

Identification of *Ganoderma boninense* Infection Levels on Oil Palm Using Vegetation Index

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ABSTRACT

Basal stem rot (BSR) is known as a deathly disease in oil palm. It can immediately cause a significant decrease in the population of oil palm per hectare. BSR is associated with infection of *Ganoderma boninense*. The identification of infected palms at an early stage is the key to control the disease. Manual identification by observing an individual palm in the field is the most common method; however, it is time consuming as well as laborious and expensive. A faster, less laborious, and less expensive method is by analyzing multispectral aerial photograph from unmanned aerial vehicle (UAV). A study to test this method was conducted in an oil palm plantation in Batubara region, North Sumatera. The plantation was acknowledged as an endemic area of *G. boninense*. The objectives of this study were to identify levels of *G. boninense* infection in oil palm based on spectral difference by counting the vegetation index from the multispectral image of UAV and mapping the distribution of BSR infection. Four methods were used to transform vegetation index, i.e. simple ratio (SR), normalized different vegetation index (NDVI), enhanced vegetation index (EVI) and atmospherically resistance vegetation index (ARVI). The results show that the index transformation of SR, NDVI, EVI and ARVI was able to identify the infection level of *G. boninense*.

Keywords: basal stem rot, multispectral image, soil-borne pathogen, unmanned aerial vehicle

INTRODUCTION

Basal stem rot (BSR) disease caused by infection of *Ganoderma boninense* has been threatening the sustainability of palm oil industry in Indonesia (Susanto 2013). Incidence of BSR had been reported in Sumatera, Kalimantan, Java, Sulawesi and Papua

(Susanto 2009). In addition, BSR is often associated with low palm yield (Assis *et al.* 2016) and the decreasing number of palm tree per hectare. *Ganoderma boninense* is a soil-borne pathogen, as it attacks oil palm starting from the roots system and quickly spreads to plant tissues in the stem and other plant organs (Cooper *et al.* 2011; Assis *et al.* 2015). Furthermore,

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rotting stem tissues will cause disorder in nutrients and water absorption. External symptoms are early leaves senescence, smaller size of fruits and collapsed palm trees (Mih & Kinge 2015). In general, *G. boninense* is more common infecting oil palm in a replanting area (Flood et al. 2005).

Methods to control *G. boninense* have involved agronomic practices (Prasetyo et al. 2008; Chung 2011), bio-agents (Susanto et al. 2005; Shamala & Idris 2009) and chemical materials (Bivi et al. 2016; Prasetyo & Susanto 2016). Though those various methods have been employed, the results are not totally effective yet. Usually, the main problem is failure in identifying the symptoms of *G. boninense* infection at an early stage. Success in detection of infection at an early stage is the key to control *G. boninense* (Hushiarian et al. 2013).

Conventional methods of early detection of *G. boninense* infection are generally conducted through visual observation and isolation of infected tissues (Ariffin & Idris 1992; Yanti & Susanto 2004), serology detection (Shamala et al. 2006; Madihah et al. 2014), molecular (Utomo 2002; Idris et al. 2003), tomography (Ishaq et al. 2014) and analysis of satellite imagery (Lelong et al. 2010; Tajudin et al. 2016). A large area of *G. boninense* infection could be quickly monitored using analysis of satellite imagery, compared to manual monitoring which is a slow and laborious process (Nasfariza et al. 2016). Vegetation index from Quickbird satellite imagery has been used to identify and to draw the map of BSR incidences in an oil palm plantation (Santoso et al. 2010), while Izzuddin et al. (2015) used airborne imagery for the similar objective. The use of satellite imagery is an extraordinarily potential method to identify the level of *G. boninense* infection. However, its analysis

is frequently hindered by cloud coverage which is common in tropical areas. As an alternative, unmanned aerial vehicle (UAV) can be used to mount multispectral sensors and then produce imagery data. The objectives of this study were to identify levels of *G. boninense* infection in oil palm based on spectral difference by counting the vegetation index from the multispectral image of UAV and mapping the distribution of BSR infection.

MATERIALS AND METHODS

Study Site

The study site is in Block 23, Dusun Ulu Estate, PT Perkebunan Nusantara III. It is located in Batubara Regency, North Sumatera at 99° 27' 42.985"-99° 27' 53.652" E and 3° 09' 55.373"-3° 10' 7.864" N. Oil palms in this site were planted in 2004, and they were 12 years old when the study was conducted.

Imagery Taking

For imagery taking, a DJI S900 hexacopter (DJI Innovation 2014) was employed during the study. Sensor attached in the UAV was Tetracam ADC-Lite multispectral camera (Tetracam Inc. 2017). The camera had three bands i.e. blue, red, and near infra-red, it was equal to wavelength of Landsat TM (thematic mapper) as shown in Table 1. Images were taken on February 3, 2016 at 150 m of flying altitude (www.tetracam.com 2018; landsat.usgs.gov 2018). The Tetracam ADC-Lite had 3.2 megapixel CMOS sensor (2048 x 1536 pixel), the optical parameters were

Table 1 The wavelength of Tetracam ADC-Lite camera

Band	Wavelength (nm)
Blue	450-520
Red	630-690
Near Infra-Red	760-900

fixed at a nominative focal length of 8.5 mm and an optical aperture of f/3.2.

Processing Data and Data Analysis

Pre-processing of imagery data consist of geometric and radiometric corrections. Geometric correction was conducted using ArcGIS software for connective points taken by GPS EPOCH 35 RTK, while radiometric correction was performed using ENVI software by calibrating reflectance image to reflectance black and white box. Vegetation index involving three bands (red, blue, near infra-red) was transformed after radiometric correction. The vegetation indices were simple ratio (SR), normalized different vegetation index (NDVI), enhanced vegetation index (EVI) and atmospherically resistance vegetation index (ARVI). The formulas of SR, NDVI, EVI and ARVI are presented in Table 2.

Visualisation of Level of *Ganoderma* Infection

Palm-by-palm individual census was conducted to evaluate level of *Ganoderma* infection. Visual symptoms of *Ganoderma* infection were observed on leaves and stems according to standard procedures from the Indonesian Oil Palm Research Institute and Santoso et al. (2017). There are five levels of *Ganoderma* infection, namely L0 (healthy plant/no symptoms), L1 (light symptoms), L2 (medium

scale symptoms), L3 (severe symptoms), and L4 (dead or collapsed tree). Criteria for each level are presented in Table 3.

The geo-spatial position of each individual plant and its level of infection (L0 to L4) was mapped using GPS EPOCH-35 RTK. The map was used to determine the accuracy of the identification method using transformation of vegetation index. The flow chart of the study is presented in Figure 1.

The accuracy of the method at each level was measured in two steps. First, absolute value of the difference (Δ) between number of infected trees determined by digital analysis (\sum Dig Anl) and by field observation (\sum Fld Obs) was calculated using the following formula:

$$\Delta = |\sum \text{Dig Anl} - \sum \text{Fld Obs}| \dots (1)$$

Then, the Δ was used to calculate the accuracy (Acu) using formula 2 below:

$$\text{Acu} = 100 - ((\Delta / \sum \text{Fld Obs}) \times 100) \dots (2)$$

Table 3 Criteria for levels of *Ganoderma* infection on oil palm (Santoso et al. 2017)

Level (code)	Criterion
Level 0 L0	Healthy plant, normal growth, perfect canopy.
Level 1 L1	Appearance of two spear leaves, or yellowing leaves, but rotting in the basal stem parts barely seen and palm still producing fruits.
Level 2 L2	Appearance of two or more spear leaves, yellowing leaves while new leaves growing smaller, early senescence on old leaves, frond fracture incidence, rotting on basal stem, palm still producing fruits.
Level 3 L3	Appearance of more than three spear leaves, frond fracture on most of the old leaves, yellowing leaves followed by necrosis, rotting on basal stem or appearance of <i>Ganoderma</i> fruiting body, no fruits in the palm.
Level 4 L4	Necrosis on all leaves or collapsed tree.

Table 2 Formula of vegetation index employed in the study

Vegetation index	Formula
Simple ratio (SR)	SR=NIR/R
Normalized different vegetation index (NDVI)	NDVI=NIR-R/NIR+R
Enhanced vegetation index (EVI)	EVI= 2.5 (NIR-R)/ (NIR+6R-7.5B+1)
Atmospherically resistant vegetation index (ARVI)	ARVI=NIR-(2R-B)/ NIR+(2R-B)

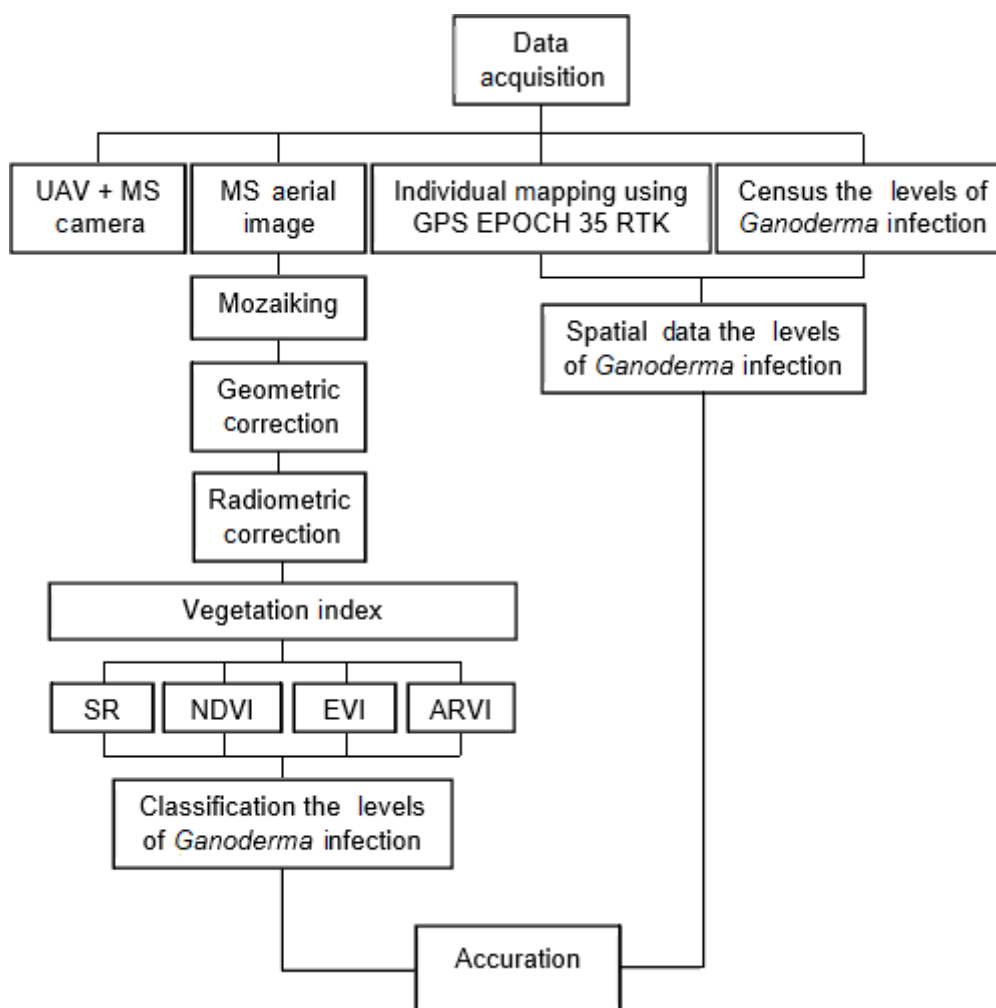


Figure 1 Flow chart of the study.

RESULTS AND DISCUSSION

Simple Ratio

SR transformation on each level of *Ganoderma* infection is presented in Table 4. In general, values of SR are distributed within the range of 0 to 1. Increase on SR values means the increase on the health level of the oil palm. SR values of 0.1 to 0.7 represent *Ganoderma* infection at level L1 to L4 (light to severe), while SR values of 0.8 to 1.0 represent healthy oil palm (L0). The similar results were reported by Izzuddin *et al.* (2015), where low and high positive SR values represent *Ganoderma* infection and healthy oil palm, respectively. Distribution of the SR values is presented in Figure 2.

Normalized Different Vegetation Index

The transformation of NDVI on each level of *Ganoderma* infection is presented in Table 5. NDVI values are distributed within the range of 0-1 and higher NDVI values represent higher level of infection. NDVI values of 0.19 to 1.0 represent *Ganoderma* infection of L1 to L4; on the other hand, NDVI values below 0.1 represent healthy palm. The results are similar to result of study by Izzuddin *et al.* (2015) who stated that low NDVI values indicate healthy palm and high NDVI values indicate an infection of *Ganoderma*. Distribution of the NDVI values is presented in Figure 3.

Table 4 The distribution of simple ratio values on each level of *Ganoderma* infection

Vegetation index	Level of <i>Ganoderma</i> infection				
	L0	L1	L2	L3	L4
Simple ratio	0.8-1.0	0.7-0.9	0.4-0.7	0.1-0.4	0.0-0.3

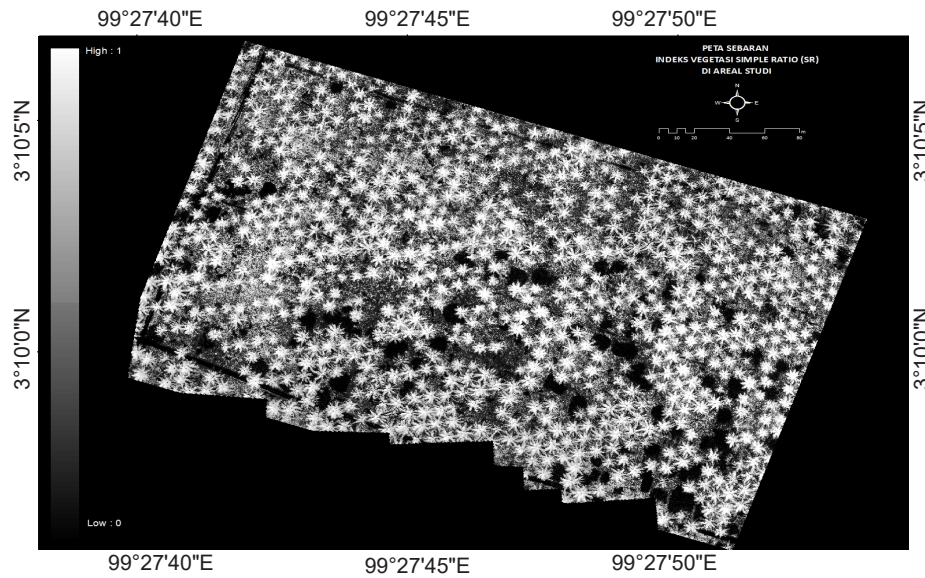


Figure 2 Simple ratio values in the study site.

Table 5 Distribution of normalized different vegetation index values on each level of *Ganoderma* infection

Vegetation index	Level of <i>Ganoderma</i> infection				
	L 0	L 1	L 2	L 3	L 4
Normalized different vegetation index	0-0.19	0.19-0.34	0.27-0.45	0.36-0.68	0.60-0.99

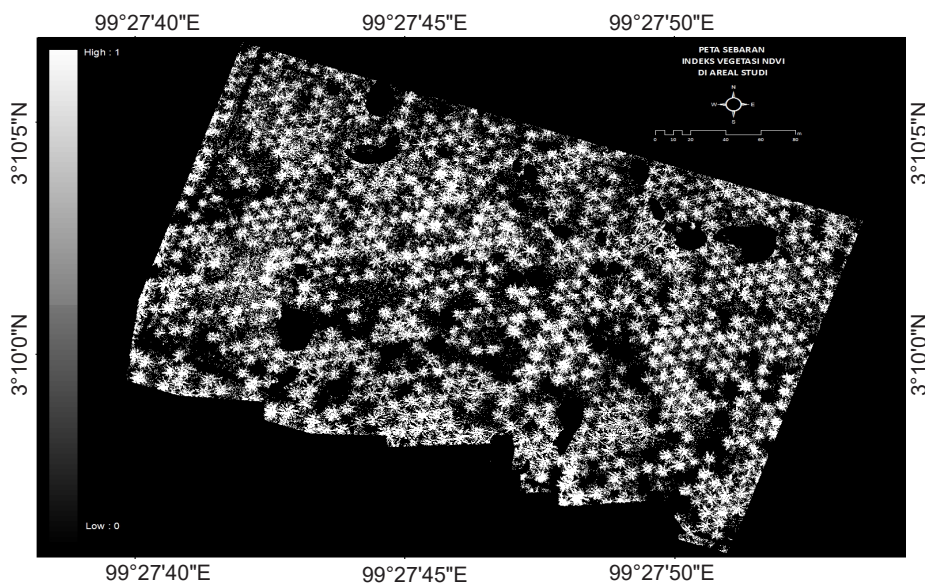


Figure 3 Normalized different vegetation index values in the study site.

Enhanced Vegetation Index

The transformation of EVI on each level of *Ganoderma* infection is presented in Table 6. The EVI values are distributed within the range of -0.38-2.49. Increase on EVI values indicates the decrease on palm health. EVI values of 1.49-2.46 represent *Ganoderma* infection at L1 to L4, while EVI values of 0.92-1.52 represent healthy palm. The distribution of the EVI values is presented in Figure 4.

Atmospherically Resistant Vegetation Index

The transformation of ARVI on each level of *Ganoderma* infection is presented in Table 7. ARVI values are distributed within the range of (-0.38)-2.49, and higher ARVI values mean higher level of *G. boninense* infection. The ARVI values of 0-0.05 represent healthy palm, conversely the ARVI values of 0.04-0.39 represent infection of *G. boninense* at L1 to

L4 (Table 7, Figure 5). Images character formed from transformation of SR, NDVI, EVI and ARVI on the five levels of *Ganoderma* infection are presented in Table 8.

Table 8 describes the level of *Ganoderma* infection by transforming vegetation index. At L0 (healthy plant), complete canopy appears on the image of vegetation index. When there is an increase on the level of infection, there will be a reduction on canopy in line with increment from L1 to L3. At L4, and the palm already collapses and canopy could not be identified.

Accuracy of The Method

Values obtained from transformation of vegetation index (SR, NDVI, EVI and ARVI) were compared to the values of infection level generated by individual census. From the comparison, it could be stated that the method to identify *Ganoderma* infection by transforming vegetation index is fairly accurate. The highest

Table 6 Distribution of enhanced vegetation index values on each level of *Ganoderma boninense*

Vegetation index	Level of <i>Ganoderma</i> infection				
	L 0	L 1	L 2	L 3	L 4
Enhanced vegetation index	0.92-1.52	1.49-1.89	1.79-1.94	1.92-2.32	2.12-2.46

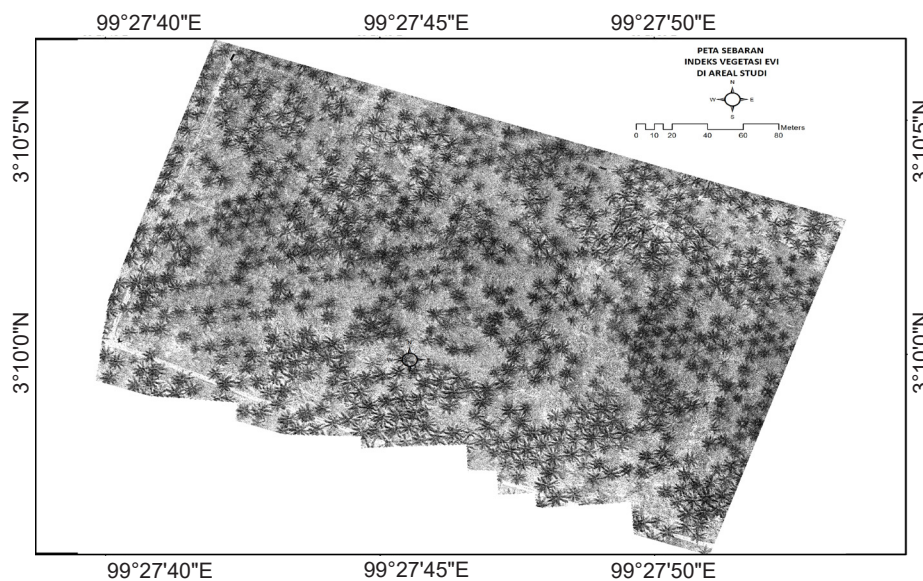


Figure 4 Enhanced vegetation index values in the study site.

and lowest percentage of accuracy was found by transforming SR and NDVI values, respectively. The results are similar to study by Izzuddin *et al.* (2015) who found that the accuracy of the method by transforming SR was higher than that by transforming EVI and NDVI. However, there is a little gap on the percentage of accuracy values resulted from the four vegetation indexes, which all are about 85% (Table 9).

The discrepancy between the two methods (transformation of vegetation index and manual census) might be related to the technique of interpretation. In the transformation of the vegetation index method, interpretation focuses on the palm canopy; therefore, some infected palms do not show the symptoms. The study by Breton *et al.* (2010) shows that 15% or more of oil palm did not show

external symptoms of *Ganoderma* infection, though there was a rotting process in the basal stem. In addition, Wening *et al.* (2016) reported that for 8 months, there were 26.15% of oil palm nurseries inoculated with *Ganoderma* that did not show any symptoms on leaves, though there were necrotic symptoms on roots and rotting on parts of basal stem. This technology would help in the implementation of survey on the severity of *Ganoderma* infection at a national level.

CONCLUSION

Vegetation index on the multispectral aerial photograph could help to identify the levels of *G. boninense* infection on oil palm. The highest percentage of accuracy was found by transforming SR. There is a little gap on the percentage of the

Table 7 Distribution of atmospherically resistance vegetation index values on each level of *Ganoderma* infection

Vegetation index	Level of <i>Ganoderma boninense</i> infection				
	L 0	L 1	L 2	L 3	L 4
Atmospherically resistance vegetation index	0-0.05	0.04-0.11	0.10-0.18	0.14-0.22	0.21-0.39

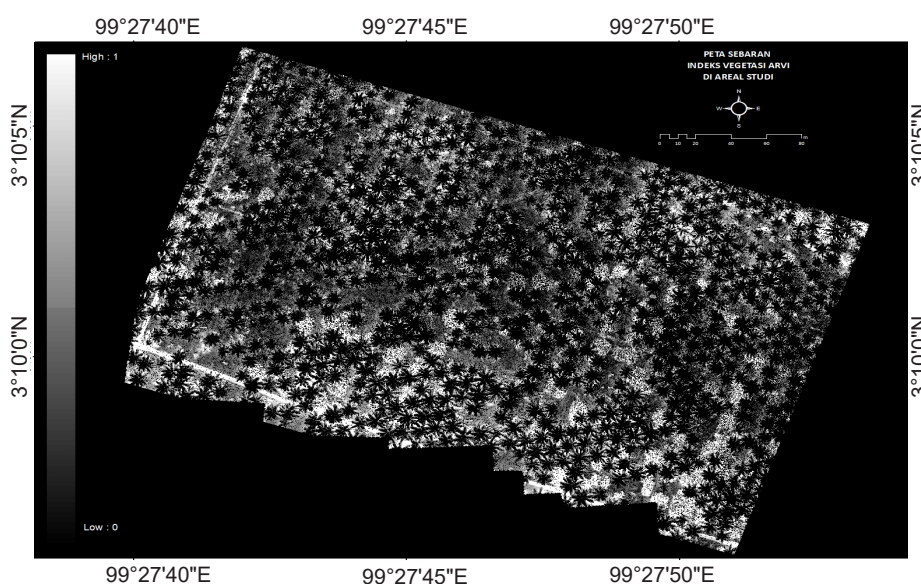


Figure 5 Atmospherically resistance vegetation index values in the study site.

Table 8 Character of the images formed from transformation of simple ratio, normalized different vegetation index, enhanced vegetation index and atmospherically resistance vegetation index on five levels of *Ganoderma* infection

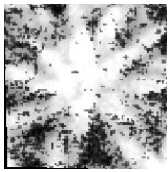

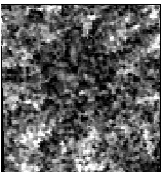

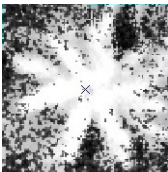
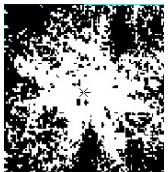
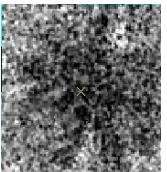
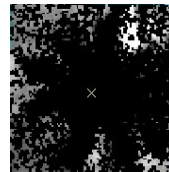
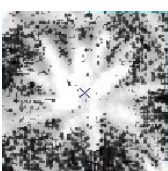
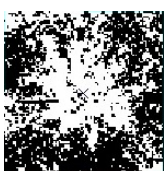
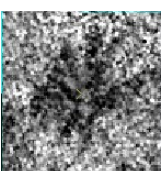
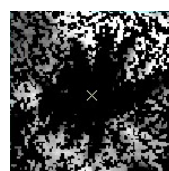
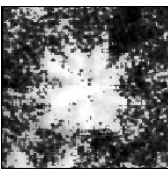
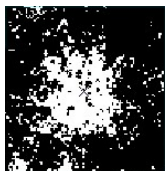
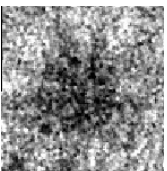
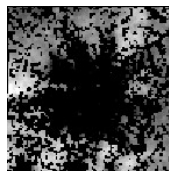



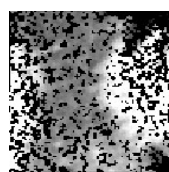
Level of infection	Vegetation index			
	SR	NDVI	EVI	ARVI
Level 0 Healthy palm				
Level 1 light				
Level 2 medium				
Level 3 severe				
Level 4 collapsed				

Table 9 Accuracy of method to identify *Ganoderma boninense* infection by transforming vegetation index compared to the individual census method

Level of infection	Accuracy (%)			
	SR	NDVI	EVI	ARVI
Level 0	85.2	85.2	85.2	86.1
Level 1	81.8	79.5	84.1	82.8
Level 2	86.1	83.3	83.3	86.1
Level 3	85.5	85.5	86.7	85.4
Level 4	92.7	95.1	92.7	92.6
Mean	86.5	85.7	86.4	86.4

accuracy values resulted from the four vegetation indexes, which all are about 85%. Further research is required to obtain more consistent data.

ACKNOWLEDGEMENT

We would like to thank Badan Pengelola Dana Perkebunan Kelapa Sawit (BPDP-KS) for supporting this research. We are also grateful to PT. Perkebunan Nusantara III for giving us permission

to do our research at Dusun Ulu Estate, Batubara Regency, North Sumatera.

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