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Application of UAV data to assess damage intensity of bacterial leaf blight disease on rice crop in Indonesia

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Abstract.

The Government of Indonesia launched the agricultural insurance program in 2016. The current method is to inspect the damage with the human eyes of specialists having experience. This method, however, costs much and is difficult to estimate disease-infected fields precisely in a wide area. With this background, we conducted research on the development of a new method using UAV data for the evaluation of damage intensity caused by bacterial leaf blight (BLB) in West Java, Indonesia.

During the time between the dry season of 2019 and 2020, damage assessment of BLB was conducted by damage assessors using the current assessment method. UAV imagery was acquired using the sequoia camera before assessing BLB by damage assessors. The ortho-mosaic images were created and then the normalized reflectance value was calculated for a green band, red band red-edge band and near-infrared band. The relationships between Ngreen, Nred, N red-edge, NNIR, NDVI, GNDVI, RGI and the BLB damage assessment result by the damage assessor were analyzed to derive the estimation equation of BLB damage assessment. Comparing the correlation coefficient before and after normalization of the reflectance, all the correlation coefficients between normalized reflectance and BLB damage intensity were higher than before the normalization of the data. The evaluation result shows a positive correlation with the reflectance of Nred of which values are 0.72 (significant at 1% level).

Our results indicate the possibility of developing a new damage assessment method that could realize a more effective BLB evaluation by integrating drone data into the current method and utilizing the integrated data.

Keywords.

agricultural insurance, damage assessment of pests and diseases, adaptation to climate change, food security, UAV data

1. Introduction

The Indonesian government launched an agricultural insurance program in 2016. An essential part of agricultural insurance is damage assessment, which must be done accurately, quickly, and inexpensively. Currently, the damage is inspected by experienced and expert human eyes. Agricultural insurance payments in Indonesia are not based on yield loss. In other words, the current method of assessing rice damage in West Java, Indonesia, does not use yield data for the assessment method but instead uses visual damage assessment by a damage assessor called a pest observer. The pest observer first visually evaluates the number of buds, the color and appearance of leaves, and the ears' condition and then determine the degree of damage based on the results. Specifically, three paddy fields are selected as sampling plots on a diagonal line covering an area of approximately 10 to 20 ha, and ten clumps are visually observed in each plot and evaluated in light of six damage grades. One pest observer is assigned per district to assess approximately 5,000 to 10,000 hectares.

Many reports of studies use remote sensing data to detect crop diseases. In a study using ground-based observation data, the risk of blast disease development was evaluated using satellite data (C. Hongo *et al.*, 2015). It was reported that there is a high relationship between the intensity of BLB infection and reflectance in the near-infrared and short-wavelength infrared regions (B. Singh *et al.*, 2012) and that the difference in reflectance between healthy and BLB-infected rice plants is significantly different in the 770-860 nm and 920-1050 nm wavelength bands (C. M. Yang, 2010). Studies using aircraft and UAV observation data have also reported that it is possible to evaluate the severity of BLB and rice blast disease (B. Singh *et al.*, 2012) (T. Kobayashi *et al.*, 2016). However, BLB research using remote sensing data is still scarce, and there are no such previous studies in Indonesia.

Therefore, we conducted a study on developing a new damage assessment method using UAV data to see if remote sensing data can be used to assess BLB damage, using West Java, Indonesia, where severe BLB damage occurs every year, as the study site. This report provides a summary of our study results.

2. Methodology

2.1 Study area

The study area was situated at lat. 6°50′S. and long. 107°16′E in the Cihea irrigation district, northeast of Cianjur, West Java, Indonesia. The climate in this region is temperate throughout the year because of the tropical climate near the equator. It has both a dry season (April to August) and a rainy season (November to March of the following year). Rice plantings are performed two to three times a year. This area is a large-scale irrigation area with an area of more than 7,800 ha, and the BLB occurrence at a certain point is carried to the downstream area by irrigation water and spreads to the entire area, causing severe damage every year.

2.2 On-site field investigation data

BLB damage assessment data were obtained in 2019 and 2020 by pest observers according to the current assessment methodology in Indonesia. BLB damage assessments and damage intensity calculations were performed using the following steps. First, three paddy plots were selected for sampling on the diagonal of the assigned study area. Ten clumps in each selected plot were visually evaluated by a pest observer. BLB damage intensity was determined according to six grades: 0 = 0%, 1 = 1-20%, 3 = 21-40%, 5 = 41-60%, 7 = 61-80%, and 9 = 81-100%. Finally, the BLB damage intensity was calculated by entering the determined damage intensity for each agglomerate into the following equation

$$\text{BLB damage intensity (\%)} = (n\_1 + n\_2 + ... + n\_10) / (9 \times 10)$$

n: BLB damage degree of each clump using six grades

2.3 UAV data

Aerial photography was conducted using the Sequoia camera, which has observation wavelength bands in the visible and near-infrared regions. The ground altitude was 50-60 m, and the overlap and sidelap rates were both 80% or higher. In addition, due to local solar altitude conditions, the UAV shoot was conducted between 9:00 and 10:00 AM or between 14:00 and 15:00.

2.4 Data analysis procedure

First, the images acquired by the UAV were imported into the SfM-MVS software to create an orthomosaic image. Next, a geometric correction was performed to overlay all UAV images. After executing the geometric correction, the reflectance of each observation band was converted to normalized reflectance using the following equations.

$$\mathrm{r_0} = \frac{\mathrm{Green} + \mathrm{Red} + \mathrm{Red\ edge} + \mathrm{NIR}}{4} \qquad (1)$$

$$\mathrm{Ngreen} = \frac{\mathrm{Green}}{\mathrm{r_0}} \qquad (2)$$

$$\mathrm{NRed} = \frac{\mathrm{Red}}{\mathrm{r_0}} \qquad (3)$$

$$\mathrm{NRed\ edge} = \frac{\mathrm{Red\ edge}}{\mathrm{r_0}} \qquad (4)$$

$$\mathrm{NNIR} = \frac{\mathrm{NIR}}{\mathrm{r_0}} \qquad (5)$$

The band-normalized reflectance for each of the BLB assessment points surveyed by the pest observers was extracted. Multiple regression analysis was performed on these, along with the NDVI, GNDVI, and NRGI (Red edge multiplied by Green edge Index) indices, to develop an equation for estimating BLB damage intensities. The accuracy of the estimation was verified by 10-fold cross-validation.

3. Results and Discussion

The relationships between Ngreen, Nred, N red-edge, NNIR, NDVI, GNDVI, RGI and the BLB damage assessment result by the damage assessor were analyzed to derive the estimation equation of BLB damage assessment. The correlation coefficients between each band reflectance and each index and BLB damage degree before and after the normalization treatment were analyzed. The correlation coefficients with and without normalization treatment are shown in Table 1. The results show that for all each band reflectance and each index, the correlation coefficients were higher with the normalization treatment applied. In particular, correlation coefficients exceeded 0.8 for the red and near-infrared bands after the normalization of the 2019 acquisition UAV data, suggesting that this index is helpful for estimating BLB damage degree in addition to NDVI.

Table1 Correlation coefficient between BLB damage degree and each band and index

year	Normalization	Green	Red	Red edge	NIR	NDVI	GNDVI	RGI
2019	without	0.343*	0.765**	0.049	-0.573**	-0.841**	-0.797**	0.173
	applied	0.530*	0.852**	-0.02	-0.786**			0.562**
2020	without	0.641**	0.639**	-0.530*	-0.436**	-0.607**	-0.629**	0.148
	applied	0.692**	0.620**	-0.741**	-0.555**			0.474**

The result of the analysis shows a positive correlation with the reflectance of Nred of which values are 0.72 (significant at 1% level) (Fig.1). The BLB symptoms show the following progression: first, the edge of the leaf near the leaf tip becomes yellowish green; the leaf edge then gradually yellows; as the disease progresses, the yellow part changes to yellowish-white and finally becomes white. In case of serious disease, the leaf is dehydrated and curls up. It acquires a straw-like color, and after losing all color, finally withers (Encyclopedia Britannica, 2020). A negative correlation was obtained between the Nred, which is the absorption band of chlorophyll, and SPAD values(Konica Minolta Chlorophyll Meter SPAD-502Plus) (Fig. 2). The result suggests that the reason for the high correlation between the Nred and BLB damage degree is that the chlorophyll decreased with increasing damage intensity, resulting in differences in leaf color.

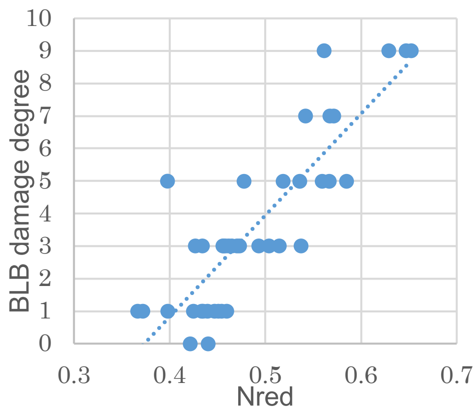


Fig.1 Relationship between NRed and BLB damage degree

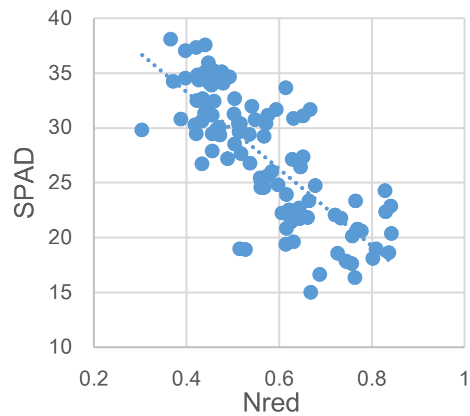
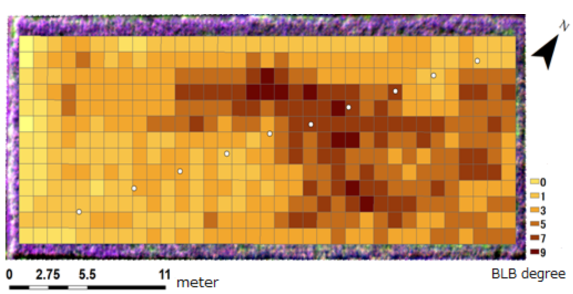


Fig.2 Relationship between NRed and SPAD value

As a result of analyzing the BLB damage degree and UAV data, it is considered that the damage assessment result of the pest observer by visual inspection can be expanded more widely by using the UAV data. Therefore, the following formula for estimating the BLB damage degree was obtained from the normalized red band data.

$$\text{BLB damage degree} = 31.228 * \text{Red band} - 11.67$$

After that, the BLB damage intensity was calculated by substituting the BLB damage degree estimation result into the formula for calculating the damage intensity. The resulting visualization map is shown in Figure 3.



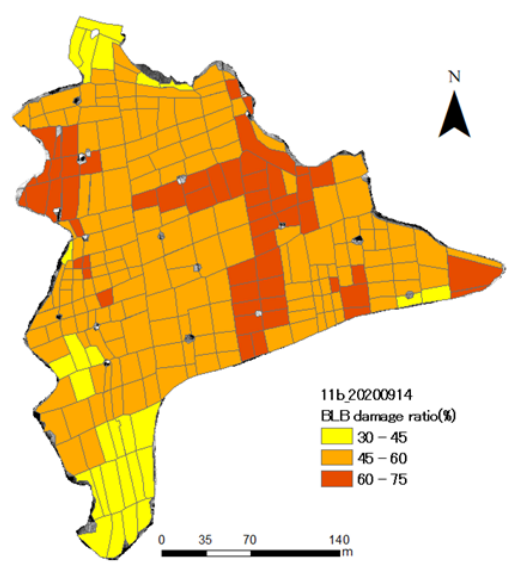


Fig.3 Map of bacterial leaf blight (BLB) damage degree (left) and BLB damage intensity (right)

Our results indicate the possibility of developing a new damage assessment method that could realize a more effective BLB evaluation by integrating drone data into the current method and utilizing the integrated data.

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