	3.95%	4.67%
20k	68.11	67.21	71.9	3.79%	4.69%
20k	81.22	79.19	87.9	6.68%	8.71%
19k	54.37	53.22	59.3	4.93%	6.08%
18k	91.23	92.15	95.8	4.57%	3.65%
18k	65.39	65.16	68.6	3.21%	3.44%
Average Error				**3.76%**	**4.53%**

After doing several experiments, the average error obtained is not far adrift. The average error value obtained by the canny method is smaller at 3.76% while the error value obtained through ImageJ is 4.53%. For the median error value obtained through both measurement techniques, namely canny 3.79% and ImageJ 3.67% as listed in Table 2.

5 CONCLUSION

The conclusion obtained through the test results and analysis that has been done is that the canny edge detection method and ImageJ software are able to provide the LAI value of the rice plant object. The whole method involves a camera for image capture, sunlight, and millimeter blocks as conventional measurements. The application of canny edge detection has a smaller average error compared to ImageJ software. The average value given from the canny method is 3.76% while in ImageJ it is 4.53%. Considering that the measurement of LAI values is influential in measuring physiological parameters such as photosynthesis, transpiration, and biomass production. The canny method can be an alternative to measuring LAI values on rice plant leaves in addition to ImageJ software and conventional measurements through millimeter block pap.

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