Basal Stem Rot (BSR) Detection Using Textural Analysis of Unmanned Aerial Vehicle (UAV) Image

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***Abstract*—Basal Stem Rot (BSR) disease is one of the most destructive diseases affecting oil palm plantation in Malaysia. The first critical step for a successful control of BSR is its detection and diagnosis. This study presents a new approach of high spatial resolution aerial Red, Green, Blue (RGB) image for BSR detection using a low-altitude remote sensing Unmanned Aerial Vehicle (UAV) platform. The co-occurrence measures for textural analysis were performed to the RGB band to determine the best parameter for BSR detection. Descriptive statistical as well as One way ANOVA were executed to indicate which bands are giving significant level (p<0.05). Apparently, the test gave three significant properties which are Correlation taken from R, G and B band. The developed conditional statement of detection was tested for distinguishing between healthy and BSR-infected trees. Total accuracy acquired for healthy trees was 86.21% whereas for BSR-infected trees was 75.00%. Hence, average accuracy assessment was 80.61%.**

Keywords—image, texture, disease, canopy.

I. INTRODUCTION

Basal Stem Rot (BSR) disease is caused by species of Ganoderma. It is the only pathogenic disease causing serious losses of field palms in South-East Asia [1]. It is a major problem of oil palm plantation in Malaysia, Indonesia and affects the subsequent economic loss. There are no doubts about the economic importance of BSR disease which will continue to be problematic in absence of adequate control measures. The disease can result in death to 80% of plantings by half of the normal economic life, and losses reaching 50% have frequently occurred. Effects on yield reduction may occur from death of palms and reduced yield from standing palms [2].

There are several specific symptoms that indicate the strong probability of such disease prevalence in oil palm including wilting the green fronds and hanging downward, converting the fronds colour from green to yellow [3, 4], reducing the fronds production that causes small size of canopy [5] and finally basidiomata existence on the trunks [6, 4].

Textural analysis by using UAV images could be a tool to evaluate the pathological conditions of plants and in detecting an invisible disease in plants. Using human eye to detect BSR could only lead to more severe deaths of oil palm plantation because some of the pathological effects of BSR will only be seen at later stage or in some cases it could not be seen at all.

This study explores the use of textural analysis from imagery acquired by RGB camera mounted on the UAV for BSR detection in oil palm trees. It will provide a new benchmark in evaluating the use of technology since this technique has never been applied before. The main objective of this study is to detect BSR using textural analysis of UAV image. The specific objectives of this study includes to determine the specific textural properties of canopy image for BSR detection and to develop suitable model of BSR detection.

II. MATERIALS AND METHODS

A. Study area

The focus of this study was to detect BSR in oil palm tree by textural analysis of images taken using UAV. This study was done at oil palm plantation located at Seberang Perak, Perak. A total of 117 samples of oil palm trees with the age of 9 years old were used. The samples were categorised according to its severity level, which are T1 (Healthy palm, no foliage symptom (0%), no fruiting body), T2(Mild infection, no foliage symptom (0-25%), produce fruiting body), T3(Moderate infection, produce foliage symptom (25-50%), fruiting body) and T4(Severe infection, produce foliage symptom (50-75%) and fruiting body). The result and discussions onwards will be based on this severity level of trees. The severity level of BSR infection of trees was identified based on the visual symptoms by the expert from Malaysia Oil Palm Board (MPOB).

B. Image acquisition

The Turnigy 9XR Octocopter UAV as shown in Figure 1 was used as an image acquisition platform in this study. The UAV fly at 50m altitude above the oil palm tree for 25 minutes per full charged of battery (Figure 2). Comparatively, UAV image will give better result in term of spatial resolution than satellite image.

Figure 1: Turnigy 9XR Octocopter UAV.

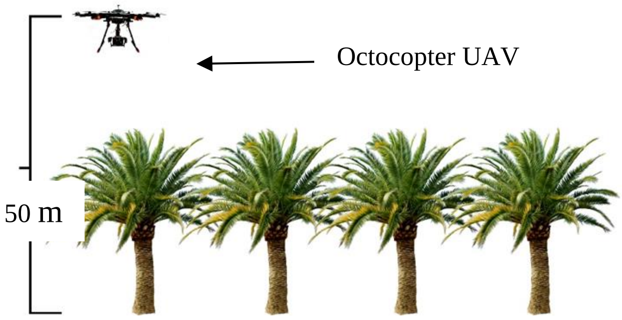
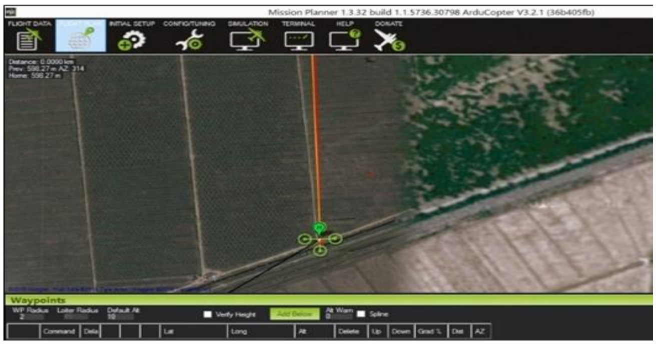
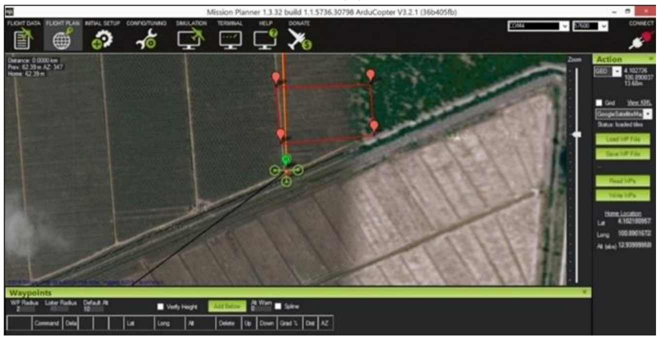


Figure 2: Illustration diagram of flying UAV.

Figure 3 shows steps involved in creating waypoints using a Mission Planner software. First, a Mission Planner software was opened in a laptop and the flight plan feature was shown as in Figure 3 (a). After the exact location has been detected, a polygon with four vertices that represent the working area was drawn in a map (Figure 3 (b)). Survey (Grid) was added by clicking right button of mouse and selecting a survey (grid) → Auto Waypoint (WP) as shown in Figure 3 (c). The number of auto waypoint is actually depending on how big polygon has been drawn. The bigger area means, more WP will be generated. After fixing all flying data eg: Takeoff, Waypoint, Altitude, etc., the 'Write WPs' and 'Read WPs' button were then clicked to enable system to read navigation waypoint of vehicle for flying.



(a)



(b)

(c)

Figure 3: Creating waypoints using a Mission Planner software.

C. RGB camera

The Canon PowerShot SX240 HS (Figure 4) was used to acquire image of the canopy. It has 12.1 MP CMOS and three optically separated spectral bands in the visible spectrum which are R (570-690nm), G (480-580nm), and B (400-500nm).

Figure 4: Canon PowerShot SX240 HS camera.

D. Software

The process of registering image, build up Region of Interest (ROI) and performing co-occurrence textural measures was done by utilizing ENVI software. ArcMap software was used to georeference ROI image to registered image. Therefore, the control points were maintained. Besides, shapefile (vector) was created by using ArcMap to overlay with textural data in .tiff format. The process is called digitizing canopy of oil palm trees into vector polygon. ArcMap also platform to zonal texture data and to display attribute table before it being converted into excel file.

E. Image Analysis

Co-occurrence measures of textural analysis were done by applying the texture filters to the co-occurrence matrix. These filters include mean, variance, homogeneity, contrast, dissimilarity, entropy, second moment, and correlation defined as follows:

Mean: The local mean value of the processing window.

Variance: The local variance of the processing window. This value is based on the **Greyscale Quantization Level** that had been specified.

$$f_4 = \sum_i \sum_j (i-u)^2 \, p(i,j) \quad (1)$$

Homogeneity: ENVI computes homogeneity using the "inverse difference moment" equation. Values range from 0 to 1.0.

$$f_5 = \sum_i \sum_j \frac{1}{1+(i-j)^2} p(i,j) \quad (2)$$

Contrast: ENVI computes contrast using the following equation:

$$f_2 = \sum_{n=0}^{N_g - 1} n^2 \left\{ \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} p(i,j) \right\}_{|i-j|=n} \quad (3)$$

Dissimilarity: ENVI computes dissimilarity using the absolute values of the greyscale differences:

$$f = \sum_{n=1}^{N_g - 1} n \left\{ \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} p(i,j)^2 \right\}_{|i-j|=n} \quad (4)$$

Entropy: ENVI computes entropy using the following equation. Values range from 0 to the *alog* of the processing window size.

$$f_9 = -\sum_i \sum_j p(i,j) \log(p(i,j)) \quad (5)$$

Second Moment: ENVI uses the "angular second moment" equation. Values range from 0 to 1.0.

$$f_1 = \sum_i \sum_j \{p(i,j)\}^2 \quad (6)$$

Correlation: ENVI computes correlation using the following equation. Values range from -1.0 to 1.0.

$$f_3 = \frac{\sum_i \sum_j (ij) p(i,j) - \mu_x \mu_y}{\sigma_x \sigma_y} \quad (7)$$

III. RESULTS AND DISCUSSION

A. Samples

This section presents results for canopy textural analysis. For canopy textural measures, mean value of each band were extracted. After that, all data were sorted accordingly to its severity level. The study area was divided into 2 parts i.e. Part A (model development) and part B (model validation). Table 1 shows number of oil palm trees sorted accordingly to its severity level. For Part A image, in total, there were 84 oil palm trees with 73 samples of T1, 3 samples of T2, 4 samples of T3 and 4 samples of T4. As for model validation (Part B), there were 33 oil palm trees in overall. These 33 samples comprises of 29 samples of T1, 3 samples of T2 and 1 samples of T3.

Table 1: Number of tree based on different severity level in Part A and Part B image

Severity Level	Part A	Part B
T1	73	29
T2	3	3
T3	4	1
T4	4	0
Total	84	33

B. Image Analysis

All recorded GPS data were used as input in order to ensure each single image is correctly arranged. The more overlapping area with at least 30% of image width is preferred in order to get an accurate mosaicked image. After that, the mosaicked image was opened in ENVI software, followed by the process of image registration by defining its coordinate system. Thus, it had georeference framework. The Universal Transverse Mercator (UTM) WGS 1984 zone 47 was used as spatial reference system in this study.

Then, a ROI was created within interested working area that are going to be analysed. This ROI was saved as new image in .tiff format. Image of Part A is shown in Figure 5.

Figure 5: Image of Part A based on ROI save in .tiff format

Figure 6 shows digitized image of part A. Polygon representing trees had been created properly so that there's no overlapping condition between polygons. Therefore, the number of digitized vector polygon is exactly the same as the number of samples. Basically, each separated polygon contain information of ID number, area in square metre, minimum value, maximum value, mean value, standard deviation and summation of textural properties.

Figure 6: Digitized image for Part A.

The result gained from one way analysis of variance (ANOVA) shows that three textural parameters gave significant result ($p<0.05$), meaning that, these bands are able to classify oil palm trees into its level of severity effectively. Those textural properties that give significant result with level of confidence more than 95%. There are Red Correlation (0.006 level of significant), Green Correlation (0.004 level of significant) and Blue Correlation (0.003 level of significant). Other textural properties have not meet desired level of significant.

Table 2: ANOVA result for textural analysis of Part A Image

		Sum of Squares	df	Mean Square	F	Sig.
RED CORRELATION	Between Groups	.018	3	.006	4.522	.006
	Within Groups	.105	80	.001		
	Total	.122	83			
GREEN CORRELATION	Between Groups	.018	3	.006	4.891	.004
	Within Groups	.099	80	.001		
	Total	.118	83			
BLUE CORRELATION	Between Groups	.022	3	.007	5.088	.003
	Within Groups	.113	80	.001		
	Total	.134	83			

To prove ANOVA result, a post-hoc test was then be executed. The result shows that three bands are capable to distinguish data of severity level into different class. Red Correlation perform well in differentiating class of T2 (Mild Infection) from T1, T3 and T4 as shown in Table 3. At the same time, Green Correlation as well as Blue Correlation performed best in isolating T2 from T1, T3 and T4 as presented in Table 4 and Table 5, respectively. This post-hoc test used Harmonic Mean Sample Size = 4.722.

Although Duncan test in post-hoc shows that T1 is in the same class with T3 and T4, but these healthy trees seem possibly be classified from those level BSR-infected trees by using certain threshold range value for each severity level. Means, the gap between heathy tree, T1 and BSR-infected tree level 3 and level 4 have quite a narrow value of difference. For instance, range of T1 in red correlation texture is below 0.30000 whereas T3 and T4 have greater value which are 0.315821 and 0.321294 respectively. Thus, it can be concluded that although T1 is misclassified into group of T3 and T4, but it still can be distinguished by its range value for these three texture properties.

Since the severity of T3 and T4 is high and it gave quite clear physical symptom as compared to T2. That's why it is grouped into different class. This is probably due to several specific symptoms that indicate such disease critically sick in T3 and T4 which causing more wilting the green fronds and hanging downward, converting the fronds color from green to yellow [3, 4], reducing the fronds production that causes small size of canopy [5]. All these physical symptoms that have been mentioned above just start happen to T2 and its effect still not obvious as disease when the severity level of infection is around 8% attack only in plant roots.

Table 6 shows the range of textural properties for each severity levels fixed based on its statistical analysis. The possibility of this range to detect and classify BSR into its severity level are then tested using Part B image.

Table 3: POST-HOC TEST OF RED CORRELATION

Duncan[a,,b]

		Subset for alpha = 0.05	
CONDITION	N	1	2
T2 (Mild Infection)	3	.229166	
T1 (Healthy)	73		.288922
T3 (Moderate Infection)	4		.315821
T4 (Severe Infection)	4		.321294
Sig.		1.000	.199

Table 4: POST-HOC TEST OF GREEN CORRELATION
Duncan[a,,b]

CONDITION	N	Subset for alpha = 0.05	
		1	2
T2 (Mild Infection)	3	.256605	
T1 (Healthy)	73		.308601
T3 (Moderate Infection)	4		.343447
T4 (Severe Infection)	4		.345585
Sig.		1.000	.132

Table 5: POST-HOC TEST OF BLUE CORRELATION
Duncan[a,,b]

CONDITION	N	Subset for alpha = 0.05	
		1	2
T2 (Mild Infection)	3	.223785	
T1 (Healthy)	73		.292819
T3 (Moderate Infection)	4		.320509
T4 (Severe Infection)	4		.325186
Sig.		1.000	.217

Table 6: Range value for each model in different severity level.

Model	Severity level	Standard deviation	Lower bound	Upper bound
Red	**T1**	0.0357349	0.2533	0.3247
	T2	0.0306744	0.1983	0.2597
	T3	0.0293763	0.2856	0.3444
	T4	0.0526157	0.2664	0.3716
Green	**T1**	0.0332193	0.2758	0.3422
	T2	0.0273148	0.2317	0.2863
	T3	0.0304829	0.3205	0.3815
	T4	0.0722886	0.2907	0.4353
Blue	**T1**	0.0375248	0.2555	0.3305
	T2	0.0237097	0.2013	0.2487
	T3	0.0268202	0.2962	0.3498
	T4	0.0524068	0.2766	0.3814

C. Validation

The range tabulated in Table 6 has been tested to detect BSR and its severity level in Part B image. The results are tabulated in Table 7. Based on the results, only 21 samples from T1 were within correct range of Red correlation. Meanwhile, Green correlation shows that 16 samples from T1, 1 sample from T2 were lies within correct threshold value. At the same time, Blue correlation finds 19 samples of T1 and 1 sample of T3 were within the right threshold. Therefore, in summary, the Red correlation attained 24.14%, Green correlation attained 29.5% and Blue correlation attained 55.17% of accuracy.

Table 7: Accuracy assessment for severity level detection

Severity Level	Red Correlation	Green Correlation	Blue Correlation
T1	21/29 = 72.41%	16/29 = 55.17%	19/29 = 65.51%
T2	0/3 = 0%	2/3 = 66.67%	0/3 = 0%
T3	0/1 = 0%	0/3 = 0%	1/1 = 100%
Average Percentage	24.14%	60.92%	55.17%

Regardless severity level of BSR, the detection model was tested to categorize between healthy and BSR-infected tree by considering all of the three textural properties. The conditional statement that associated to this test tell that if the sample have mean values that lies within threshold at least in one textural properties, it was identified as correct detection. Summary of the result is shown in Table 8. It shows that the developed conditional statement is capable to differentiate between healthy and unhealthy with percentage of 86.21% and 75.00%, respectively.

Table 8: Accuracy assessment to distinguish healthy and BSR-infected trees

	Sample of tree	Percentage	Total percentage of accuracy
Healthy tree	25/29	86.21%	$\frac{86.21\% + 75.00\%}{2} = 80.61\%$
BSR-infected tree	3/4	75.00%	

IV. CONCLUSIONS

In this study, the potential of textural analysis for BSR detection in oil palm trees by using UAV image was assessed. The results has shown that the severity level of BSR in oil palm tree can be classified using Red Correlation, Green Correlation and Blue Correlation texture as tested by ANOVA. Through Duncan test, T2 can be distinguished from

T1, T3 and T4 in one class. High accuracy can be gathered from the developed model using combined Red Correlation, Green Correlation and Blue Correlation. It can differentiate between healthy and BSR-infected trees with the average total accuracy gained of 80.61%.

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