UNIVERSITI PUTRA MALAYSIA

GIS AND UAV AERIAL IMAGING APPLICATIONS FOR DURIAN PLANTATION MANAGEMENT

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BACHELOR OF ENGINEERING

(AGRICULTURAL AND BIOSYSTEMS)

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GIS AND UAV AERIAL IMAGING APPLICATIONS FOR DURIAN PLANTATION MANAGEMENT

BY

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A Final Year Project Submitted to the Department of Biological & Agricultural Engineering, Universiti Putra Malaysia

FACULTY OF ENGINEERING

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APPROVAL SHEET

This project report entitled "**GIS AND UAV AERIAL IMAGING APPLICATIONS FOR DURIAN PLANTATION MANAGEMENT**" is prepared and submitted by **NOR FATIN SYAFIQAH BT MOHAMAD TOEL** in partial fulfilment of the requirement for degree in Bachelor of Engineering (Agricultural and Biosystems) at Universiti Putra Malaysia is hereby accepted.

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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), Normalised Difference Red-Edge (NDRE), Chlorophyll Index-Green (ClG), Chlorophyll Index - Red-Edge (ClRE). 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.

ABSTRAK

Sistem Maklumat Geografi (GIS) melibatkan pengumpulan, pengurusan dan analisis data spatial. Pengimejan udara adalah salah satu daripada derivasi untuk pengambilan data dari platform Pesawat Udara Tanpa Pemandu (UAV). Pengimejan udara telah digunakan secara meluas untuk pemetaan tumbuhan dalam pelbagai bidang. Di Malaysia, pemantauan tanaman di kawasan perladangan durian masih dilakukan secara konvensional walaupun di kawasan ladang durian yang besar. Gabungan pengimejan udara dan teknik pemprosesan imej UAV boleh digunakan untuk memperbaiki pengurusan ladang durian. Vegetasi mempunyai pengenalan elektromagnet yang unik dan setiap band dapat dikenal pasti untuk menganalisis kesihatan tanaman dari nilai reflektansi tandatangan elektromagnetik. Oleh itu, UAV dapat menangkap imej band spectra yang berbeza. Dalam kajian ini, kami membuat peta digital ladang durian dan menggunakannya untuk menghasilkan Indeks Tumbuhan (VI); Indeks Pertumbuhan Normal (NDVI), Perbezaan Normalized Red-Edge (NDRE), Indeks Chlorophyll-Green (ClG), Indeks Chlorophyll - Red-Edge (ClRE). Visualisasi Indeks Vegetasi adalah dibandingkan dengan pemerhatian pokok kebenaran tanah. Kami kemudian menganalisis untuk Indeks Tanaman terbaik. Indeks Vegetasi terbaik boleh digunakan oleh petani untuk menguruskan perladangan mereka. NDRE adalah petunjuk terbaik dalam menggambarkan kesihatan tumbuhan di ladang durian. Ketepatan yang diperoleh adalah 92%. Petani mendapat manfaat dengan menggunakan peta ini kerana lawatan lapangan dapat dikurangkan. Nilai indeks tumbuhan boleh digunakan dalam pangkalan data GIS di mana nilai analisis imej dapat direkodkan dalam pangkalan data sehingga dapat

membantu petani untuk menekankan pada kawasan yang bermasalah. Menggunakan peta ini, para petani boleh menumpukan perhatian kepada pokok-pokok bermasalah dan rawatan yang sesuai dapat diberikan.

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LIST OF ABBREVIATIONS

AGL	Above Ground Level
GSD	Ground Sampling Data
ClG	Chlorophyhll Index-Green
ClRE	Chlorophyll Index Red-Edge
DOA	Department of Agriculture
GCP	Ground Control Point
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LiDAR	Light Detection and Ranging
NDI	Normalized Difference Index
NDRE	Normalized Difference Red-Edge
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared Reflectance
RGB	Red, Green, Blue
RS	Remote Sensing
SWIR	Short Wave Infrared
TIFF	Tagged Image File Format
UAV	Unmanned Aerial Vehicle
VI	Vegetation Indices
VHR	Very High Resolution
IMU	Inertial Measurement Unit

CHAPTER 1

INTRODUCTION

1.1 Background

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.

Table 1. 1 The total amount of overall local fruits produces in Malaysia (DOA, 2016)

STATE	Production (MT)				
	2012	2013	2014	2015	2016
JOHOR	31,224.3	42,342.9	101,383.7	93,839.4	85,117.5
PAHANG	107,216.4	120,325.0	69,397.5	79,974.7	50,911.6
KELANTAN	21,970.5	53,541.0	49,776.9	40,301.7	37,655.9
PERAK	21,178.5	27,860.5	27,106.7	33,987.1	25,641.8
NEGERI SEMBILAN	24,750.1	22,143.0	20,492.6	14,124.3	12,950.2
KEDAH	19,137.5	11,604.3	11,472.5	17,448.3	11,513.7
PULAU PINANG	7,237.4	9,102.6	5,120.0	6,298.9	8,560.3
MELAKA	31,068.0	14,548.4	10,491.9	16,180.9	7,657.4
TERENGGANU	3,431.1	9,827.6	3,542.2	7,127.5	5,065.8
SELANGOR	35,249.0	3,595.2	1,647.2	331.6	2,024.3
PERLIS	74.0	490.0	30.1	556.6	0.8
PENINSULAR MALAYSIA	**295,003.5**	**322,913.7**	**300,461.4**	**310,170.9**	**247,099.4**
SARAWAK	35,892.5	36,909.9	34,586.9	34,879.0	33,499.5
SABAH	16,785.6	13,217.4	16,453.3	23,202.9	22,046.9
W.P. LABUAN	22.7	41.9	16.3	17.9	-
TOTAL	**347,704.4**	**373,082.9**	**351,517.9**	**368,270.7**	**302,645.8**

The amount of total fruits produced per hectare is indicated as table below shows local fruits produced per hectare in Johor are the highest in 2016 which is 6.56mt/ha followed by Selangor and Pulau Pinang. The production of fruits in Pahang shows decreased value. The lowest production per hectare is 0.01mt/ha in Perlis. This table indicate that there are problems in crop plantation management.

Table 1. 2 The total amount of local fruits productivity per hectare (DOA, 2016)

STATE	**Production (MT/ha)**
	2016
JOHOR	6.56
SELANGOR	6.10
PULAU PINANG	5.83
PERAK	5.34
MELAKA	4.66
KELANTAN	4.27
PAHANG	3.89
NEGERI SEMBILAN	3.47
KEDAH	3.08
TERENGGANU	2.99
PERLIS	0.01
PENINSULAR MALAYSIA	**46.2**
SARAWAK	3.24
SABAH	0.95
W.P. LABUAN	-
TOTAL	**50.39**

1.2 Problem statement

Durian is the most popular seasonal fruit with Malaysia being one of the highest durian production countries. Due to the strong demand of durian production from local and global market, durian growers in Malaysia could not meet the large durian production quantity customers need as the fruit is seasonal. Most of the durian growers have lack access and knowledge of modern technology for plantation management. Currently, most farmers rely on conventional methods and are too dependent on human observation to detect plant health. On the other hand there is a lack of research on durian to determine which index is best to determine durian health stage. In this research, we want to make the durian management system more efficient by determining the best index for durian tree health. We want to introduce and promote the use of UAV to automate the manual process and utilize vegetation health map for better visualization by the growers.

1.3 Aim

The aim of the project is to create digital maps of a durian plantation and use it to produce Vegetation Indices (VI); Normalised Difference Vegetation Index (NDVI), Normalised Difference (NDRE), Chlorophyll Index-Green (ClG), Chlorophyll Index-Red-Edge (ClRE) by using Geographic Information System (GIS) and remote sensing application. We then analyse for the best Vegetation Index. The best VI can then be used by farmers in managing their plantation. The new management systems should allow a digital map output to farmers to visualize the vegetation health map of durian plantation. The digital map of durian plantation should produce an output of tree vegetation index such as NDVI which indicates plant health and chlorophyll content which is ClG and ClRE that allows farmers to concentrate on the stressed trees and give appropriate treatment.

1.4 Objective

The aim of this study is to create a precise GIS database durian plantation management system by using remote sensing application with the following objectives:

i) To generate digital map of Vegetation Index to visualize health of durian plantation

ii) To determine the best Vegetation Index for durian plantation management system

iii) To reduce labour by monitoring plantation area with minimum ground visits

1.5 Scope of Study

This research focus on data collection and digital map output from the UAV remote sensing multispectral images. The data collected is from image acquisition of durian plantation area. The digital output map is developed by using Pix4D mapper 4.3.2 software. The data is then imported to ArcGIS 10.3 for further investigation as the encouragement for this research is to make recommendations to the farmers to coordinate the use of present day UAV for spatial examination of their farms to help in field exploration and monitoring as well as assurance of optimal yield production and growth to support effective and efficient decision making. Several image processing technique are used in order to mosaic and generate visualization map of vegetation indices in durian plantation. Vegetation indices generated form the image is able to help the farmers to emphasize on the area that is less healthy so that appropriate treatment can be performed. Therefore, it allows the farmers to take immediate action on the problems that arises without undue delay.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Durian

Durian is one of the fruit categories that belong to family *Durio*. *Durio zibethinus* is the fundamental species available globally, while diverse species are sold in their native area (Morton, J.F., 1987). Durian is in the request of Malvales, the circle of relatives *Bombacaceae* and genus *Durio* (Vangnai, 1983). Durian is acknowledged to begin from Borneo Island, wherein more *Durio* species had been arranged than wherever else (Reksodihardjo, 1962, Siti Zainab and Zainal Abidin, 2008). Named in certain locales as the "King of Fruits", (Heaton, Donald D, 2006) the durian is unique for its size, smell and thistle covered skin. Presently, durian is currently a crucial tropical yield in South-East Asia.

Table 2. 1 Classification of Durian (Nyffeler, R. and DA Baum, 2001)

Family:	***Malvaceae***
Subfamily:	*Helicteroideae*
Tribe:	*Durioneae*
Alternate family (ies):	*Bombacaceae, Durionaceae*

Durian cultivation is concerted mainly in Thailand, Malaysia and Indonesia. The Philippines and other Southeast Asian nations additionally produced Durian for user's utilization (Cunningham, 2000). Durian production in Thailand expanded by 4.63% per year from 1922 to 1996 from its usual production 672,781 MT. Malaysia has an average production of 310,957 MT from 2006 to 2011 (Department of Statistics, Malaysia).

Despite the fact that the durian is not origin from Thailand, Thailand has positioned the world's main exporter of durian, delivering around 700,000 tons of durian for each year, 400,000 tons of which are sent out to China and Hong Kong (Svasti, Pichaya, Jariyasombat and Peerawat, 2018). Malaysia and Indonesia pursue both delivering around 265,000 tons each. Of this, Malaysia sent out 35,000 tons in 1999 (FAO, 2008).

Durian is an occasional tropical fruit, accessible mostly among May and August. A minor harvest may likewise be accessible in specific months amid December and January. Early harvests might be acquired as right on time as mid-March and late yields might be accessible in October (J. Siriphanich, 2011). With the utilization of plant development controllers, especially Paclobutrazol, durian is presently accessible lasting through the year in Thailand. Durian cultivation expands through South-East Asia, Sri Lanka, the southern piece of India and Madagascar.

Small scale cultivation is likewise found in the Northern Territory and Queensland, Australia. Production area and exchange value is insignificant there as stated in FAO statistics. Nonetheless, factual information from Thailand, Malaysia and Indonesia are shown in Table 2.2.

Table 2. 2 The amount of durian exported by countries (DOA, 2018)

Country	2014		2015		2016	
	Production (MT)	Export Value (RM)	Production (MT)	Export Value (RM)	Production (MT)	Export Value (RM)
Indonesia	11.01	20598.97	0.41	4301.48	10.03	87572.58
Malaysia	13,215.239	42,183986.12	19,891.629	69,091697.09	17,754.25	74,362440.40
Thailand	369,602.48	1,606350282.22	358,192.28	1,609058772.75	402,660.50	2,054073555.54

As indicated in the statistics in Table 2.2, Durian is presently a noteworthy crop traded arising out of Thailand. It is notable among Asian social order joining those in Australia, Europe, and North America, in spite of the way that the foremost exchange publicize is China.

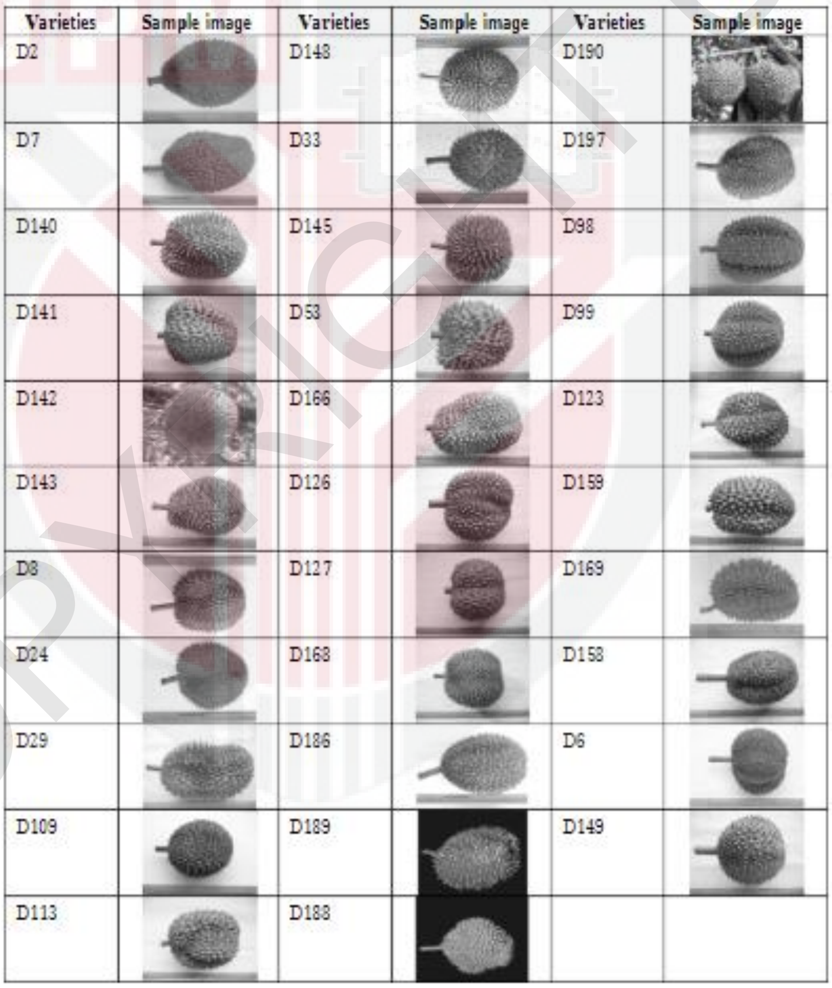
2.2 Durian in Malaysia

Malaysia is one of the major Durian fruit exporters in the world. It trades The King of Fruits to nations like China, Singapore, and even the United States. The main durian cultivation states incorporate Johor, Perak, Pahang, Kedah, Selangor, Kelantan and Terengganu (T.C.Hye, 2002). Majority of the durian trees are planted in multi-cultivated plantations and overseen by smallholders. In any case, more durian trees are being planted widely in bigger homesteads and homes overseen by dynamic ranchers, businessperson and corporate bodies. This situation mirrors the expansion in durian cultivation in Malaysia.

There are in excess of 100 durian clones accessible in the nation and they are originated locally (DOA of Malaysia, 2007). Nonetheless, just few clones have potential for cultivation and quality. Among those are Musang King, D24, XO, D2, D101, D13, D1, and Red Prawn. Durian could possibly turn into a noteworthy commodity for Malaysia whenever grew comprehensively and on a vast scale like rubber and oil palm. The durian clone, D197 or Musang King has appeared to obtain RM155, 250 per hectare or multiple times more than oil palm's return of RM17, 500 per hectare, in light of 50 fruit products for each tree every year at RM25 per kg. This exceptional high demand for the durian from China trigger off another round of hopefulness in Malaysians economic from simply 40 tons in 2011, Malaysian durian fares to China have soar to 368 metric tons in 2017.

There are few traits that can be used to separate the durian assortments. DOA has portrayed the attributes of the durian that can be founded in the fruits. The attributes consist of flesh, taste and durian's spines or can be dependent on its leaves. Salma, 2017 depicted that durian tree is dependent on the bark, bud, blossom fruits grown from the ground. This paper is concentrated on the sample picture of durian varieties as shown in the table below.

Table 2. 3 Durian varieties registered in Department of Agriculture (2019)



Varieties	Sample image	Varieties	Sample image	Varieties	Sample image
D2		D148		D190	
D7		D33		D197	
D140		D145		D98	
D141		D53		D99	
D142		D166		D123	
D143		D126		D159	
D8		D127		D169	
D24		D168		D158	
D29		D186		D6	
D109		D189		D149	
D113		D188			

2.3 Geographic Information System (GIS)

Marble, 1983 simply refers to a GIS as a spatial data handling system. Cowen (personal communication, 1986) says GIS is an information system that handles geographically or spatially referenced data. Burrough,1986 defines GIS as a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world. Berry, 1986 provides a different view, pointing out that a GIS is an inner referenced, robotized, spatial data framework. Some authors do not even concede that a GIS is necessarily computer based (Calkins and Tomlinson, 1984). Finally, Devine and Field, 1986 composed that GIS is essentially a device to extend the utilization of maps.

The significant GIS application in the normal asset the board to date is arranging. All characteristic assets the board offices are committed by law to deliver the board plans which consider a wide assortment of potential land utilizes ecological assurance measures, and general conclusions. At least fifty diverse topical maps might be digitized and utilized in different phases of the arranging procedure (Zulick, 1986). It is important to review that, regardless of the way that digitizing can be costly, it is interminable. GIS applications in the course of recent years incorporate displaying of backwoods bother impacts (White, 1986), water quality observing (Welch, 1986), demonstrating opiate crop destinations (Waltz and Holm, 1986), squander transfer site appraisal (Buckley and Hendrix, 1986), and examining impacts of carbon dioxide advancement on elk (Brekke, 1986).

2.4 Unmanned Aerial Vehicle (UAV)

Contrasted and satellite remote sensing aerial photogrammetry, UAV has its own benefits which make it a crucial field these days (Goforth and Steele, 2011). In particular, UAV can be conveyed effectively and every now and again to fulfil the prerequisites of fast checking, evaluation, and mapping in regular assets at a client characterized spatial-transient system. The UAV's sensor acquires better pictures over that Very High Resolution (VHR) satellite.

The sub-decimetre obtained goals pictures can catch subtleties of ground items to help for exceptionally precise durian manor mapping. It give a more secure and cost-effective route for information procurement. Likewise, UAV can work at a lower height. Crude information got by UAV generally comprise of several computerized pictures gaining at various brightness conditions and flight statures. The pre-processing of UAV symbolism intends to orthorectify each picture and mosaics them into a solitary one. This is an extreme errand since crude pictures experience the ill effects of lighting variety, stage influence, and sensor relocation. In this examination, Pix4D was utilized to pre-process the crude pictures, which give brilliant information to facilitate urban vegetation extraction and classification (Qin, 2014).

UAV goals symbolism gives better pictures which can catch rich subtleties of ground items to help for extremely exact durian manor mapping. In any case, investigations of utilizing UAV pictures for durian ranch the board frameworks are as yet uncommon. Current investigations (Laliberte and Goforth, 2011) for the most part centred on timberland mapping, rangeland observing and riparian vegetation extraction, and so forth. In this specific circumstance, we are exceptionally energetic to legitimize the execution of UAV remote detecting in durian estate the executives.

A UAV remote detecting structure, for the most part, contains sensor payload for data acquiring, autopilot for control of the entire workmanship, GPS for a course, Inertial measurement Unit (IMU) for attitude estimation, a data interface for banner trade and ground station for mission orchestrating and information association. The on board sensor transforms from the off-the-rack propelled camera, multispectral camera, a hyperspectral imager, and Light Detection and Ranging apparatus (LiDAR) (Honkavaara, 2013). Unrefined data got by UAV ordinarily include a few electronic pictures verifying at different brightness conditions and flight statures. The pre-processing of UAV imagery expects to orthorectify each image and mosaics them into single image. This is an extraordinary errand since rough pictures experience the ill impacts of lighting assortment such as stage influence and sensor expulsion. In this examination, Pix4D was used to pre-process the raw pictures, which can give amazing data to encourage urban vegetation extraction and portrayal.

2.5 Remote Sensing Application in Durian Plantations

It is enticing to characterize remote sensing as an information source innovation, and GIS as an information handling innovation. An ongoing precedent is given by (Cibula and Nyquist, 1987), who utilized topographic and climatological information in a GIS to increment from 9 to 21 the quantity of land-spread classes recognized, via Landsat information. This idea is currently new and was regularly called "auxiliary". Today, it is likely increasingly precise to portray the remote sensor information as "subordinate," on the grounds that a GIS can contain a large number of information layers, just one or a couple of which are gotten from remote detecting.

In durian ranch checking, remote sensing has been utilized in different applications, including land spread grouping, programmed tree tallying, change the identification, age estimation, over the ground biomass (AGB) estimation, carbon estimation, bug and diseases recognition, and yield estimation.

By changing explicit band esteems, we can acquire vegetation records that portray vegetation by its greenness. The most well-known parameter being used is the Normalized Difference Vegetation Index (NDVI), which is a standardized proportion of close infrared to unmistakable red. It is a flexible and ground-breaking marker to separate vegetation from non-vegetation. In an investigation to discover the best performing vegetation files to isolate durian from its experience, it was discovered that the Normalized Difference Index (NDI) shows the most astounding separating power utilizing a histogram disparity measurements (Srestasathiern and Rakwatin 2014) (Srestasathiern, P and P. Rakwatin, 2014).

2.6 Image Processing

Each object which includes plant, soil, and water will have different rate of reflection and absorption of light energy emitted from the sun. In this study, plant has unique features that reflect differently. The parts of the plant that affect the reflectance of the plants are the amount of chlorophyll content in the leaf, leaf water content, and as well as the intercellular space in the leaf cell. The chemical characteristic of the pigment, dry matter content and water in the plant are able to create unique spectral reflectance due to it different absorption features (Jimenez & Diaz-Delgado, 2015). General example of a reflectance plot for some (unspecified) vegetation type with the dominating factor influencing each interval of the curve indicated as Figure 2.1.

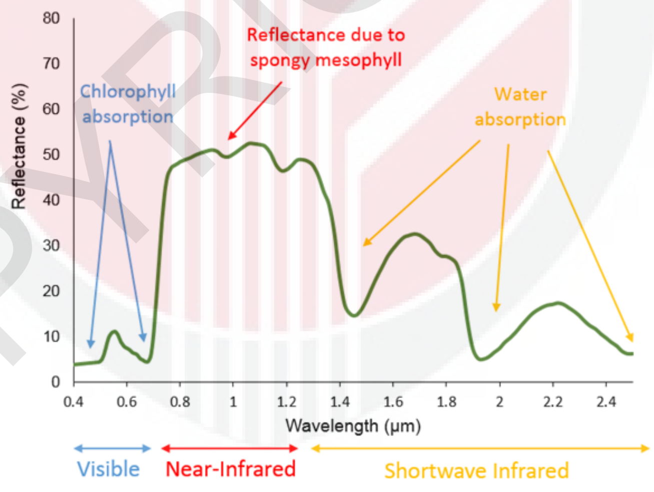


Figure 2. 1 Reflectance plots of spectral signatures (Roman and Ursu, 2008)

For vegetation, visible band indicates Chlorophyll absorption in blue and red, reflection in green. NIR ranging (0.7 – 1.3 µm) where reflectance increases dramatically and plant leaf reflects 40 – 50%. The absorption is minimal so remainder is transmitted. The reflection is due to the internal structure of plants which allows discrimination of species and plant stresses determination. SWIR ranging (1.3 – 3.0 µm) where incident energy is absorbed or reflected, little is transmitted. Water absorption bands in this range. For soil, it is considerably less peak and valley variations in reflectance. Factors that influence soil reflectance act over less specific spectral bands.

For water, distinctive characteristic is absorption at NIR and beyond. Delineate water bodies using NIR but it depends on water quality, clarity, biology in the visible bands. Water and vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared. Sensors operating in green, red, and NIR can discriminate absorption and reflectance of vegetation as shown in Figure 2.2.

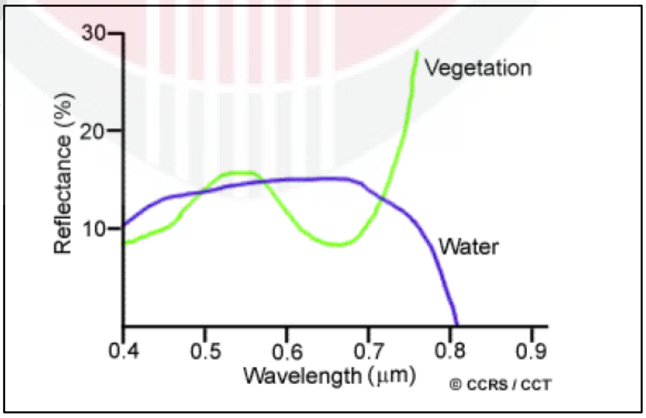


Figure 2. 2 Spectral reflectance of vegetation vs water

2.7 Image Analysis

2.7.1 Vegetation Index Analysis

The spectral composition of the radiant flux emanating from the Earth's surface provides information about the physical properties of soil, water, and vegetation features in terrestrial environments. Remote sensing techniques, models, and indices are designed to convert this spectral information into a form that is readily interpretable (Huete, 1989). Pearson and Miller (1972) are the pioneers that developed the first two indices in the form of ratio to be applied for crop monitoring and estimation.

CHAPTER 3

METHODOLOGY

The entire work process of durian plantation mapping can be categorized into three sections: (i) data acquisition and pre-processing; (ii) image processing; (iii) data analysis. Data pre-processing was an essential which includes information downloading from UAV advanced camera, image registration, orthorectification and programmed mosaicking. Samples were R, G, B, and empowering Red Edge assurance. Accuracy assessment was done dependent on disarray network got from approval tests to test the execution.

3.1 Study Area

The study area for this study as shown in Figure 3.1 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.

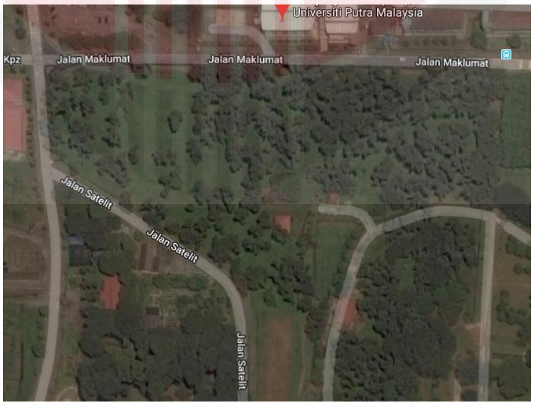


Figure 3.1Mata Tunas Durian Plantation area

Mata Tunas Durian Plantation area is located at Universiti Putra Malaysia (UPM), Serdang, Malaysia. According to (Shazery, 2019), Mata Tunas Durian Plantation is mainly focused for the production of buds. The total area of the overall durian plantation in UPM is 7.5 ha. Mata Tunas Durian Plantation has an overall of 2.5 ha of the total area. Mata Tunas Durian Plantation has many varieties cultivated such as Musang King, D24, D168, D2 and others. Durian fruit production in UPM has increased of 70% majority of fruits harvested from previous year records.

The overall production of durian fruits in 2018 is 6068 kg (Shazery, 2019). However, this plantation area has low yield production as compared to other plantation area. There is not much journal publication on the application of remote sensing in durian plantation area and more research should be carried out to test the high yielding potential of durian plantation area. In the future, durian cultivation will be able to increase country’s economic as well as local farmer’s income.

The main problem in Ladang Mata Tunas is the decreasing yield. The main factors are because of insufficient amount of fertilizers given. Furthermore, climate change is one of the contributions. Most of the durian trees are affected with the *Phytophthora Palmivora* (Kanker Batang) diseases.

3.2 Methodology Flow Chart

The workflow of this project is presented in the Figure 3.2 below. All the steps of UAV image processing are carried out using Pix4D Mapper software. The vegetation Indices are generated in Pix4D Mapper software. The image of the orthomosaic image is then imported to ArcGIS software to create GIS attributes table. Thus, the comparison of ground truth trees observation can be done. The digital output maps of vegetation indices are then generated.

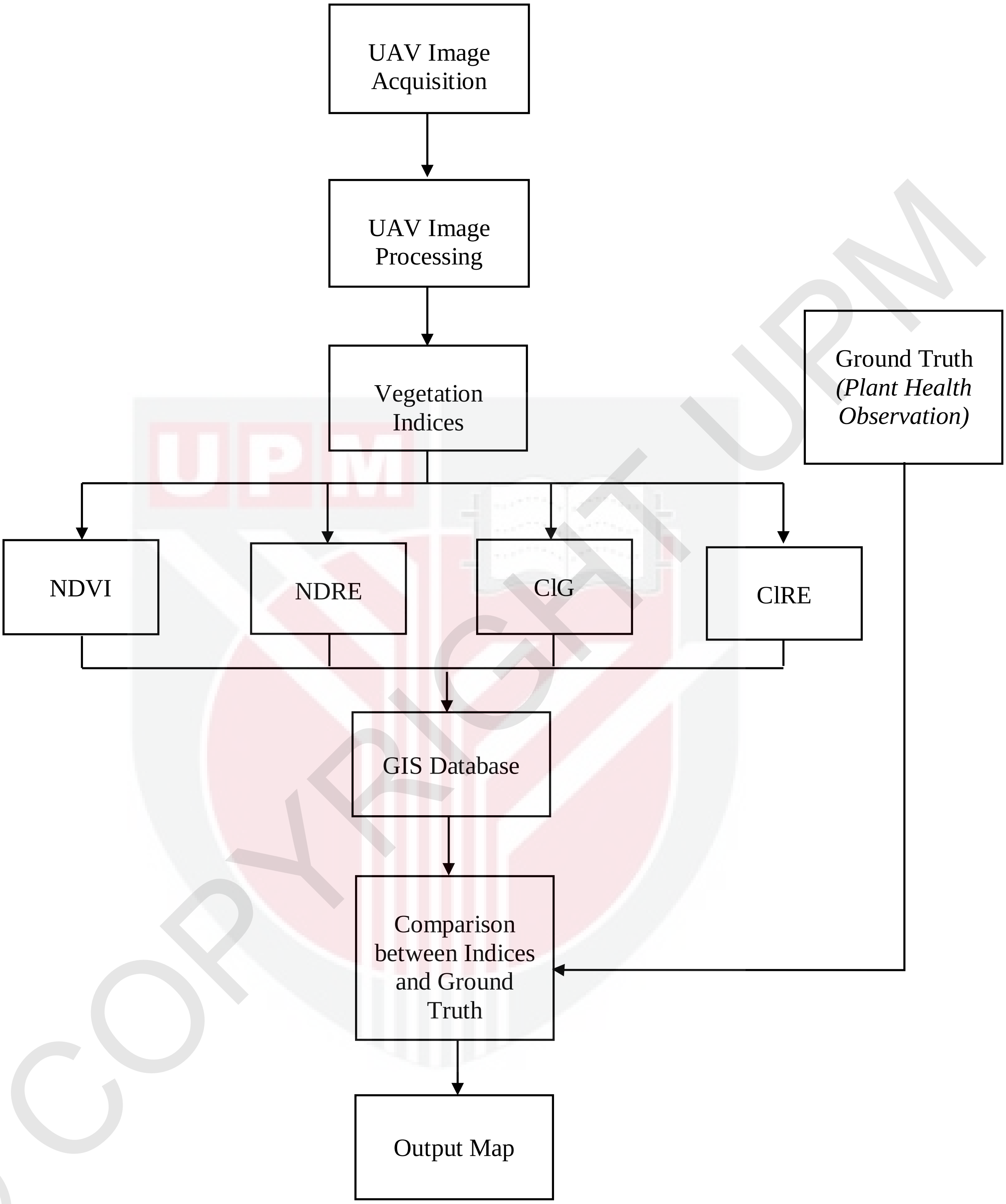


Figure 3. 2 Workflow of Project Study

3.3 Data Collection

3.3.1 Data Acquisition

Data acquisition of durian plantation area was captured by using multispectral camera and mounted in UAV fixed wing called UX5AG. The sensor used is MicaSense 5 bands. The UAV is plant focused and rugged for relevant crop with an all-terrain and intuitive solution.

Figure 3.3 below shows the outlook of UAV UX5AG and multispectral camera MicaSense Red-Edge. The UAV key applications are for monitoring crop plantation area, tree characterization as well as precision farming. The UAV is 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.

Figure 3. 3 UAV UX5AG and Red-Edge multispectral camera

The flight altitude was 150m and the resolution was 9.06cm per pixel. The data is then processed in Pix4D mapper for mosaicking. The overlaps were set to 70%. The picture taken utilizing UAV is then mosaicked into a solitary picture by utilizing programming Pix4D mapper. Pix4D is preferred as a pre-processing tool because of its efficiency and high accuracy. The map is then subset into crop plantation area. The specification of the UAV Delair UX5AG and MicaSense Red-Edge multispectral camera are listed in Table 3.1 and Table 3.2 respectively.

Table 3. 1 Specification of UAV Delair UX5AG

Criteria	**Specification**
Endurance	Up to 45 minutes
Weight (payload included)	2.5 kg
Wingspan	1 m
Flying range	9.06cm GSD @ 150m AGL
Material	EPP foam, carbon frame structure
Cruise speed	80 km/h

Table 3. 2 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

3.3.2 Flight Planning

The flight attitude for the UAV was 150m AGL which produced 9.06cm pixel size. The UAV was controlled by using a remote controller. Waypoint was designed to produce a comprehensive overlap map, therefore the flight mission were preprogramed and planned in the flight mission planner Pix4D mapper software. The front lap and side lap distance were set based on the total coverage area. There was extra track or space for the UAV to stabilize for straight track as well as full coverage of the study plot. The flight mission was carried out at the time 08:30 morning till 12:00 noon because the wind speed were lower during morning and the image captured are free of the shadow from the UAV. The view of the image position is shown in the Figure 3.3.

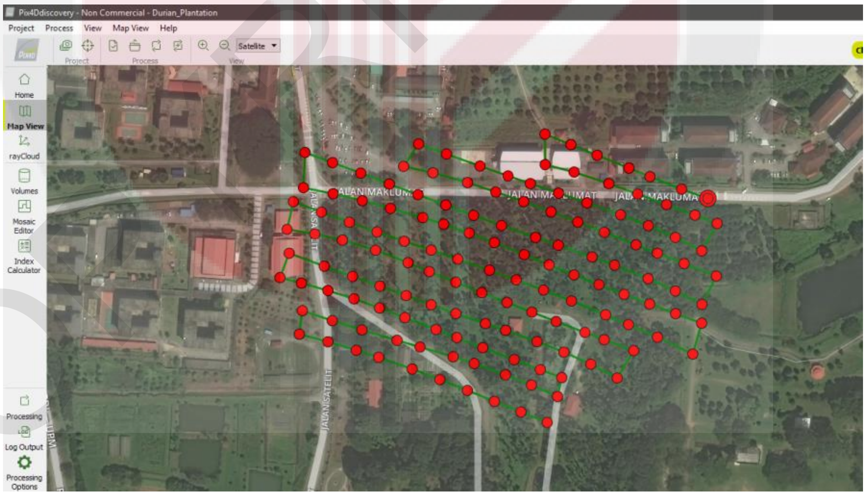


Figure 3. 4 Image position of UAV from Pix4D Mapper view

Figure 3.5 shows the handheld GPS device (Trimble Juno 3B). The GPS was used to collect the position of the GCP and the coordinates in Durian Plantation area. This GPS device contains high sensitivity Global Navigation Satellite System (GNSS) receiver, build-in Bluetooth, Wi-Fi receiver, 5 mega pixel cameras, cellular modem supported with voice call and text messaging. Furthermore, it provides accurate positioning information within 3m distance.

Figure 3. 5 Handheld GPS Trimble Juno 3B

3.4 Image Processing

The conventional photogrammetric technique cannot be used when managing the UAV pictures. Since absolute positioning information cannot be acquired, 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.

3.4.1 Pre-processing

Remote Sensing (RS) is the study of acquiring and deciphering data from a separation, utilizing sensors that are not in physical contact with the item being observed (Jensen, 1996). The art of remoted sensing incorporates aerial, satellite and spaceship perceptions of the surfaces and environments of the planets in our close planetary system, while the Earth is perceptibly the most successive focus of study. The pre-processing step of the image is then conducted. The raw image from the SD card is downloaded into the computer. The image downloaded is then proccessed in the Pix4D Mapper software to create an orthomosaic.

3.4.2 Calibration

We have to do calibration by using Pix4D mapper, the software will auto detect the white panel then we have enter the reflectance factor calibration value. The table of reflectance value adjusted in in the Table 3.3 below. The white panel value of Red, Blue, Green, NIR and Red-Edge. The calibration process is conducted in Pix4D mapper software as presented in Figure 3.6 and Figure 3.7 below.

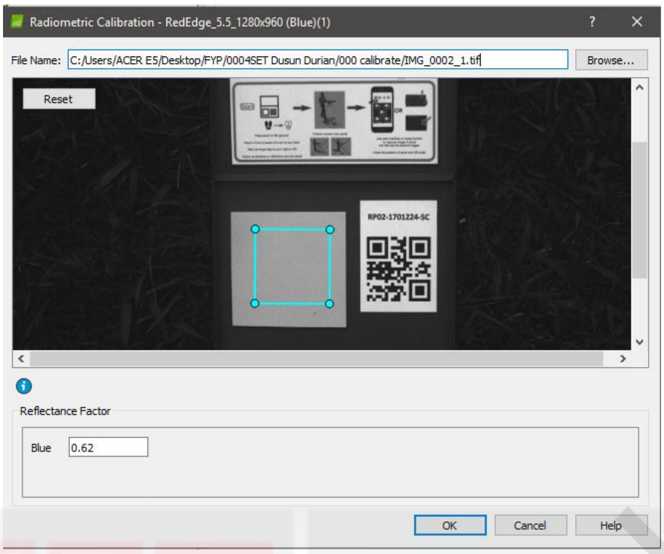


Figure 3. 6 Adjusting the reflectance factor and the white panel

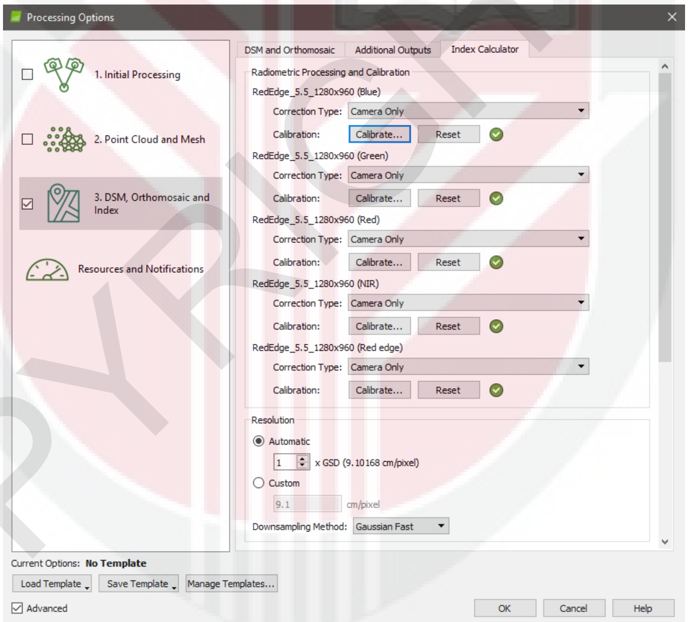
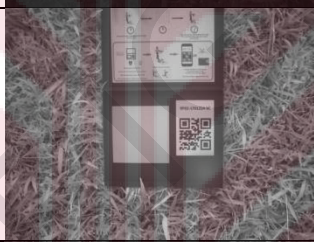


Figure 3. 7Calibration process of white panel in Pix4D Mapper software

Table 3. 3Reflectance factor value of white panel

White Panel	Sample Image	Reflectance Factor
Red		0.63
Green		0.63
Blue		0.62
NIR		0.58
Red-Edge		0.62

3.4.3 Mosaicking

UAV had the capacity to catch quantities of covered elevated picture dependent on the size of the examining zone. This process is done in Pix4D Mapper as shown in Figure 3.8 and Figure 3.9 respectively.

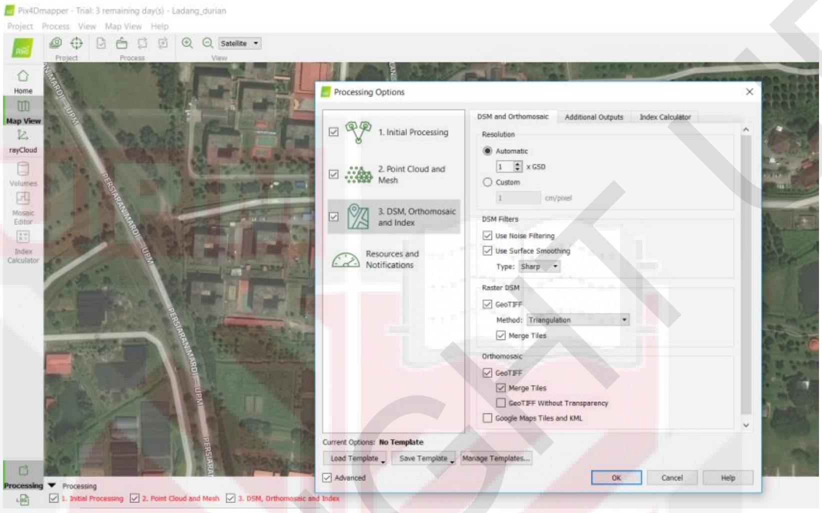


Figure 3. 8 Mosaicking UAV image in Pix4D Mapper

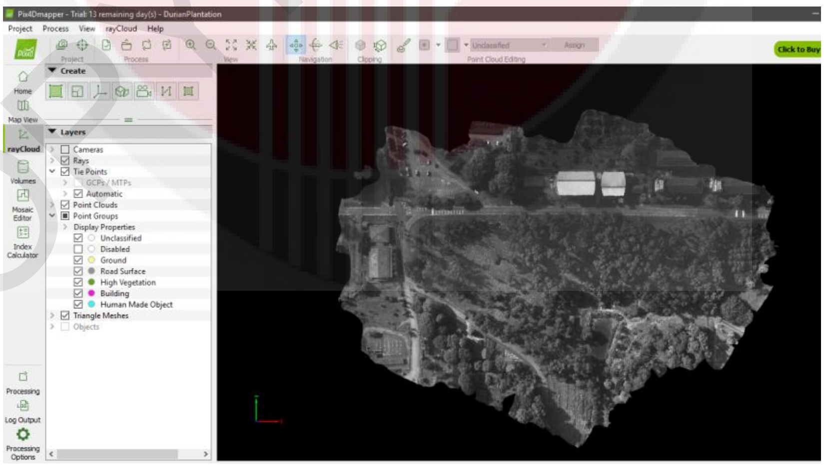


Figure 3. 9 Orthomosaic image from the raw image

Those pictures were experienced orthomosaic to deliver a solitary covered picture. These raw images are processed into orthomosaic to produce single overlapped image. The crude picture from the multispectral and RGB cameras was changed over into tiff document position by utilizing Pix4D Mapper. Figure below shows general workflow of orthomosaic in Pix4D Mapper software.

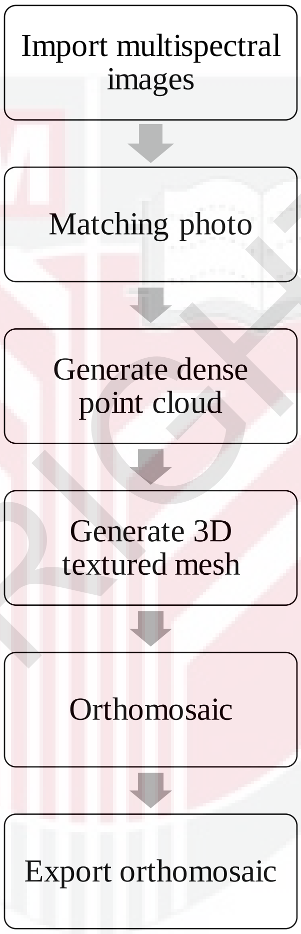


Figure 3. 10 Workflow of UAV image processing

3.5 Image Analysis

3.5.1 Normalised Difference Vegetation Index (NDVI)

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):

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \tag{1}$$

3.5.2 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):

$$NDRE = \frac{(NIR - RedEdge)}{(NIR + RedEdge)} \tag{2}$$

3.5.3 Chlorophyll – Index Green (ClG)

Having broad NIR and green wavelengths provides a better prediction of chlorophyll content while allowing for more sensitivity and a higher signal-to-noise ratio (Gitelson and Merzlyak, 2003). This index is used to estimate leaf chlorophyll content across a wide range of plant species. Calculation of the value is based on equation below:

$$ClG = \frac{(NIR)}{(Green)} - 1 \quad (3)$$

3.5.4 Chlorophyll – Index Red-Edge (ClRE)

Chlorophyll Index - Red-Edge (ClRE) vegetation index for estimating the chlorophyll content in leaves using the ratio of reflectivity in the near-infrared (NIR) and red-edge bands (Gitelson and Merzlyak, 2003). The equation used shown as below:

$$ClRE = \frac{(NIR)}{(Red-Edge)} - 1 \quad (4)$$

3.6 Ground Data Collection

We did ground data survey by going to the site. The data consist of the total area of the durian plantation and sample of trees that have diseases and making a set data of number of tree. The tree health is classified by healthy and unhealthy by looking at the stem of the trees which are affected by disease. 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 3.11 below shows the image of sample trees that are affected by diseases.

Figure 3. 11 Sample trees affected by diseases

3.7 Data Import into GIS

The orthomosaic images from Pix4D Mapper that have been georeferenced can be imported into any GIS software for further analysis and investigation. Once the results of Vegetation Index are obtained in the Pix4D Vegetation Index calculator, these data will be saved as GeoTIFF and can be imported into any GIS software. These data have spectral information of the area that is affected by diseases and plant health can be identified.

3.8 Accuracy Assessment Procedures

The accuracy assessment is performed by comparing the results obtained from ground truth observation and Vegetation Index equation by software. The formula of the accuracy of vegetation analysis is shown as below:

$$Accuracy\ of\ Vegetation\ Calculation = \frac{Total\ number\ of\ trees\ predicted\ correctly}{Total\ number\ of\ trees} \times 100$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Image Processing and Analysis

The results from the image processing and analysis are discussed. Image processing is divided into orthomosaic, georeferencing, and image calibration and vegetation index (VI) analysis. The obtained data is then imported to ArcGIS software for further investigation. The area for the study site shown in the Figure 4.1 below is the orthomosaic results processed in Pix4D Mapper software.

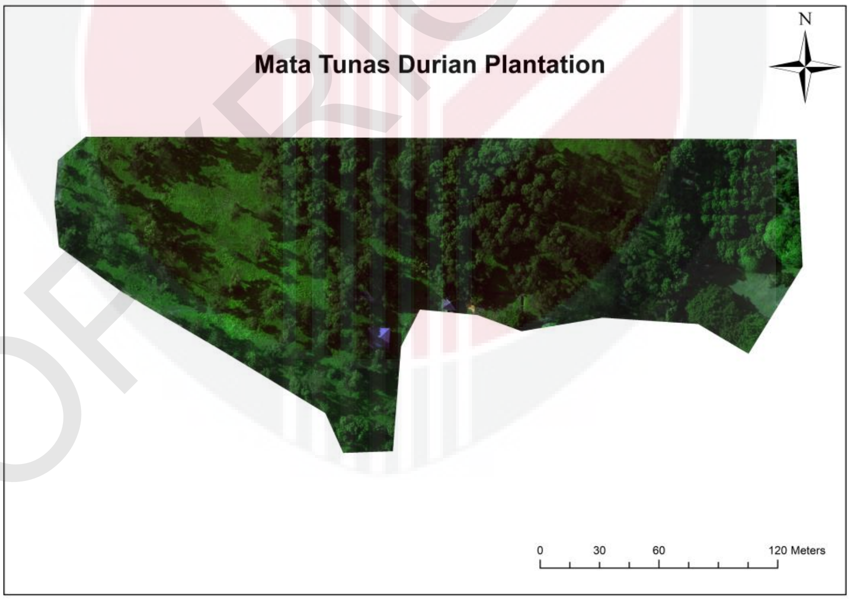


Figure 4. 1 Orthomosaic study area map

4.2 Vegetation Index Map

The broadband greenness VIs is among the least complex proportions of the general amount and vigour of green vegetation. The Vegetation Indices NDVI, NDRE, ClG and ClRE map were analysed to produce digital map visualization of chlorophyll content in the plantation area. VI from the data acquisition is generated in the Pix4D Mapper software with equations following their VI.

4.2.1 Normalised Difference Vegetation Index (NDVI)

Normalised Difference Vegetation Index (NDVI) was analysed to produce digital map visualization of the plant health. Figure 4.2 shows the visualization of NDVI values. Plant health can be identified and monitored in this map. Different vegetation indices analysis has shown different pattern of indices value across the study area. The green colour represents the healthy region while the yellow colour represents the less healthy plant zone.

4.2.1.1 NDVI Value Visualization Map

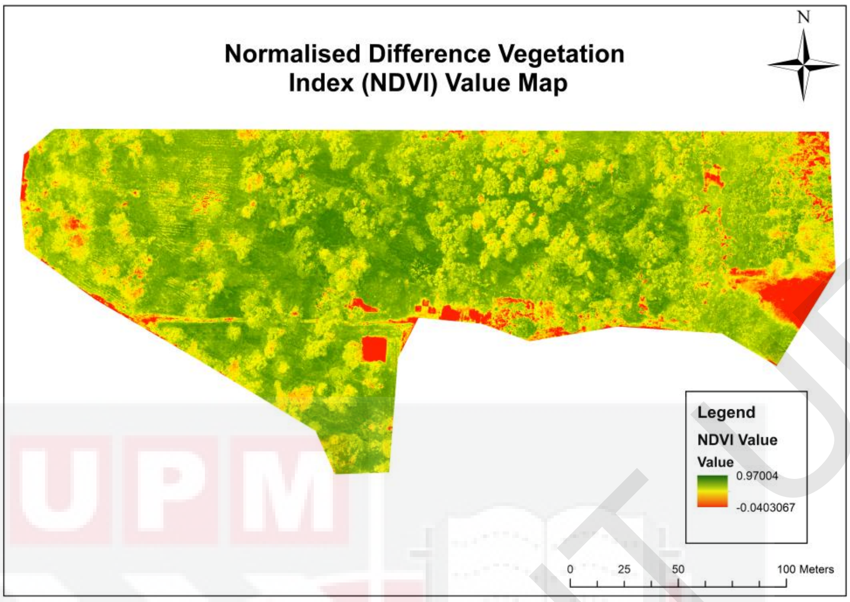


Figure 4. 2 NDVI value visualization map

The red colour indicates problematic area. The healthy vegetation tends to absorb visible band and reflects most of the NIR light. Meanwhile, the unhealthy vegetation reflects less on NIR light and more on visible band (Tugi, 2015).

NDVI produce a value range from +1.0 to -1.0. High vegetation value will be in the range close to 1.0 while lowest vegetation value will be in the range close to 0, for instance, forest has thicker canopy which will reach the NDVI value close to 1.0. Usually value close to 0 indicates less or no vegetation (Weier & Herring, 2000). At the durian plantation in this study, most of the reflectance was affected by the canopy of the durian trees which reflects Green band due to the high chlorophyll and absorbs Red and Blue band due to low chlorophyll and this helps to explain the outcome of the NDVI value.

4.2.1.2 NDVI Value Classification Map

Image classification map is produced and majority of durian crops fall in the 1st class NDVI value classification which is; healthy with the NDVI value range from 0.88-0.98. The highest NDVI value that can be seen in the plantation area has achieve around 0.88 – 0.98. The durian trees with NDVI value less than 0.82 needs to be paid attention to as its growth is not at the optimum rate. The low NDVI value could be due to several factors such as lack of nutrients in the soil, insufficient amount of fertilizer, diseases, pest attack and so on. Figure 4.3 shows the digital output map of the NDVI classification map.

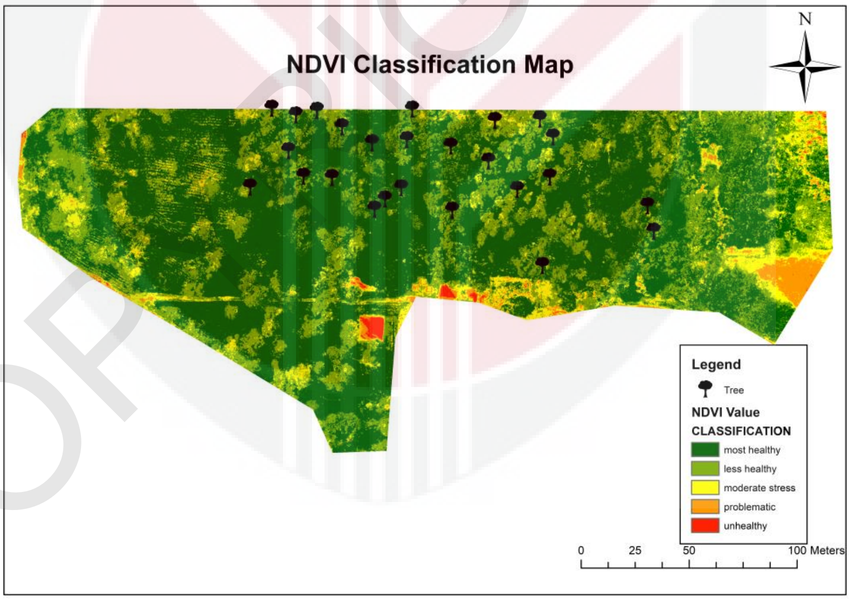


Figure 4. 3 NDVI classification map

NDVI is the best VI used to differentiate between vegetation and non-vegetation. As in the map, we can see clearly there is a red area and it can be compared to ground truth to determine and identify the object in the plantation area without going to the ground. The comparison of the ground truth image can be done in the Pix4D Fields software. In this case the red area turns out to be a building as shown in the Figure 4.3.

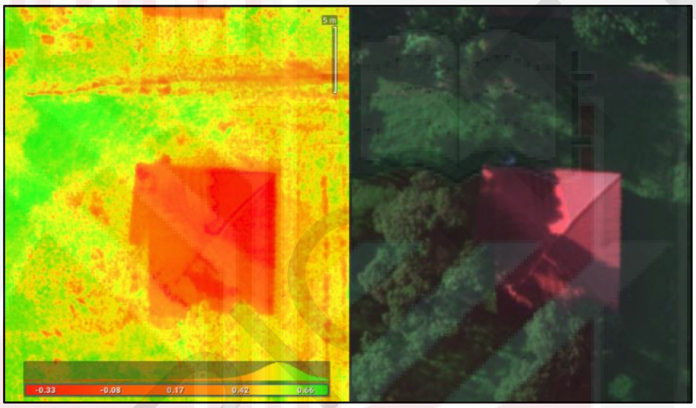


Figure 4. 4 Comparison between NDVI value and ground truth image

4.2.2 Normalised Difference Red-Edge (NDRE)

Normalised Difference Red-Edge was analysed to produce digital map visualization to the farmers. NDRE produce value range from -1 to 1. The NDRE index results shows ranging from -0.32 to 0.83. The NDRE index is the best VI to determine the estimating of vegetation health using the red-edge band. Also, it can be used to map the within-field variability of nitrogen foliage to understand the fertilizer requirements of crops. The result of NDRE index distribution is smaller. This shows that precise value of crop health can be obtained as the pixel value is smaller. Figure 4.5 below shows the output results of the NDRE value map.

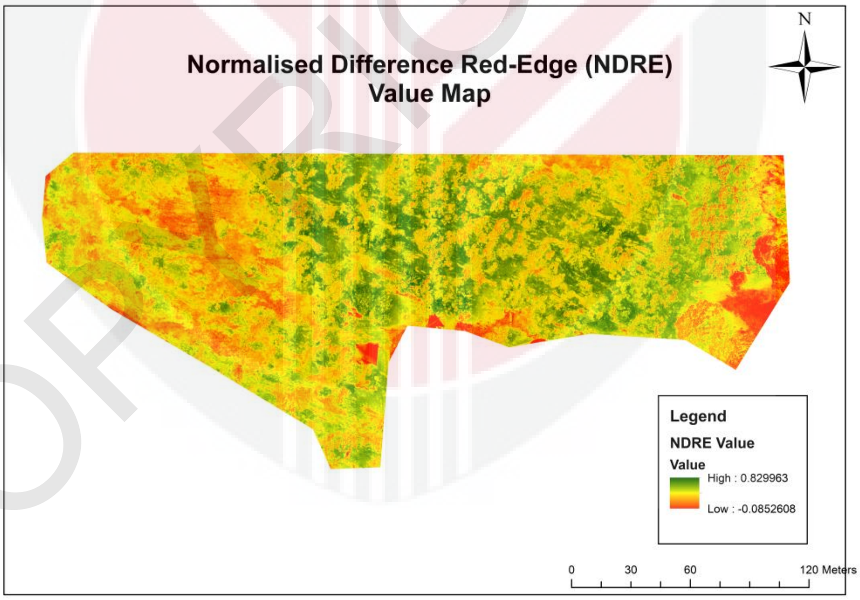


Figure 4. 5 NDRE value visualization map

4.2.2.1 NDRE Value Classification Map

Image classification map is produced and majority of durian crops fall in the 2nd class NDVI value classification; less healthy with the NDRE value range from 0.48 – 0.55. The highest NDRE value that can be seen in of the plantation area has achieve around 0.56 – 0.83. The NDRE values that were less than 0.48 needs to be paid attention to as its growth is not at the optimum rate. Figure 4.6 shows the digital output map of the NDVI classification map.

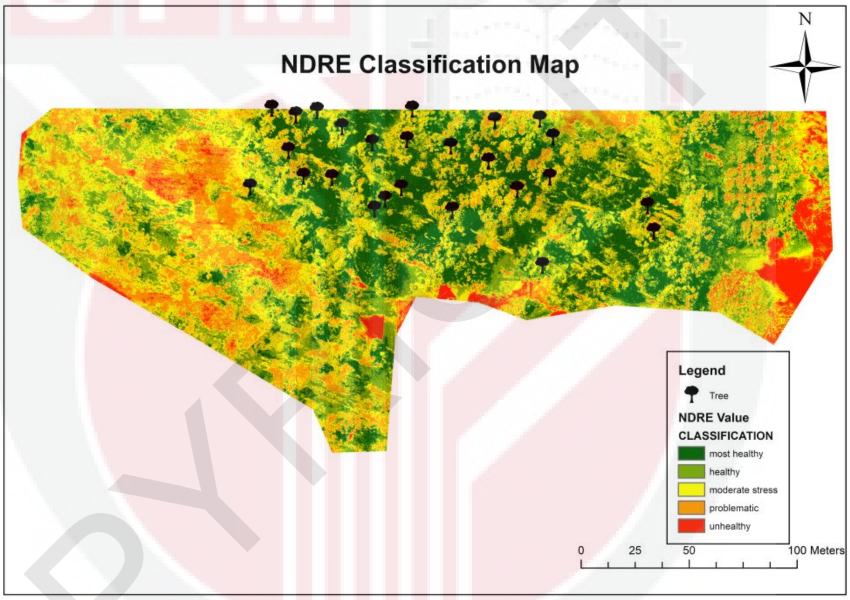


Figure 4. 6 NDRE classification map

4.2.3 Misclassification map

The NDRE and NDVI classification map is then overlaid with the ground truth trees point to see the misclassified tree. 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.

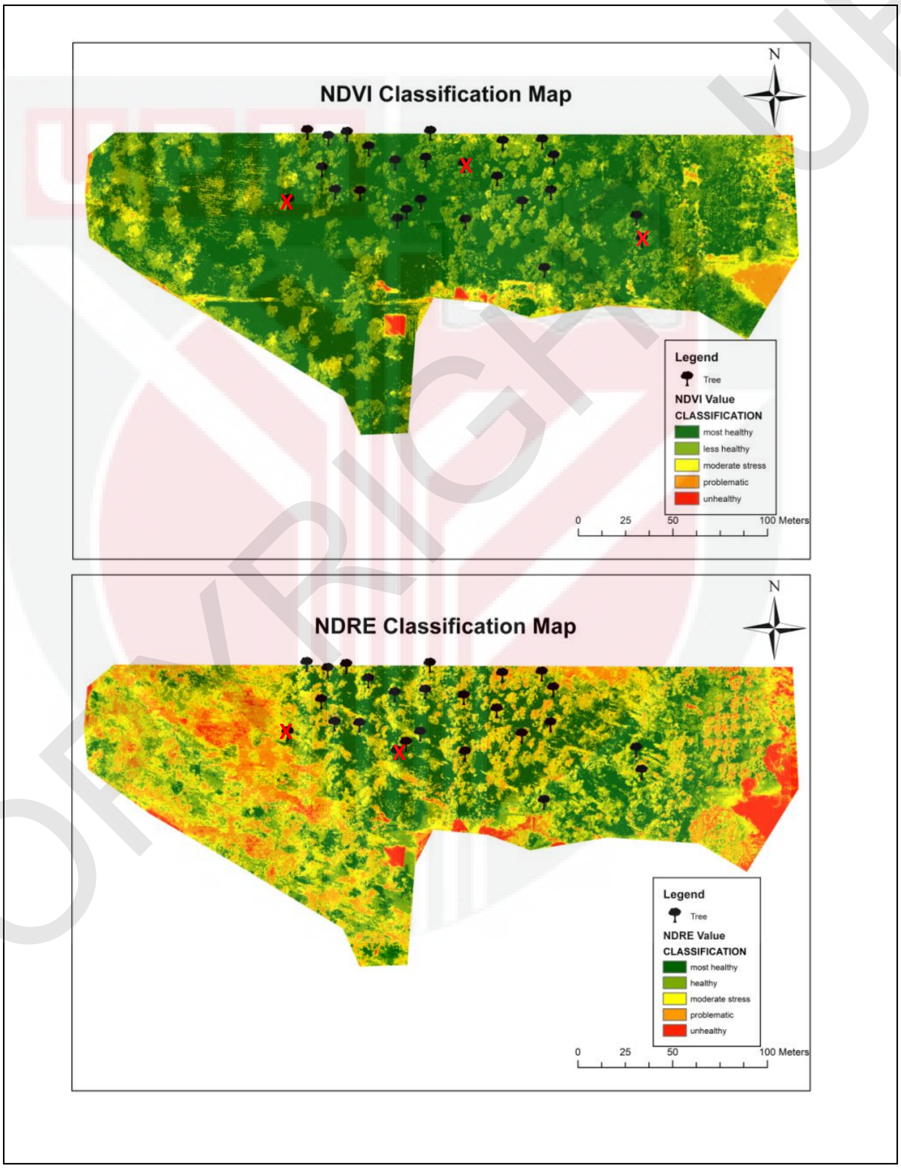


Figure 4. 7 The overlaid map of misclassification trees with the actual ground truth observation

4.2.4 NDVI and NDRE Comparison

The NDVI and NDRE maps are compared with the 25 samples of trees used for the ground truthing and the difference can be seen clearly. NDRE index classification value had smaller value compared to NDVI classification value. This is because of the narrower wavelength in the Red edge band.

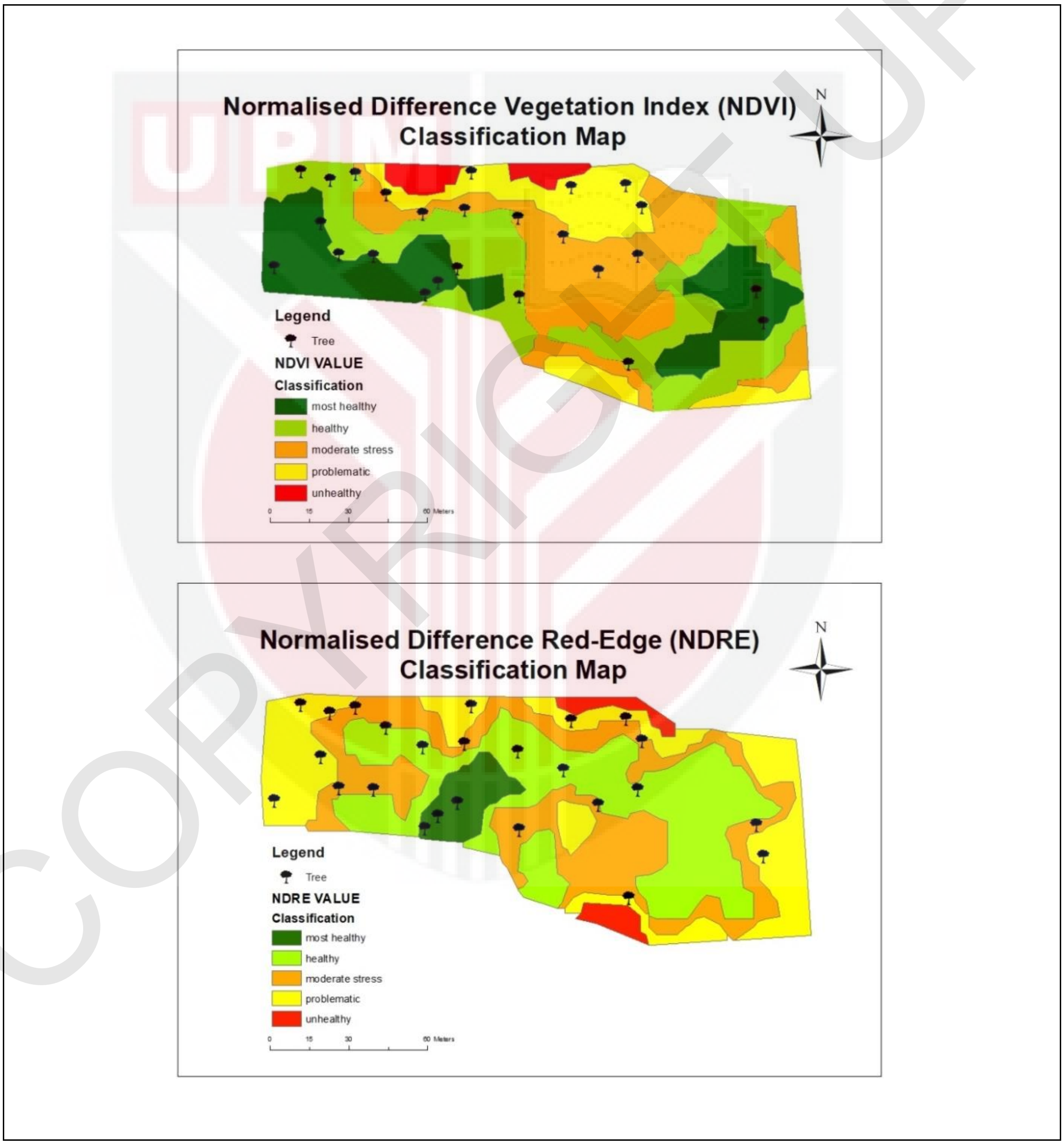
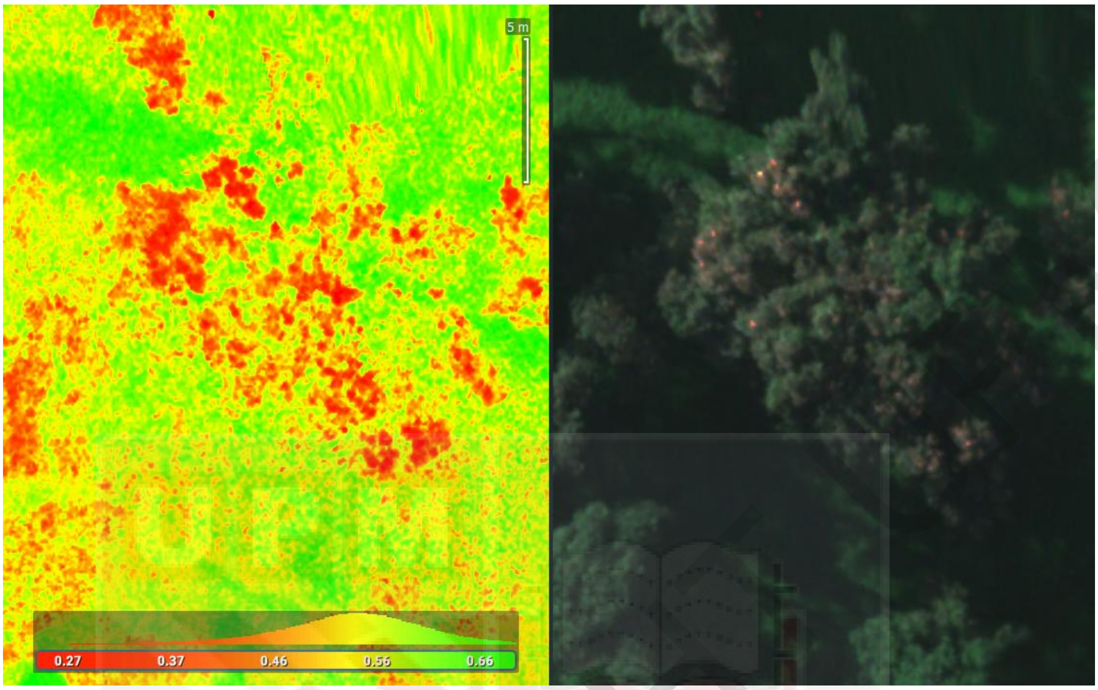


Figure 4. 8 Image classification visualization comparison between NDVI and NDRE map

Figure 4.8 shows image classification visualization comparison between NDVI and NDRE. The map shows that more area is classified in NDRE as compared to NDVI map. Figure 4.9 below 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.

a) NDVI value map compared to ground truth image of aerial imagery



b) NDRE value map compared to ground truth image of aerial imagery

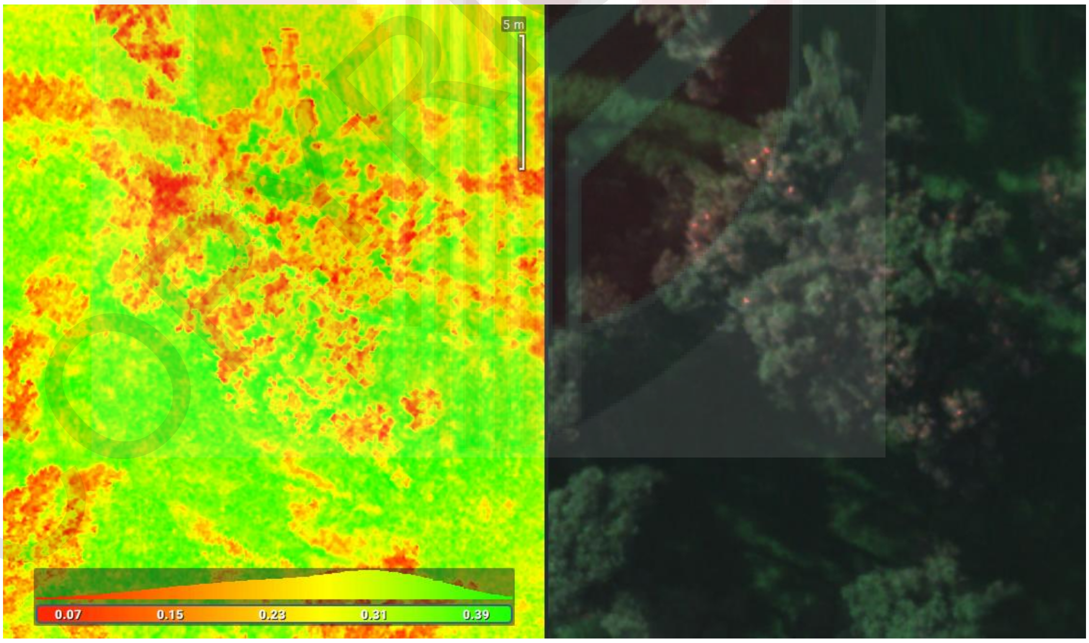


Figure 4. 9 Vegetation Index value map as compared to ground truth imagery

4.2.5 Chlorophyll – Index

The visualization map of the amount of chlorophyll content in the plantation area is generated using the ClG and ClRE indices where different bands which are Red and Red Edge are used. Figure 4.10 below shows the results of the output map. Visualization of chlorophyll content shows that the amount chlorophyll analysis based on green band and Red-Edge band. The chlorophyll maps are useful to farmers to check on the diseases that affected the leaves. The similarity of Chlorophyll Index of the vegetation health is similar to NDVI and NDRE. Here, we found that ClRE has smaller value as compared to ClG because of the Red Edge band used. ClRE can be used in visualizing the chlorophyll level in the durian trees as the value is not influenced by the grass in the plantation area. The visualization maps can be seen as below.

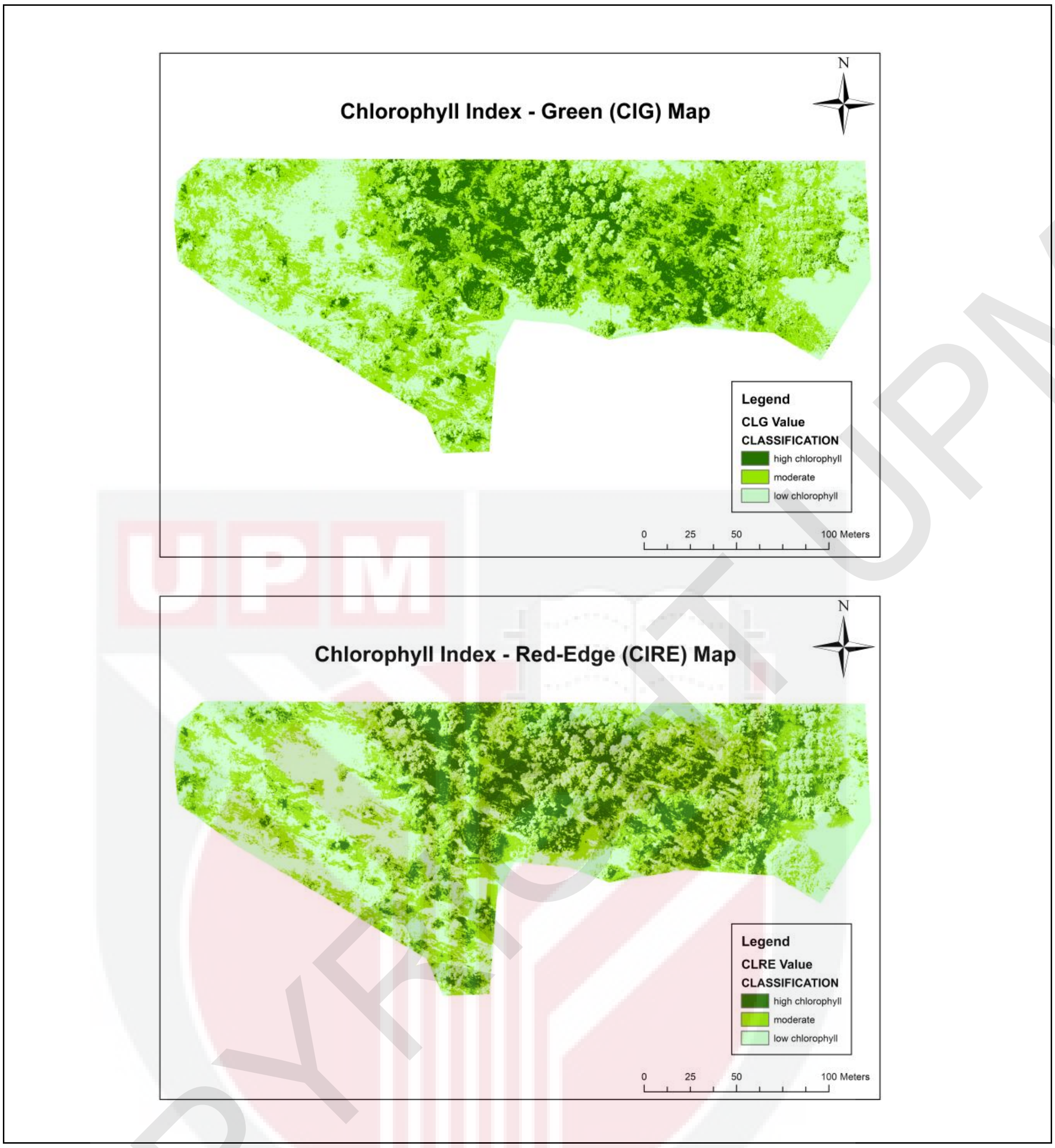


Figure 4. 10 The visualization map of Chlorophyll Index

4.3 Import of Data to GIS

The orthomosaic images from Pix4D Mapper software as shown in Figure 4.9 below which has been georeferenced and vegetation index analysed is imported to ArcGIS to create attributes table and digital map output.

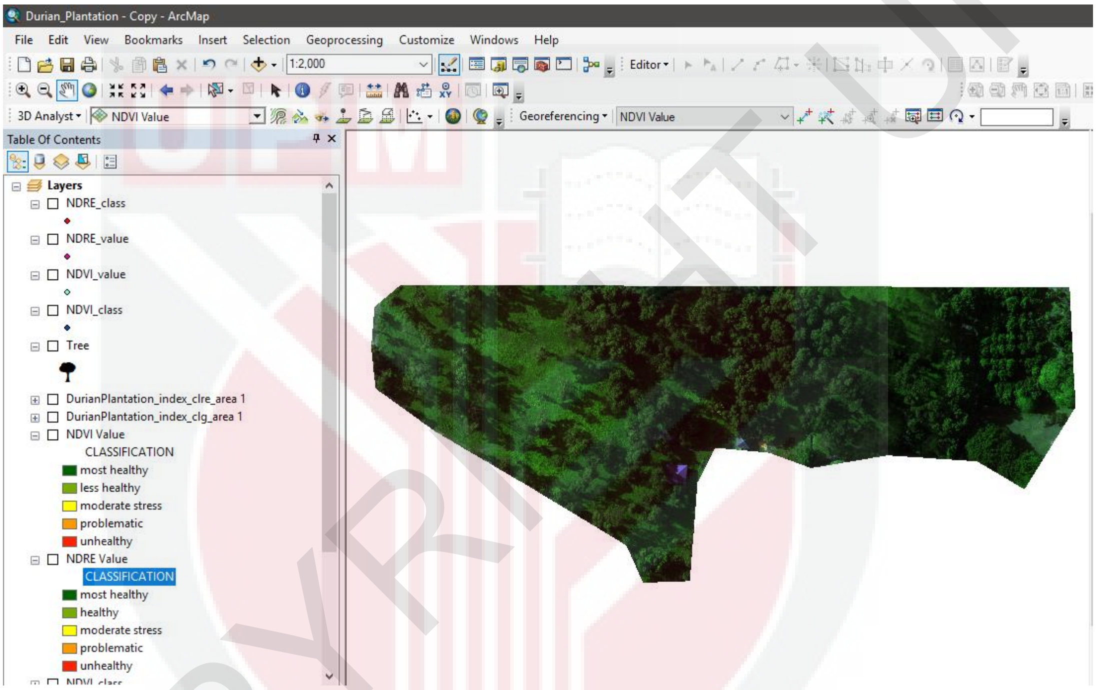


Figure 4. 11 Durian plantation orthomosaic

Then, the map coordinates of GPS location of ground truth tree observation are imported to ArcGIS and overlaid on the Vegetation Index Map. Figure depict that the trees points is successfully overlaid on the NDRE and NDVI classification map shown in Figure 4.12 and 4.13 respectively.

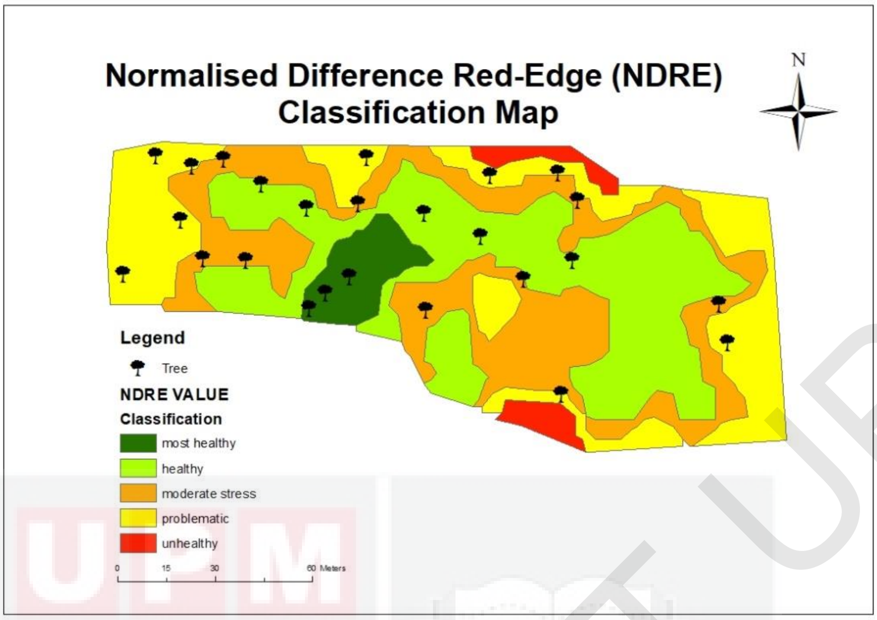


Figure 4. 12 The map of trees points were imported and overlaid on the NDRE value classification map

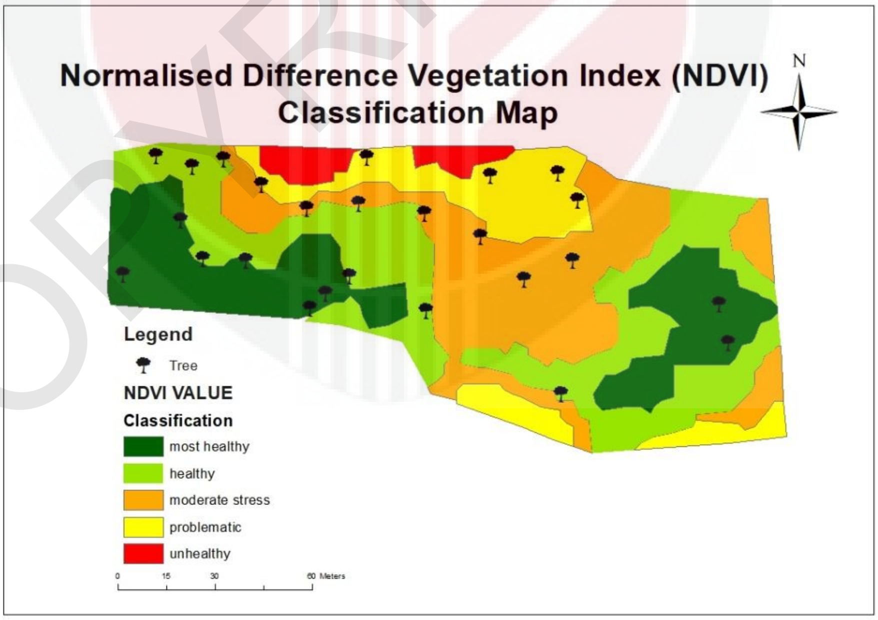


Figure 4. 13 The map of trees points were imported and overlaid on the NDVI value classification map

4.4 Accuracy Assessment

The accuracy of the durian trees health classification between NDRE map classification and the ground truth observation is presented in Table 4.1. The positions of the trees have been validated with the GPS Trimble Juno3B and imported to ArcGIS. The trees condition is then be compared to ground truth image from the UAV. The NDRE accuracy obtained with the ground truth is 92%. NDRE classification was checked with ground truth observation of 25 trees. 23 trees correctly predicted by NDRE. Accuracy with ground truth is 92%.The incorrect trees out just by one class. The accuracy for NDVI with 25 samples of ground truth observation is checked. 22 trees correctly predicted by NDVI. The accuracy achievable is 88%. The trees condition of ground truth and NDVI index is shown in Table 4.2 below.

Table4. 1 Comparison of the classification between NDVI and ground truth observation

Tree ID	Type Clone	NDVI value	NDVI classification	Ground Truth classification
T 08	D 24	0.53	unhealthy	unhealthy
T 09	D 24	0.57	unhealthy	unhealthy
T 10	D 24	0.69	unhealthy	unhealthy
T 11	D 24	0.51	unhealthy	unhealthy
T 12	D 16	0.70	unhealthy	unhealthy
T 19	D 24	0.67	unhealthy	unhealthy
T 20	D 24	0.81	healthy	healthy
T 21	D 24	0.58	unhealthy	healthy
T 22	D 24	0.81	healthy	healthy
T 23	D 2	0.89	healthy	healthy
T 24	D 2	0.88	healthy	healthy
T 25	D 2	0.87	healthy	healthy
T 26	D 16	0.86	healthy	unhealthy
T 27	D 16	0.91	healthy	healthy
T 28	D 2	0.89	healthy	unhealthy
T 29	D 24	0.57	unhealthy	unhealthy
T 30	D 2	0.61	unhealthy	unhealthy
T 31	D 24	0.87	healthy	healthy
T 32	D 2	0.86	unhealthy	unhealthy
T 33	D 16	0.88	healthy	healthy
T 34	D 2	0.92	healthy	healthy
T 37	D 24	0.58	unhealthy	unhealthy
T 38	D 24	0.90	healthy	healthy
T 39	D 2	0.85	healthy	healthy
T 40	D 16	0.48	unhealthy	unhealthy

Table 4. 2 Comparison of the classification between NDRE and ground truth observation

Tree ID	Type Clone	NDRE value	NDRE classification	Ground Truth classification
T 08	D 24	0.41	unhealthy	unhealthy
T 09	D 24	0.45	unhealthy	unhealthy
T 10	D 24	0.34	unhealthy	unhealthy
T 11	D 24	0.40	unhealthy	unhealthy
T 12	D 16	0.43	healthy	unhealthy
T 19	D 24	0.42	unhealthy	unhealthy
T 20	D 24	0.65	healthy	healthy
T 21	D 24	0.68	healthy	healthy
T 22	D 24	0.56	healthy	healthy
T 23	D 2	0.51	healthy	healthy
T 24	D 2	0.51	healthy	healthy
T 25	D 2	0.50	healthy	healthy
T 26	D 16	0.49	unhealthy	unhealthy
T 27	D 16	0.61	unhealthy	healthy
T 28	D 2	0.43	unhealthy	unhealthy
T 29	D 24	0.46	unhealthy	unhealthy
T 30	D 2	0.36	unhealthy	unhealthy
T 31	D 24	0.49	healthy	healthy
T 32	D 2	0.44	unhealthy	unhealthy
T 33	D 16	0.58	healthy	healthy
T 34	D 2	0.59	healthy	healthy
T 37	D 24	0.42	unhealthy	unhealthy
T 38	D 24	0.48	healthy	healthy
T 39	D 2	0.54	healthy	healthy
T 40	D 16	0.44	healthy	unhealthy

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

Crops scouting using visual ground observation are time consuming and it is not an easy task to monitor every part of the durian plantation especially for larger plantation area. Along these lines, application of aerial imaging such as UAV can be one of the best effective approaches for crops scouting. This research effectively demonstrated on the potential of utilizing UAV as one of the modern agriculture tools to monitor crops in the field and to estimate vegetation health.

From the results, the accuracy achievable by using NDVI to determine plant stress health is 88% and NDRE 92%. NDRE is the best index that can be used to visualize the chlorophyll content in the durian trees. This is because of the higher sensitivity of the chlorophyll absorption from the Red-Edge band in this equation. The Red-Edge band is capable to penetrate further in the tree canopy and leaf from the visible light due to low chlorophyll absorption in the Red-Edge band. The absorption sensitivity in the Red-Edge band is high in the visible light. The reflection feature in the Red-Edge of the spectrum characterized by the dark colour in the red portion of the visible spectrum is caused by absorption of Red and Blue band by chlorophyll. In contrast to high reflectivity in NIR, due to the light scattered from refraction along between leaf and space cells air in the leaves. Therefore, Red-Edge strips can be used as a benchmark to determine variation between absorption and reflection features.

The Vegetation Indices NDVI, NDRE, ClG and ClRE 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.

5.2 Recommendation for Future Work

An enhancement of this project should be conducted to improve the comparison carried in this research. Thus, the accuracy can be increased. From the results and findings it is recommended to consider the specifications of the UAV used so that minimal cost of data acquisition can be achieved thus can reduced the overall cost for farmers to implement the applications of UAV in the durian plantation management.

Additional data such as the amount of chlorophyll content of durian leaves, the soil moistures and the monthly occasional data of the crops should be obtained so that better prediction of vegetation health can be made. Besides, it is recommended to take the data acquisition from the young and mature trees so that more comparison of durian characterization can be obtained.

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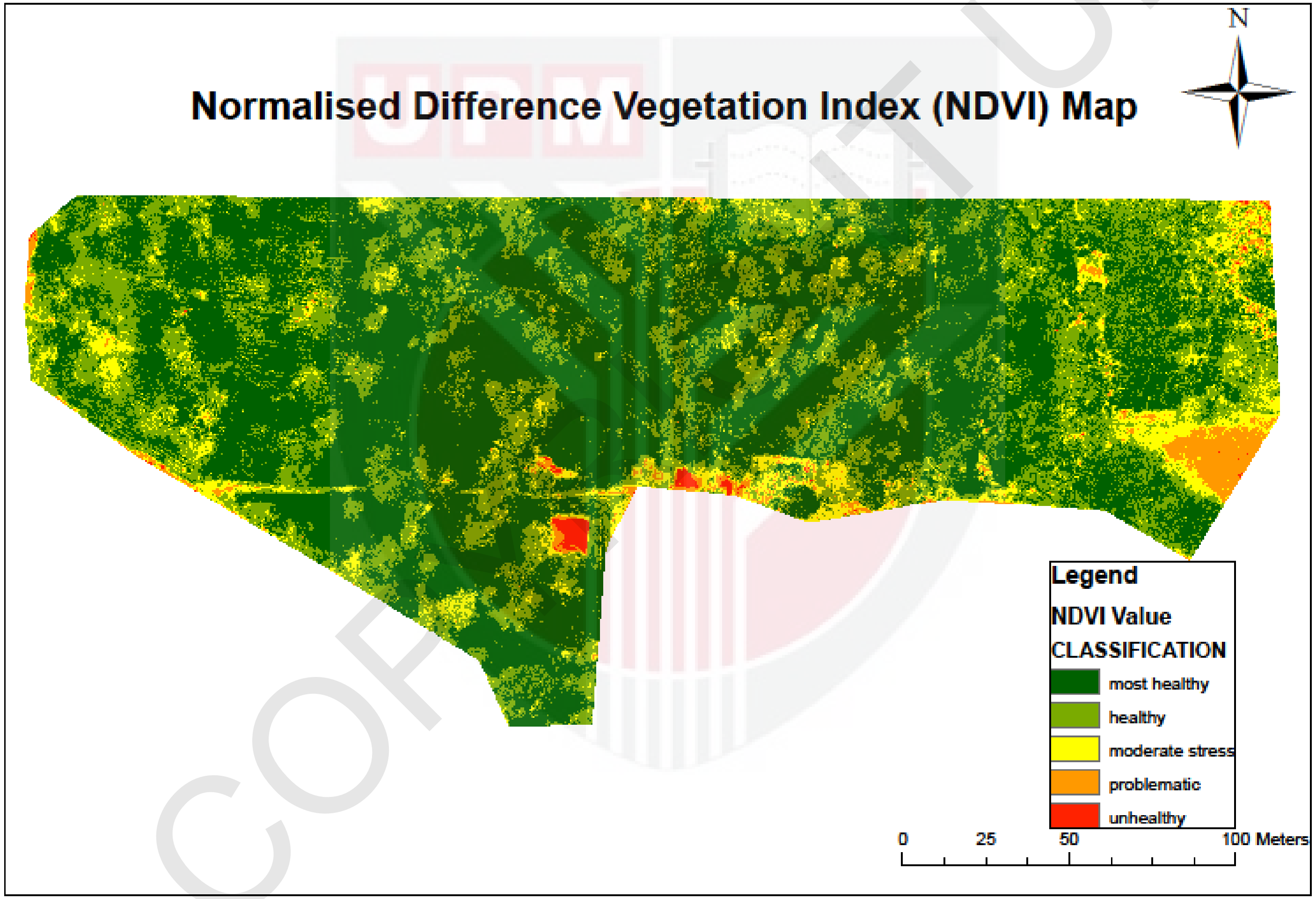
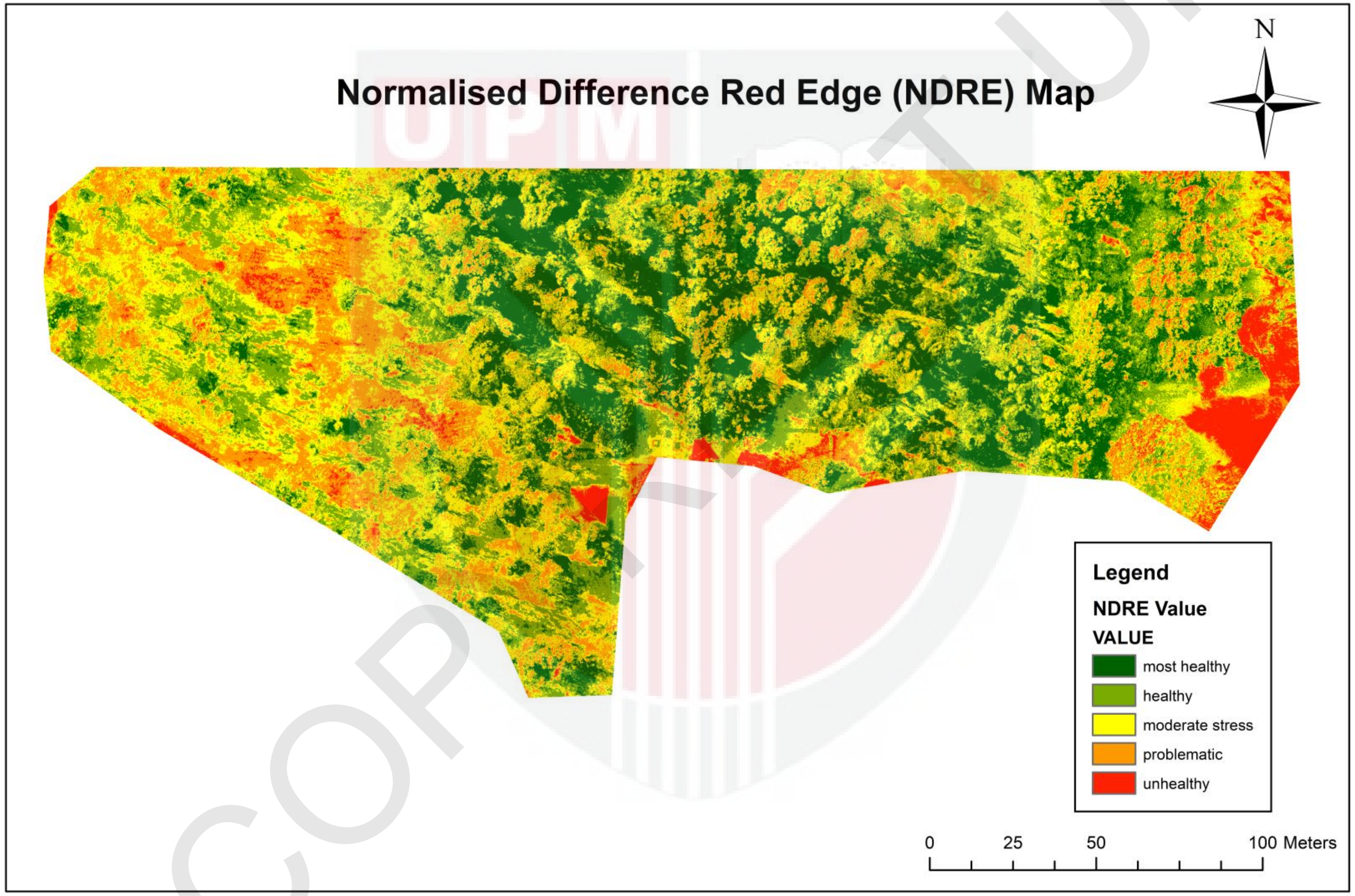
APPENDICES

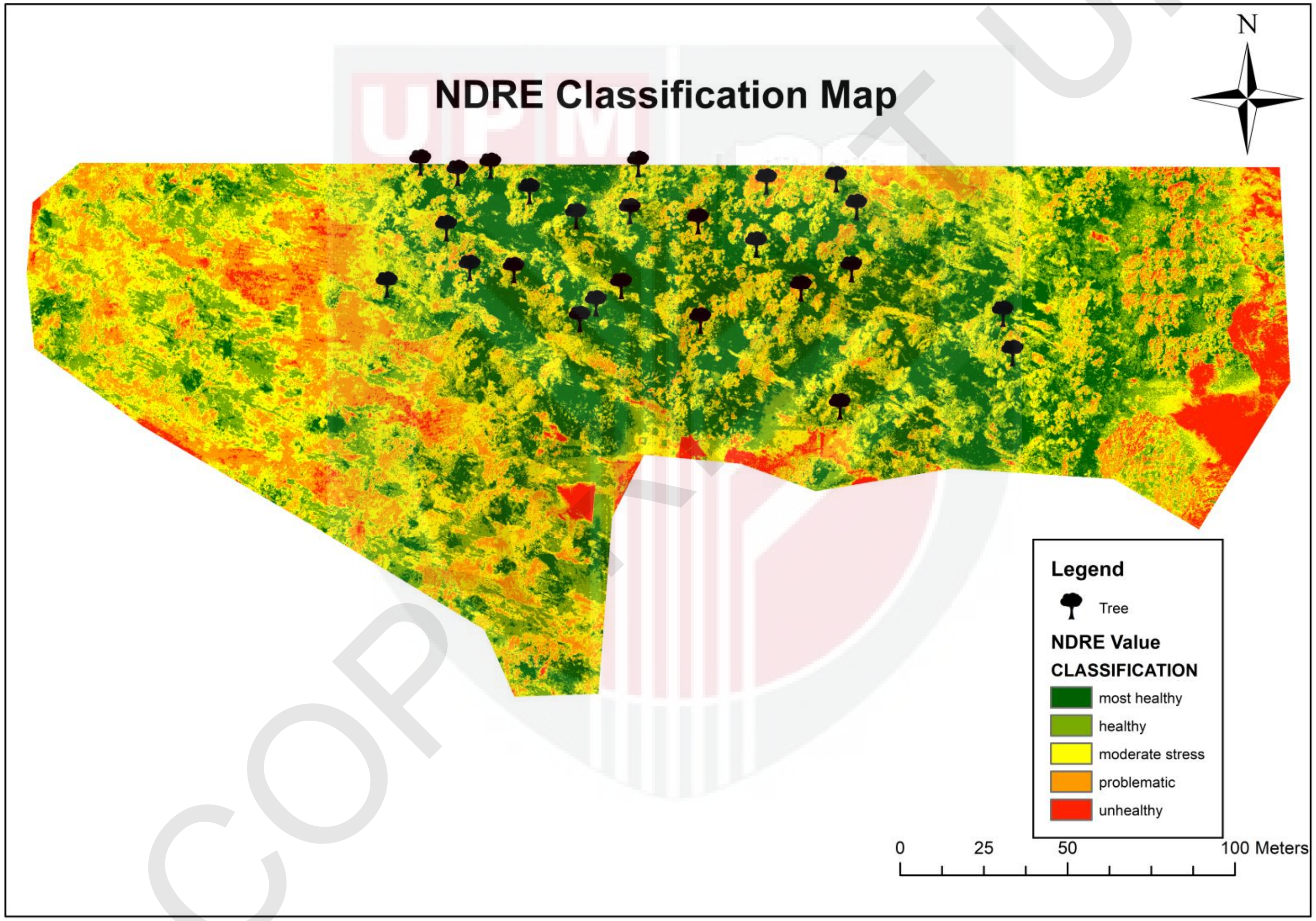
MATA TUNAS DURIAN PLANTATION DATABASE

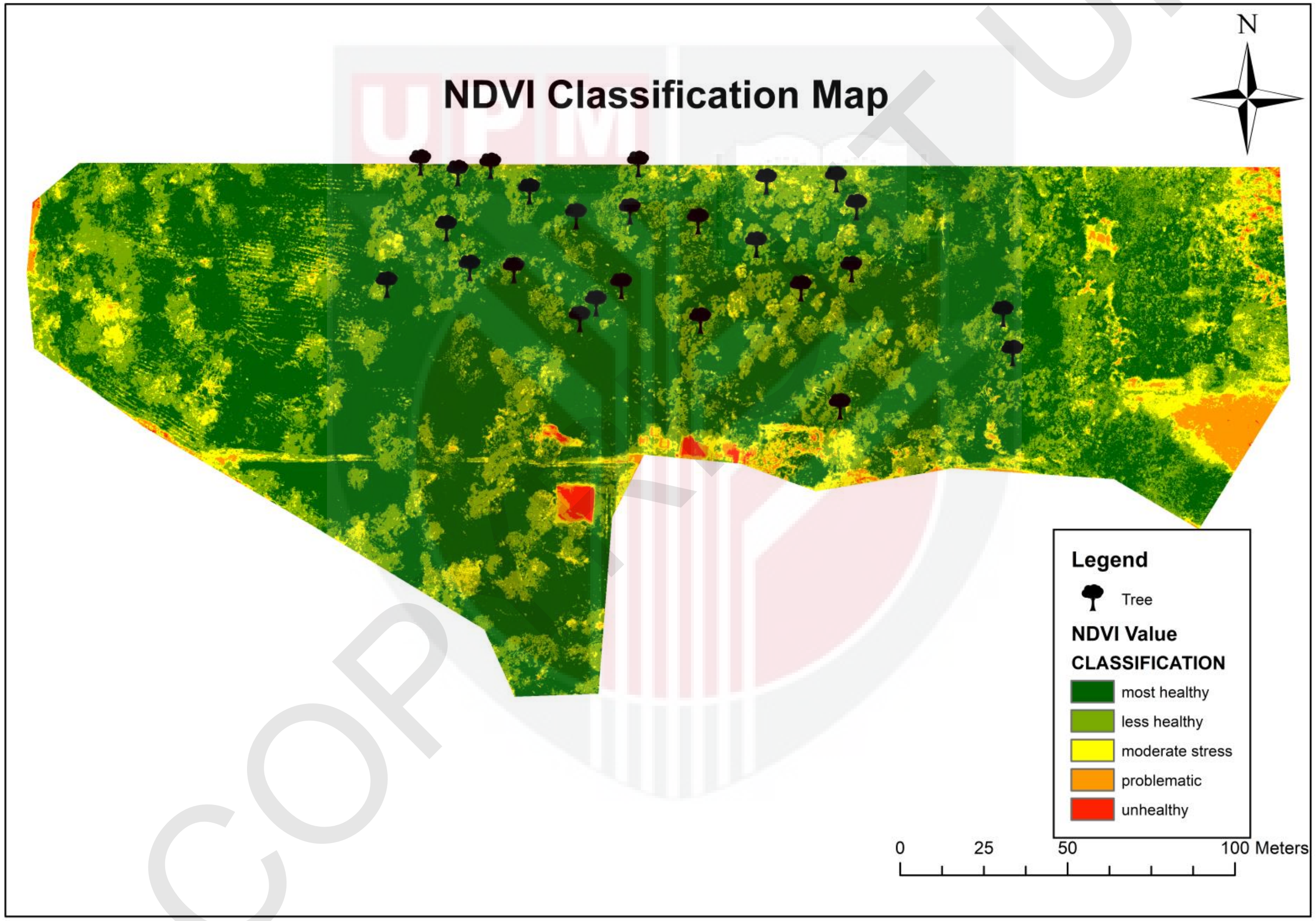
Tree_ID	Type_Clone	NDVI_value	NDRE_Value	NDVI_Class	NDRE_class	Ground_data
T 08	D 24	0.53	0.41	unhealthy	unhealthy	unhealthy
T 09	D 24	0.57	0.45	unhealthy	unhealthy	unhealthy
T 10	D 24	0.69	0.34	unhealthy	unhealthy	unhealthy
T 11	D 24	0.51	0.40	unhealthy	unhealthy	unhealthy
T 12	D 16	0.70	0.43	unhealthy	healthy	unhealthy
T 19	D 24	0.67	0.42	unhealthy	unhealthy	unhealthy
T 20	D 24	0.81	0.65	healthy	healthy	healthy
T 21	D 24	0.58	0.68	unhealthy	healthy	healthy
T 22	D 24	0.81	0.56	healthy	healthy	healthy
T 23	D 2	0.89	0.51	healthy	healthy	healthy
T 24	D 2	0.88	0.51	healthy	healthy	healthy
T 25	D 2	0.87	0.50	healthy	healthy	healthy
T 26	D 16	0.86	0.49	healthy	unhealthy	unhealthy
T 27	D 16	0.91	0.61	healthy	unhealthy	healthy
T 28	D 2	0.89	0.43	healthy	unhealthy	unhealthy
T 29	D 24	0.57	0.46	unhealthy	unhealthy	unhealthy
T 30	D 2	0.61	0.36	unhealthy	unhealthy	unhealthy
T 31	D 24	0.87	0.49	healthy	healthy	healthy
T 32	D 2	0.86	0.44	unhealthy	unhealthy	unhealthy
T 33	D 16	0.88	0.58	healthy	healthy	healthy
T 34	D 2	0.92	0.59	healthy	healthy	healthy
T 37	D 24	0.58	0.42	unhealthy	unhealthy	unhealthy
T 38	D 24	0.90	0.48	healthy	healthy	healthy
T 39	D 2	0.85	0.54	healthy	healthy	healthy
T 40	D 16	0.48	0.44	unhealthy	healthy	unhealthy


Normalised Difference Vegetation Index (NDVI) Map
N
Legend
NDVI Value
CLASSIFICATION
most healthy
healthy
moderate stress
problematic
unhealthy
0
25
50
100 Meters

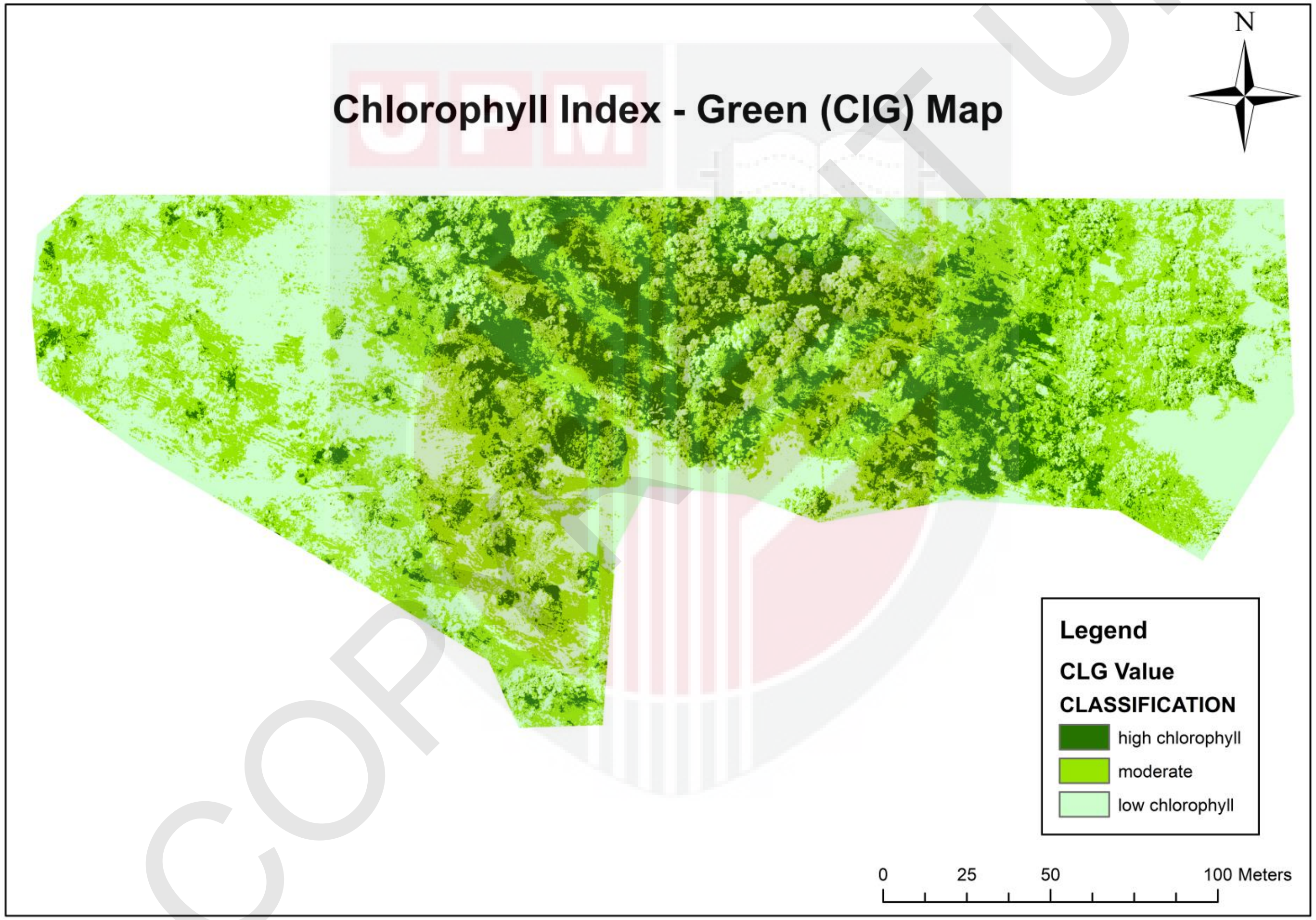


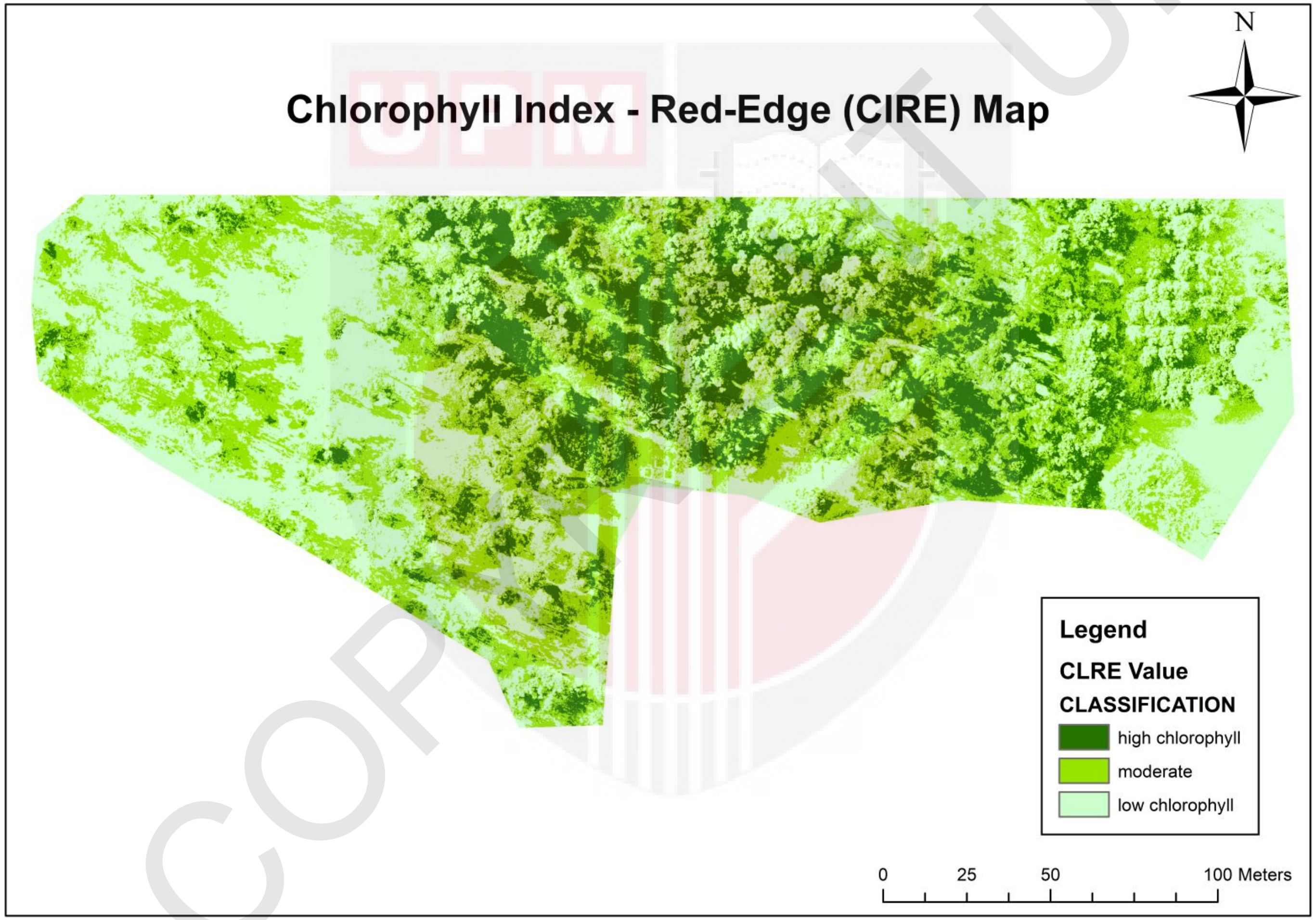
Normalised Difference Red Edge (NDRE) Map
N
Legend
NDRE Value
VALUE
most healthy
healthy
moderate stress
problematic
unhealthy
0
25
50
100 Meters


NDRE Classification Map
N
Legend
Tree
NDRE Value
CLASSIFICATION
most healthy
healthy
moderate stress
problematic
unhealthy
0
25
50
100 Meters



NDVI Classification Map
N
Legend
Tree
NDVI Value
CLASSIFICATION
most healthy
less healthy
moderate stress
problematic
unhealthy
0
25
50
100 Meters


Chlorophyll Index - Green (CIG) Map
N
Legend
CLG Value
CLASSIFICATION
high chlorophyll
moderate
low chlorophyll
0
25
50
100 Meters


Chlorophyll Index - Red-Edge (CIRE) Map
N
Legend
CLRE Value
CLASSIFICATION
high chlorophyll
moderate
low chlorophyll
0
25
50
100 Meters