Mapping Vegetation Cover of *Acacia mangium* Plantation by Age

Aqilah Nabihah Anuar[1#], Ismail Jusoh[1], Affendi Suhaili[2], Mohamad Bodrul Munir[1]

1 Faculty of Resource Science and Technology, Universiti Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Malaysia.
2 Forest Operation Branch, Forest Department Sarawak, Wisma Sumber Alam, Petra Jaya, 93660 Kuching, Sarawak, Malaysia.
Corresponding author. E-Mail: aqilahanuar5093@gmail.com ; Tel: +60-124615093

ABSTRACT This paper aims to provide a method in mapping the vegetation cover of *Acacia mangium* plantation using the advanced survey technology of satellite remote sensing. This method would serve as an alternative to the conventional field sampling which is laborious and time consuming. Satellite images obtained from Landsat 8, provide the current view on vegetation cover of the whole plantation area. Two areas were targeted for the study which was area with *A. mangium* stands aged below 5 years old and another aged above 5 years old. Image analyses performed on Landsat 8 satellite image showed that vegetation coverage in area over 5 years old stands were significantly denser compared to within 5 years old stands. Low solar radiation (reflectance) was detected on area with high vegetation cover while higher radiation was detected on lesser vegetation cover. Overall findings of the study shows that the older *A. mangium* stand age greatly decreased the transmittance and reflectance of solar radiation in the visible light spectrum due to the increase in biomass. Hence, biomass played a key factor in distinguishing the vegetation covers between the two age classes (below 5 years old and above 5 years old).

KEYWORDS: Vegetation cover; age; *Acacia mangium*; image processing; Landsat 8

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INTRODUCTION

Acacia mangium is a tropical lowland tree which had been introduced as one of the commercial timber species used in making fiberboard, pulp and paper mills. The tree has superior ability to colonize in many kind of sites such as degraded and non-degraded forest area. Therefore, Sarawak Forest Department had planted 69% with acacia trees in 335,049 hectare of forest land for reforestation up till 2014 (Wong *et al.*, 2014). Based on previous studies from Thailand, China, Indonesia and Malaysia, reforestation and afforestation were conducted by planting exotic and native quick growing timber species in order to mitigate exploitation on naturally existed forest resources (Suratman, 2003; Iglesias, 2007; Liu, *et al*, 2014). The new forest area can be assessed by conventional method using forest stand parameters such as wood volume, biomass and basal area. However conventional method for assessing the said parameters is difficult and time consuming when covering a large forest area. The advance tool of remote sensing is likely to be an alternative for conventional method, because remote sensing acquired information about an object without direct contact with the object itself. Satellite remote sensing uses multi-spectral bands that provide a summarized view on the whole planted area at an acceptance level of accuracy and cost-efficient (Lehmann *et al.*, 2017). Landsat satellites such as Landsat 4 Thematic Mapper (TM), Landsat 5 Multi Spectral Scanner (MSS), Landsat 7 Enhance Thematic Mapper Plus (ETM+) and Landsat 8 Operator Land Imager (OLI) have long been used in determining forest biomass and wood volume ever since 1989 (Sader *et al.*, 1989; Lu *et al.*, 2004; Gunlu *et al.*, 2014). This study objective was to utilize satellite images from Landsat 8 OLI to map the vegetation cover of *Acacia mangium* plantation in Bintulu, Sarawak by age.

METHODOLOGY

Study area

The study area was a reforested area, replanted with *Acacia mangium* trees located in Bintulu, Sarawak, Malaysia (Figure 1). The plantation is owned by Daiken Sarawak Sdn. Bhd. Tree ages were divided into two classes of below 5 years and over 5 years old.

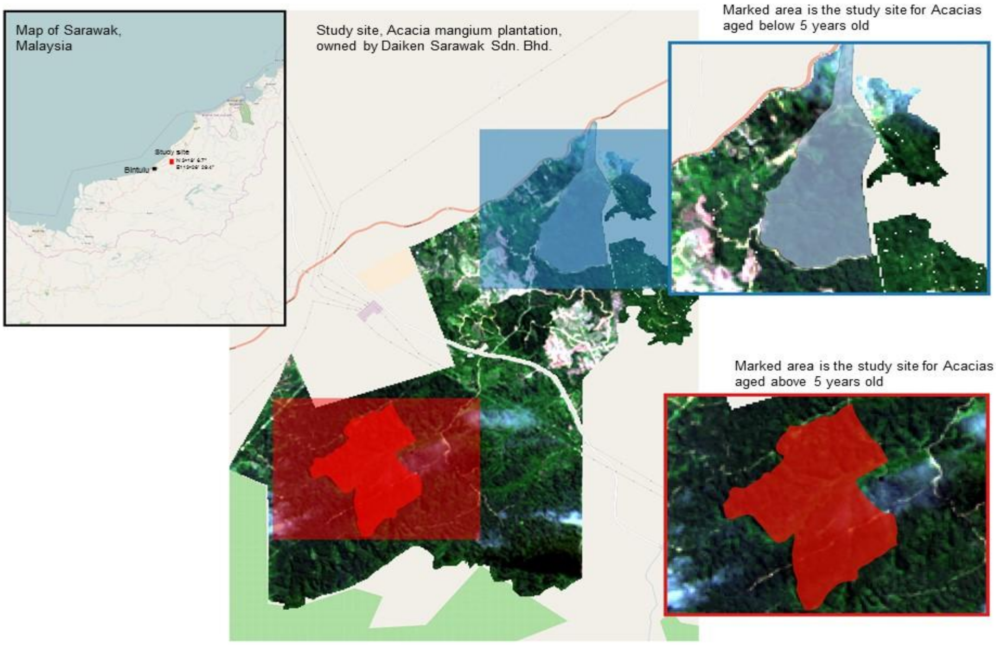

Figure 1. Study site located in Bintulu, Sarawak, Malaysia

Image analysis

Landsat 8 data set, LC81190582016145LGN00 dated 6th June, 2016 was downloaded from United States Geological Survey (USGS) database. Data set was chosen based on the duration of field verification took place from March until September 2016, with the least cloud cover (below 20%). Quantum GIS version 2.8.2 software was used to analyse the image data. The vegetation cover was measured from the satellite image using object-based image analysis method (Blaschke, 2010). Congedo (2016) colour composition method was used to improve interpretation of the vegetation pixel. Similar pixels that represent bare soil and vegetation were grouped together through image segmentation (Blaschke, 2010). The two classes of bare soil were road and harvested area while three classes of vegetation were high, moderate and low vegetation cover. The division between the vegetation classes were made based on field verifications, high vegetation cover area was represented by the dominant acacias' canopy cover, with an average of 141 tonnes/ha of aboveground biomass, moderate vegetation cover class referred to young developing *A. mangium* vegetation canopy, while low vegetation cover referred to riparian buffer area and other vegetation aside from *A. mangium* within the plantation area. Subsequently, spectral angle mapping classification algorithm was performed on the classified classes, and accuracy assessment was done on these classes using Kappa index.

Digital Elevation Model (DEM) and contour mapping were generated using the data stored in Google Earth Pro (Lehmann *et al.*, 2017). Generation of DEM was made using SAGA (2.1.2) tool, through natural neighbour interpolation (Childs, 2004). Interpolation on the elevation of the study area helps reducing external noise that was caused by distortion and provide general view on the elevation and other spatially-based phenomena of the sampling area (Childs, 2004). Differential comparison study between acacias aged below 5 years old and above 5 years old was conducted after image analysis to illustrate the different between the studied age classes.

RESULTS AND DISCUSSION

Figure 2 showed area of planting with acacias aged below 5 years, while Figure 3 showed the area with acacias aged above 5 years old. Vegetation coverage was higher in the area with acacias aged above 5 years old (Figure 3). Colour composite using true-colour and false-colour combinations displayed the general principal of remote sensing when visible light interacted with vegetation. Higher density of vegetation cover reflected less solar radiation, in which causing the darker area in the images, mostly due to the presence of chlorophyll in leaf pigment (Gausman, *et al.*, 1969). Leaves of a tree, including the branches and stem are all part of a tree's biomass. Through aging, acacias increased in term of their heights and diameter at breast height (DBH). Heriansyah, *et al*. (2007) reported that leaves biomass of *A. mangium* remained relatively unchanged when they reached maturity stage, thus, leaving the stem and branches biomass to differentiate between the two age classes. Meanwhile, bare soils reflected more solar radiation compared to vegetation (Basso, et al., 2004). The brighter area in Figure 2 shows there were numerous areas represented bare soil and low vegetation cover in the plantation area of acacias aged below 5 years old.

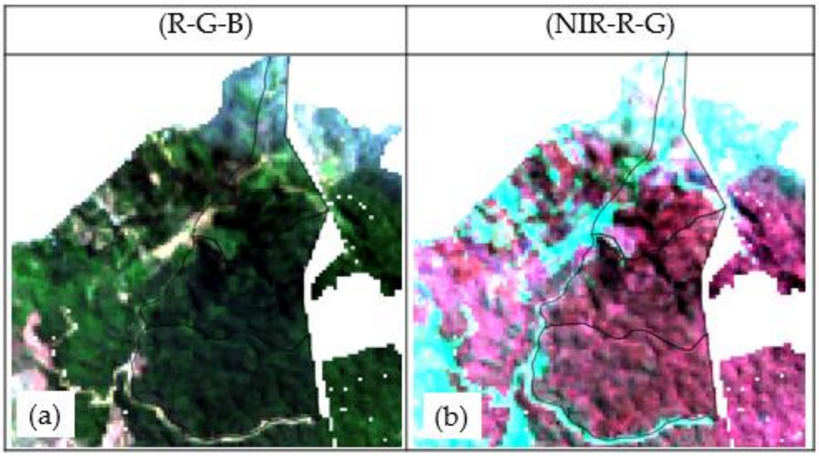

Figure 2 Colour composite image on acacias aged below 5 years old; (a) True-colour; (b) False-colour

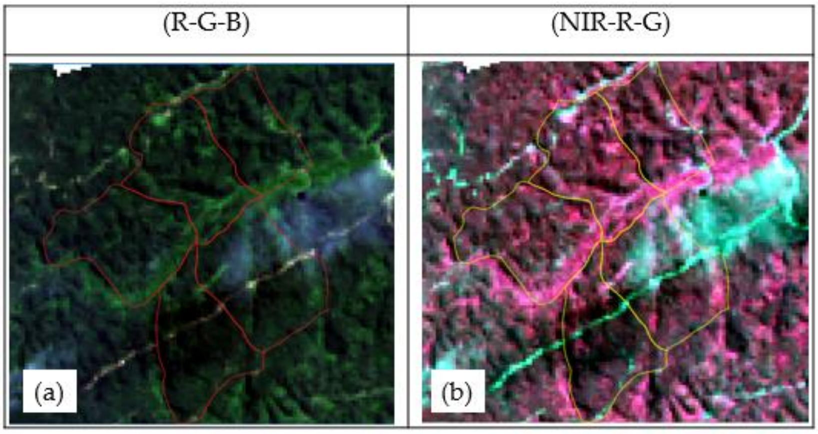

Figure 3 Colour composite image on acacias aged above 5 years old; (a) True-colour; (b) False-colour

Figure 4 shows differences of vegetation cover based on the classes determined using the classification tool. Class 3 (high vegetation cover) was more in the area with acacias aged over 5 years old in Figure 4 (b). The older *A. mangium* had larger canopy cover due to the factor of their bigger stems size, resultant to bigger size in their basal area. Field data showed that the basal area of the acacia trees of over 5 years old were within 11 - 35 m² per hectare, and averaged at 21 m² per hectare. Hence, spectral response can easily discriminated vegetation cover from low vegetation area and bare soils. Accuracy assessment on the classification between the classes was 82.72 % and Kappa analysis revealed an index of 0.73, which can be considered as acceptable according to Jenness & Wynne (2007).

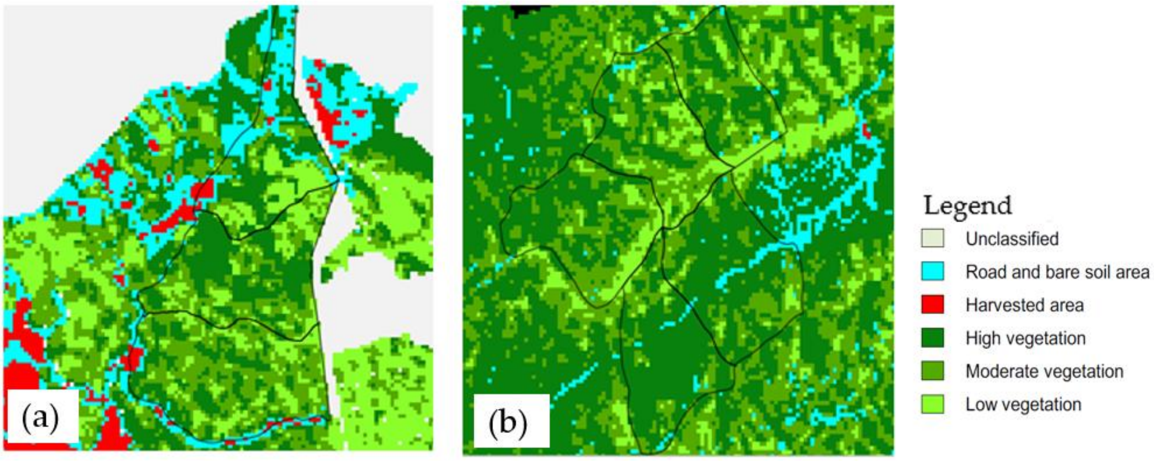

Figure 4. Classification map of the study area a) Acacias aged below 5 years old, b) Acacias aged above 5 years old

Distinguishable features of each class can be represented by their spectral plot generated for each classes (Figure 5). Each one of them is unique and corresponded differently when interacted with the visible light and near infrared that gave them specific spectral signature. This phenomenon is in agreement with Basso *et al.*, (2004).

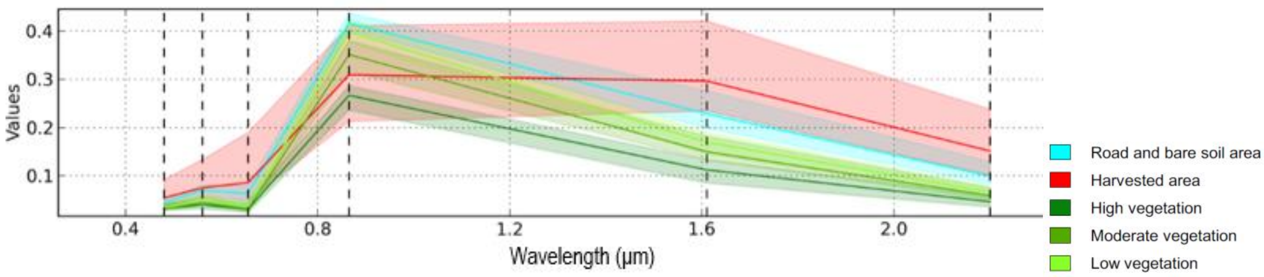

Figure 5. Spectral signature plot showing the respond of every classes against the spectral reflectance

Table 1. Total area covered by the three vegetation classes based on the stand age

Classes of vegetation cover	Area covered by each class in ha and (%)		Total area (ha)
	A. mangium aged <5 years old	*A. mangium* aged >5 years old	
High vegetation	159 (48.6%)	243 (58.1%)	402
Moderate vegetation	30 (9.0 %)	122 (29.2 %)	152
Low vegetation	81 (24.8 %)	42 (10.0%)	123
Non-vegetated area (Road and harvested area)	58 (17.7 %)	11 (2.7%)	69

Table 1 and Figure 6 show the comparison attribute in terms of area covered by the vegetation and non-vegetation cover classes between both stand ages. *Acacia mangium* stands aged above 5 years old was dominated by high and moderate vegetation cover classes, representing approximately 87.3% of the total study area, indicating that great amount of biomass present that made up from both mature acacias and young developing *A. mangium* vegetation canopy. Successful colonization of the canopy cover of *A. mangium* stands aged below 5 years old had yet taken in place causing for the 24.8 % of the total area covered by low vegetation class. However overall view on both age classes, majority of the plantation areas were dominated with high vegetation cover class suggesting the successful establishment of reforestation area with *Acacia mangium* species in Bintulu, Sarawak.

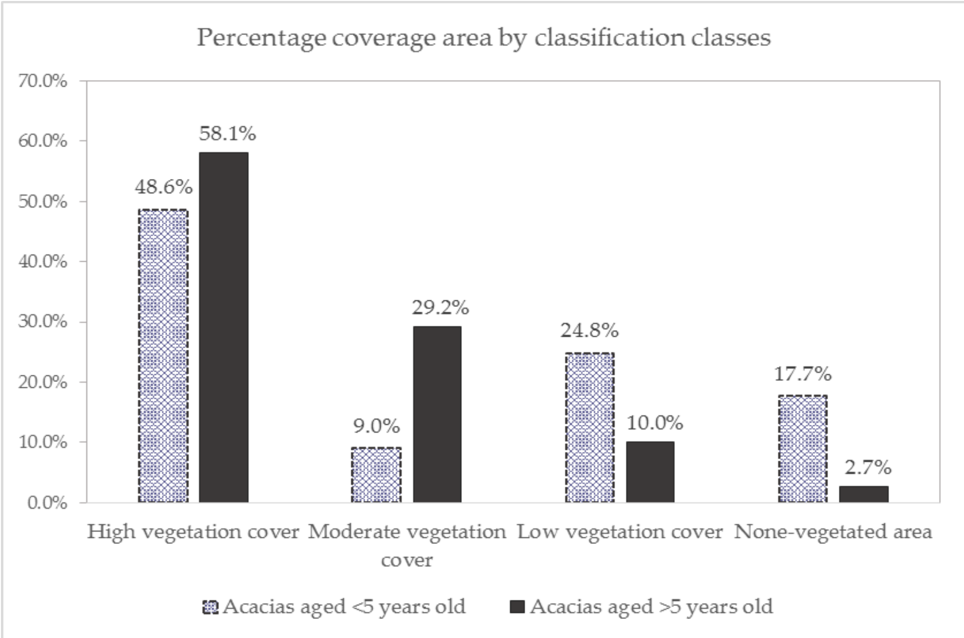

Figure 6. Percentage area represented by each classes between the areas with acacias aged below 5 years old and acacias aged above 5 years old.

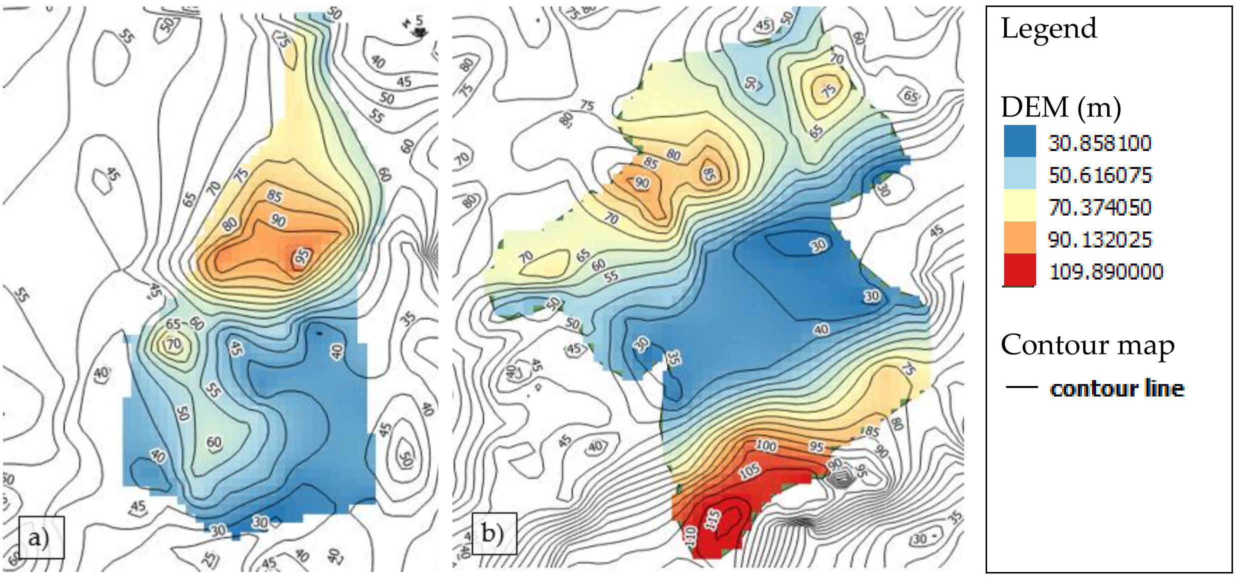

Figure 7. DEM and contour map overlay the study site; a) Acacias aged below 5 years old; b) Acacias aged above 5 years old

Figure 7 showed the topography of the study sites. Satellite remote sensing allowed generation of digital elevation model which gave us overview of the contour lines of the area. The majority of the high and moderate vegetation classes were situated in flat areas within the elevation of 30 to 75 m above sea level (asl). Low vegetation class covered most on the area situated in higher elevation of 75 m asl. The range of slope of the study area was more or less 10%. Conventional topographic correction in areas with slope values of 10% during image pre-processing is not necessary (Jiang *et al*., 2012).

CONCLUSION

The results have proven that mapping of vegetation coverage was made easier using satellite image processing method compared to the conventional method. Multi-spectral satellite image of Landsat 8 allowed manipulation of colour composition which helped in identifying vegetation area from other land covers. High level of radiation in the visible spectrum was absorbed by stand aged 5 year-old and older resulting in low transmittance and reflectance. Refining the identified vegetation into several classes using object based image analysis technique, made classification map that represent the vegetation density cover was possible. Each of the classes was distinguishable due to the unique spectral signature. Stand age of acacias played a factor in influencing the vegetation density as it influenced the increased in the trees' height and basal area. The classification map in this study showed that planted Acacia with stand aged over 5 years had denser canopy cover compared to stand age below 5 years old. The data on total area covered by the vegetation classes could be used in estimating the timber yield and monitoring the growth performance of trees in the area, however more studies are required to understand the relation between the multi-spectral images with forest stand parameters. Since Landsat 8 is an optical sensor, combining the data with other source such as microwave sensor (e.g. PALSAR or Lidar) would allow us to look into every detail on the digital surface model (DSM) and thus improving the accuracy assessment.

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