GIS and UAV Aerial Imaging Applications for Durian Plantation Management

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ABSTRACT

Geographic Information System (GIS) involves the collection, management and analysis of spatial data. Aerial imaging is one of the derivations for data acquisition from the platform of the Unmanned Aerial Vehicle (UAV). Aerial imaging has been extensively used for vegetation mapping in many fields. In Malaysia, crop monitoring of durian plantation area is still done in a conventional way despite the large area of durian plantation. Combination of the UAV aerial imaging and image processing techniques can be used to improve the durian plantation management. Vegetation has its unique electromagnetic signature and each band can be identified to analyse the crop health from the electromagnetic signature reflectance value. Therefore, UAV is able to capture different spectra band image. In this research, we create digital maps of a durian plantation and use it to produce Vegetation Indices (VI); Normalised Difference Vegetation Index (NDVI) and Normalised Difference Red-Edge (NDRE). The visualization of the Vegetation Indices is the compared to the ground truth tree observation. We then analyse for the best Vegetation Index. The best Vegetation Index can then be used by farmers in managing their plantation. NDRE was the best indicator in visualizing the vegetation health in the durian plantation. The accuracy obtained was 92%. Farmers benefit by the use of these maps as field visits can be minimized. The value of the vegetation indices can be applied into GIS database where the value of the image analysis can be recorded in the database thus it can help farmers to emphasize on the problematic area. Using this map, farmers can concentrate on the diseased trees and give appropriate treatment.

KEYWORDS: Precision Farming, Vegetation monitoring, Crop classification, Multispectral sensors

INTRODUCTION

Durian is a fruit with a distinctive smell and sweet flavour. It is one of the most popular fruits in the tropical region and is harvested twice a year. A significant numbers of farmers, mostly smallholders undertake to durian cultivation in Malaysia due to the strong demand and high economic value from the local and global market currently. Durian is exported to regional countries such as China and Singapore. Business returns from growing durians promises new wealth if prices hold up. The durian plantation area is the largest fruit crop planted area in Malaysia as compared to other fruits. Its total area is about 73,000 hectares (2017). Geographic Information System (GIS) is a study area of collecting, managing and analysing spatial data. GIS is a combination of many types of data. It scrutinizes spatial location and classifies layers of

information for visualization by using map displays from database analysis. This is because GIS can perform analysis, provides information and also maintains a database for a good durian plantation management solution. Remote sensing is one of the derivation for data acquisition from the platform of the unmanned aerial vehicle (UAV) and ground-based systems. Agricultural remote sensing is one of the anchor technologies for precision farming, which considers inside field inconstancy for site-explicit administration rather than uniform administration as in customary cultivating. Throughout the years, remote sensing has been extensively used for vegetation mapping in many fields. Aerial photogrammetry has been embraced for observing vegetation just as durian plantations. In 2012, the amount of durian exported was RM42 million per year. It was then predicted that the income will increment by 10 percent (MOA, 2012) for the following year, with durian costs floated mostly influenced by interest from China where the Musang King had gained a numerous number of steadfast and rich fans. In 2013, the normal retail cost for the eminent Musang King or Mao Shan Wang durian was RM36.50 per kg, however, the cost had shot up to a normal cost of RM90 per kg the following year, a huge increment of 42 percent (MOA, 2013). Now, in 2018- 2019 the price of Musang King is RM38.00 per kg (MOA, 2019). The value of durian exported in 2018 was RM74 million per year (UNCOMTRADE, 2018). It is a huge increment of 57% as compared to 2012. If farmers are embarking on planting durian on a big scale, they definitely need a new system that can monitor the durian plantation area as well as to provide good quality planting management plan to ensure the quantity and quality of fruits are able to meet the consumer needs. Unlike any other fruits, durian is seasonal fruits and durian trees are deemed as temperamental. In Malaysia, therefore the durian industry is still at initial stage. Over time, we anticipate greater investment in this sector, as large-scale durian production gains traction and proves successful. In contrast to commercial oil palm planting with proven success for about 100 years, large-scale durian planting in Malaysia is considered young by comparison and lacks comprehensive technical know-how.

MATERIAL AND METHODS

Study Area

The study area for this study as shown in Figure 1 concentrate on durian plantation region in Ladang Mata Tunas UPM in Serdang, Selangor. This site is situated in Selangor, Malaysia. Its geographic location is 3°02' 00" North, 101° 43' 00" East.

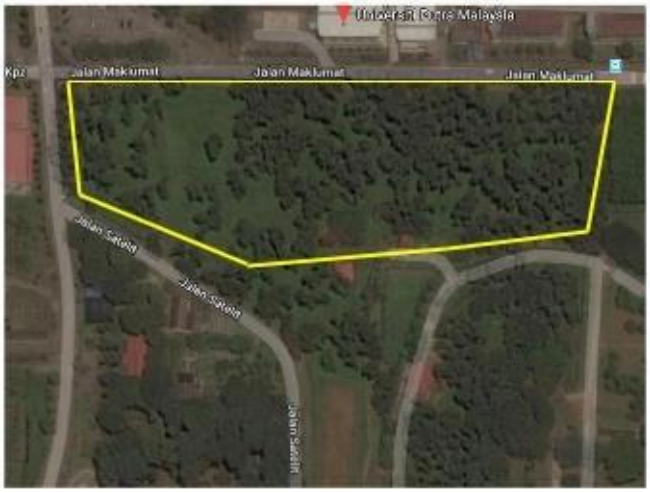

Figure 1: Plot for the durian farm

Methodology workflow

Figure 2 shows the workflow of the study. Started with the UAV image collection then image processing process and vegetation indices (VI) (NDVI, NDRE). The stored all the VI map in the GIS Database. Finally compare all the maps with the ground data.

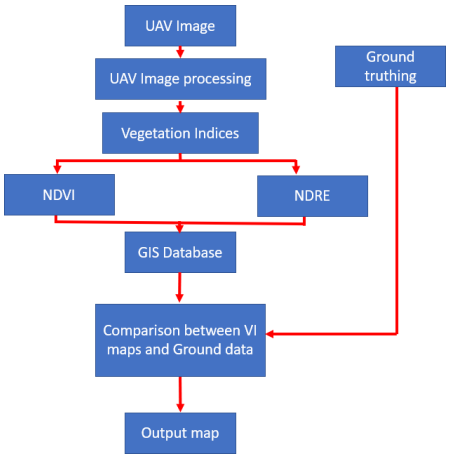

Figure 2: Workflow of the project study

i) Data acquisition

Collection of ground samples

The data consist of the total area of the durian plantation and 25 sample of trees. The tree health is classified by healthy and unhealthy by looking at the stem of the trees which are affected by disease (Figure 3). Some part of durian tree is selected as a sample of trees that affected by diseases. By doing ground data survey, we can import the data into GIS database. The collection of attribute data is defined as the data which has relation with features and it contains the information of tree features. The attribute data enables the plantation owners to do analysis so that improvements to the plantation management systems can be done.

Figure 3 shows the image of sample trees that are affected by diseases.

Image acquisition

Image acquisition of durian plantation area was captured by using multispectral camera and mounted in UAV fixed wing called UX5AG. The sensor was MicaSense 5 bands. The UAV was plant focused and rugged for relevant crop with an all-terrain and intuitive solution. The UAV key applications were for monitoring crop plantation area, tree characterization as well as precision farming. The UAV was composed with a wingspan of 1m. Despite its low payload capacity, Delair UX5AG only retains lightweight on-board multispectral camera which acquires

R, G, B, Red Edge and NIR images. The image processing was conducted using software pix4D Mapper (www.pix4D.com)

Table 1 Specification of MicaSense Red-Edge Source from (DELAIR, 2019)

Specification
• 5 spectral bands R, G, B, Red-Edge and NIR • 3.6 MP Global Shutter, Distortion free • 960 x 1280 pixels • Up to 1 FPS • SD card

Image processing

The conventional photogrammetric technique cannot be used when managing the UAV pictures. Since absolute positioning information cannot be gotten, the picture preparing strategy without absolute positioning information is proposed. The technique incorporates three stages: programmed grafting, rectification and mosaic. After the above advances, correcting pictures in all flight districts should be possible rapidly, and essential is accommodated the accompanying orthorectification and classification.

Image analysis

Normalized Difference Red-Edge (NDRE)

NDVI is a simple matric of vegetation index calculation to detect the overall plant health condition of durian plantation. The NIR value from the data acquisition will hit the leaf of the healthy tree then reflect back the light to the atmosphere. If the amount of chlorophyll content from the tree is low, it will reflect low NIR value. The algorithm of the NDVI calculation differentiates in the amount of reflected intensity from NIR and RGB. The value range from NDVI calculation will produce range from -1 to 1. The lower value indicates unhealthy plants while the highest value indicates healthy plants following the amount of chlorophyll content.

The Mica Sense Red Edge Multispectral camera from UX5AG captured R, G, B, Red-Edge and NIR value. The analysis of NDVI calculation is done using Pix4D Mapper software and imported to ArcGIS software for further analysis. Plant health algorithm such as NDVI and NDRE can differentiate the proportion of light captured across different bands to compute numerical values for each pixel of durian plantation area map. By using this value we can differentiate between healthy and unhealthy areas. NDVI formula is inserted in the Pix4D Mapper Index Calculator. The equation (1) inserted as shown as below (Rouse, J.W., R.H. Haas, J.A. Schell, and D.W.
Deering, 1974):

$$\square\square\square\square\square\square\square\square = \frac{(\square\square\square\square\square\square - \square\square\square\square\square\square)}{(\square\square\square\square\square\square + \square\square\square\square\square\square)} \quad (1)$$

Normalized Difference Red-Edge (NDRE)

Normalized Difference Red-Edge (NDRE) is a vegetation index for estimating vegetation health using the red-edge band. It is especially useful for estimating crop health in the mid to late stages of growth where the chlorophyll concentration is relatively higher. Also, it can be used to map the within-field variability of nitrogen foliage to understand the fertilizer requirements of crops. Calculation of NDRE is based on the equations as shown below (Gitelson and Merzlyak, 1994):

$$\square\square\square\square\square\square\square\square = \frac{(\square\square\square\square\square\square - \square\square\square\square\square\square\ \square\square\square\square\square\square\square\square)}{(\square\square\square\square\square\square + \square\square\square\square\square\square\ \square\square\square\square\square\square\square\square)} \quad (2)$$

RESULT AND DISCUSSION

Vegetation Analysis Visualization Map

Figure 4 and 5 show image classification visualization comparison between NDVI and NDRE respectively. The map shows that more area is classified in NDRE as compared to NDVI map.

NDVI

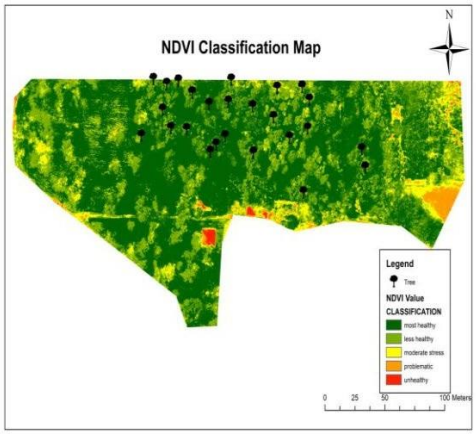

Figure 4: NDVI value

NDRE

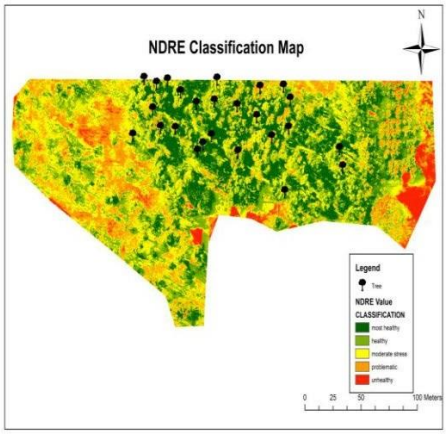

Figure 5: NDRE Value

Relationship between vegetation indices and Ground truth image

Figure 6 shows the image comparison of the NDVI and NDRE maps with ground truth image. There are difference in Vegetation Indices visualization between NDVI and NDRE. This differentiation is because of the durian trees characteristics in this study area. The distribution value that indicated infected tree with disease is smaller in NDRE map thus can detect better visualization of infected tree as compared to NDVI map. NDRE map shows clearly the leaves that are affected with diseases. This will help farmers to visualize trees which are affected by diseases. Therefore, ground visits by farmers can be minimized. (The comparison has been done using software Pix4D Field software application).

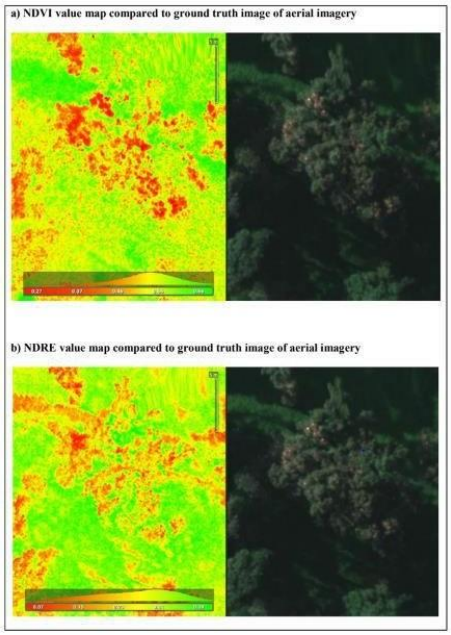

Figure 6: Vegetation Index vs ground truth

Misclassification Map

The NDRE and NDVI classification map is then overlaid with the ground truth trees point to see the misclassified tree (Figure 7). The results show that 2 trees were misclassified in the NDRE and 3 trees were misclassified in NDVI map. The x mark represents the misclassified trees.

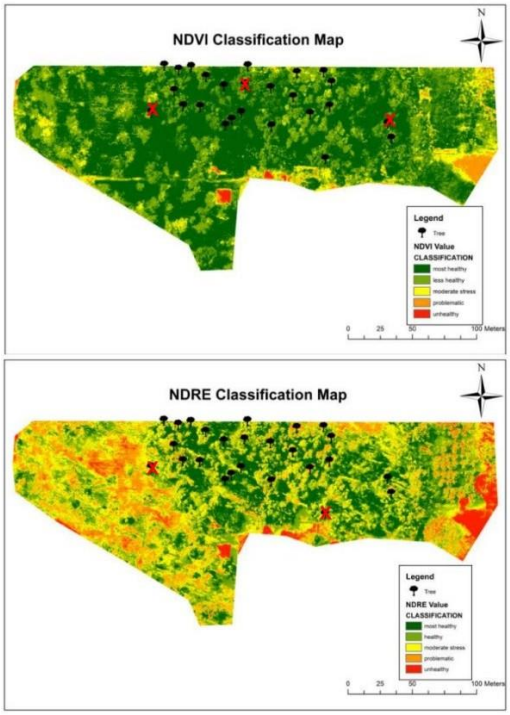

Figure 7: The overlaid map of misclassification trees with the actual ground truth observation

CONCLUSION

The Vegetation Indices NDVI and NDRE were analysed in this study to generate digital output visualization map of the chlorophyll content in the plantation. NDRE was the best indicator in visualizing the vegetation health in the durian plantation. The accuracy obtained was 92%. Compared to ground truth, NDRE prediction accuracy was 92% while NDVI prediction accuracy was 88%. This is because of the durian trees characteristics in this study area. Farmers benefit by the use of these maps as field visits can be minimized. Using these maps, farmers can concentrate on the stressed trees and give appropriate treatment. The digital map output is generated to visualize the health of durian plantation. NDRE is the best Vegetation Index for durian plantation management as discussed in this research study. Less ground visits is achieved as workers in the Mata Tunas durian plantation can monitor the tree health by using the maps.

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