CLASSIFICATION OF TROPICAL RAINFOREST USING DIFFERENT CLASSIFICATION ALGORITHM BASED ON REMOTE SENSING IMAGERY : A STUDY OF GUNUNG BASOR

by

INTAN NORADYBAH BT MD RODI

A proposal submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Natural Resources Science) with Honours

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2019

DECLARATION

I declare that this thesis entitled "Classification Of Tropical Rainforest Using Different Classification Algorithm Based On Remote Sensing Imagery : A Study Of Gunung Basor" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Natural Resource) with Honors

Signature	:	……………………………..........
Name of Supervisor	:	
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ACKNOWLEDGEMENT

I am really grateful because I managed to complete my final year project and thesis report writing. Special thanks for those who helped me throughout this journey directly and indirectly. Throughout the period of two semesters completing this project, I want to take this opportunity to express my utmost gratitude to several parties as they have been supporting me in completing this task. Firstly, I want to thank the Almighty given that I was able to complete the final year project without much difficulties.

Aside, I would like to express my utmost grateful to my final year project supervisor, Dr. Shaparas Bt Daliman for encourage and lead me in doing this project. I would like to thank her for all the guidance and time in helping me to conduct my project. I am deeply grateful for her kindness in explaining the details of the project including the help that was given when I was facing some difficulties while was on this project.

Next, I would like to thank my parent and family who give moral supports till the day I manage to complete this project. Last but not least, I also want to express my thankfulness to my supportive friends for helping and giving me support despite of their busy schedule, they taught and shared their knowledge in completing this project.

Classification Of Tropical Rainforest Using Different Classification Algorithm Based On Remote Sensing Imagery : A Study Of Gunung Basor

ABSTRACT

Remote sensing technologies are used globally to derive some of crucial spatial variable parameter such as vegetation cover. Three different classification algorithm, minimum distance classifier, Mahalanobis distance classifier and maximum likelihood algorithm was applied to classify the forest area in Gunung Basor. The study area is located in Gunung Basor, Jeli. The area is a high potential growing region for different tree species. The main objectives is to develop a forest tree recognition techniques and build a classification strategy for forest tree area segmentation. By producing classification map, accuracy for the classification can be determined. The highest accuracy for classification map of Gunung Basor is by using maximum likelihood algorithm with an accuracy of 82.90%. Thus, this project is important to increase the accuracy of forest classification by using minimum distance classifier, Mahalanobis distance classifier and maximum likelihood algorithm to develop a techniques for forest tree recognition based on remote sensing imagery. Hence, the result from this study represent the synergistic use of high resolution optical imagery can be efficient to improve the characterization of tropical rainforest.

Klasifikasi Hutan Hujan Tropika Menggunakan Algoritma Klasifikasi Berbeza Berdasarkan Imej Penderiaan Jarak Jauh : Kajian Gunung Basor

ABSTRAK

Teknologi penderiaan jauh digunakan secara global untuk mendapatkan beberapa parameter pembolehubah spatial penting seperti litupan tumbuhan dengan menggunakan data imej drone untuk hutan hujan tropika di Gunung Basor, Kelantan. Tiga algoritma klasifikasi yang berbeza, *minimum distance classifier*, *Mahalanobis distance classifier* dan *maximum likelihood algorithm* telah digunakan di kawasan Gunung Basor. Kawasan kajian terletak di Gunung Basor, Jeli. Kawasan ini merupakan kawasan yang berpotensi tinggi untuk spesies pokok yang berlainan. Objektif utamanya ialah untuk membangunkan teknik penentuan pokok hutan dan membina strategi pengkelasan untuk segmentasi kawasan pokok hutan. Dengan menghasilkan peta klasifikasi, kawasan litupan hutan dapat ditentukan. Ketepatan tertinggi untuk peta klasifikasi Gunung Basor adalah dengan menggunakan *maximum likelihood algorithm* dengan ketepatan 82.90%. Oleh itu, projek ini penting untuk meningkatkan ketepatan penghitungan pokok hutan dengan menggunakan klasifikasi jarak minimum, pengelas jarak Mahalanobis dan algoritma kemungkinan maksimum untuk membangunkan teknik pengiktirafan pokok hutan berdasarkan imej penginderaan jarak jauh. Oleh itu, hasil daripada kajian ini mewakili penggunaan kecekapan sinergistik imejan optik resolusi tinggi untuk meningkatkan pencirian hutan hujan tropika.

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LIST OF ABBREVIATIONS

2D	2 Dimensional
3D	3 Dimensional
CO_2	Carbon Dioxide
DBH	Diameter Breast Height
DEM	Digital Elevation Model
DN	Digital Number
DTM	Digital Terrain Model
DSM	Digital Surface Model
ENVI	Environment for Visualizing Images
GIS	Geographical Information System
GPS	Global Positioning System
NCC	Normalized Cross Correlation
NIR	Near Infra-red
UAV	Unmanned Aerial Vehicle

LIST OF SYMBOLS

°	Degree
d	Distance
G_{max}	Highest Grey Level
f	Image
μ	Mean Intensity Value
m	Metre
′	Minute
mm	Millimetre
×	Multiply
I_{rw}	New Image
N	North
N_{iter}	Number of iteration
%	Percent
p	Position
q	Seed Point
S	Similarity
S	South
t	Time
∑	Total

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Forest ecosystem play an important role in human society. Well managed forest not only provide multiple resources such as timber, energy and foods, it also provide essential services such as carbon sink, regulating biogeochemical cycles and climate. The foundation of forest management is acquiring detailed forest inventory information. Forest metrics frequently collected include mean basal area, mean height, density per tree, and crown closure at the compartment level as well as individual tree parameters such as location, tree species and tree-crown size.

Conventional forest inventory involves periodic field measurement of parameters for each tree in the sample area. Visual analysis of aerial photography has had major application in forest inventory and analysis as an alternative to field measurement since the early 1960s (Singh, 1986). However, both field measurement and visually based analysis techniques are labour and cost intensive. Remote sensing technology has developed rapidly. Both airborne sensors and satellite sensors are now able to acquire high spatial resolution digital imagery accurately and cost-effectively. Mirroring this progress, the increased speed found in modern computer systems has facilitated the development of digital image analysis for automated recognition of specific object characteristics. This growth provides viable sources of data and opportunities for automated forest analysis at the tree level, which requires identification of individual tree crowns.

Individual tree-crown identification has been utilised for estimating crown size, crown closure and tree species. In addition, such techniques enhance derivation of forest inventory parameters such as forest density and species composition. Other parameters, such as tree diameter breast height (DBH) can also be extracted.

Forests are valuable resource providing food, shelter, wildlife habitat, fuel, and daily supplies such as medicinal ingredients and paper. Forests play an important role in balancing the Earth's carbon dioxide (CO_2) supply and exchange, acting as a key link between the atmosphere, geosphere, and hydrosphere. Tropical rainforests is a home to huge diversity of species which is more capable of adapting to the environment. Forests has always been a green treasure in Malaysia. Forested areas in the world has faced a great reduction in quantity, thus it is important that we manage these renewable resources in a sustainable manner. In order to formulate and exercise efficient forest management policies and practices, it is important to assess the status of regenerating forest and to estimate the size of forest.

Forest resource maps were traditionally prepared from forest inventories involving aerial photography and fieldwork (Suhaili et al., 2006). However modern technology, Geographic Information System (GIS) technique and Remote Sensing (RS) from satellite platforms provides an alternative and economic tool for forest mapping (Suhaili et al., 2006). In recent decades, as an alternative or compliment to field-based assessments, high spatial resolution satellite and aerial imagery has been used to quantify various aspects of forest structure and function (Strand et al. 2008). Availability and wide coverage of high spatial resolution satellite imagery has resulted in opportunities for rapid and detailed analysis of forests over large areas, including individual tree detection in both naturally regenerating forests and vegetation plantations.

1.2 Problem Statement

There were enormous challenges for deriving forest structure parameter using high resolution optical imagery because of spectral similarity of vegetation, mixed pixels, shadows of trees, layers and multiple sizes of tree crowns. In order to reduce these uncertainties, a different classification methods will be analysed for forest area segmentation. Hence, a forest recognition techniques was developed based on the highest accuracy achieved.

1.3 Objectives

The main objectives of this research is to build a classification strategy for forest tree area segmentation based on minimum distance classifier, Mahalanobis distance classifier and maximum likelihood algorithm.

1.4 Scope Of Study

The study aims in developing a classification strategy for forest tree area segmentation based on highest accuracy obtained in forest recognition. By using remote sensing imagery data, a forest tree recognition techniques are established. The forest tree recognition techniques produced will also be used to compare the accuracy between the three algorithms.

1.5 Significance Of Study

In this study, the minimum distance classifier, maximum likelihood and Mahalonabis distance classifier classification method was applied to the tropical rainforest tree, using the remote sensing imagery data. It is expected the overall accuracy and overall kappa from each classifier is different. The three classes will be compared based on producer's accuracy and user's accuracy. The results from this study indicate that the synergistic use of high resolution optical imagery can be an efficient approach to improve the characterization of tropical rainforest tree crown.

CHAPTER 2

LITERATURE REVIEW

2.1 Rainforest

A rainforest can be defined as tall, hot and dense forest near the equator and is one of the oldest living ecosystems on earth with high intensity of rainfall every year. Most of the rainforests in the world are located around the middle of earth near the equator like South and Central America, Africa, Asia and Australia. Rainforest region have a warm climate, which explains why a majority of tropical rainforest regions are situated on or near the equator (Fisher, 2017). There are two types of rainforest which is tropical and temperate. They both have dense vegetation and are environments that produce lush growth. Tropical rainforests have more diversity than temperate rainforests.

South-east Asia are well known around the world for its biodiversity hotspots based on both animal and plant diversity (Myers et al., 2000). In mainland of Southeast Asia alone, there are nearly 500 species of mammals that have been described (Francis, 2008). Due to Southeast Asia's restricted geography, more than 50 new species including bats, rodents and insectivores have been identified (Wilson & Reeder, 2005), However, most of the diversity have been threatened by habitat loss due to human activities such as rapid urban development and agriculture activities. Thus, conservation actions are urgently needed.

Tropical rainforest is the most complex terrestrial ecosystem with high growth of vegetation that have huge tree crown which acts as a crucial reservoirs for biodiversity on earth (Sodhi et al., 2004). Tropical forest supplies a resources needed by their flora and fauna such as shelter, food, and breeding ground for species survival (Zamri & Zakaria, 2002). Almost entire Southeast Asia is considered as biodiversity hotspot because it contains high number of endemic species that are threatened by the loss of original habitats (Myers et al., 2000). The high species richness in Southeast Asia is linked to its complex geological history (Sodhi et al., 2004).

The interest in rainforests is growing rapidly since the expertise discovered the importance of these ecosystems as natural laboratories for various scientific disciplines and their crucial role in global balance, concerning their function in climate stabilisation as major carbon storage, global water balance, and prevention from soil erosion (Canadell & Noble, 2001). The increasing interest in species richness and the community composition of tropical forests during the last decade is mainly due to the threatening rate of their disturbance and disappearance. The conversion of natural habitat to the other land uses is the major driving force of biodiversity loss (Brooks et al., 2002).

Tropical rainforests are differentiated from all other terrestrial ecosystem by a very high diversity of species and are the most heterogeneous of the world ecosystems. Human activities has greatly affected the diversity in tropical rainforest. Lowland rainforests are the most species-rich of terrestrial ecosystems. Thus, their destruction may be seen the greatest threat to the biological diversity of the planet. Therefore, proper protection and sustainable management of tropical rainforests require a good knowledge of their plant diversity.

2.2 Characterisation of Tropical Rainforest

Tropical rainforest have distinct characteristics that support a variety of different species. The rainforest are warm and wet. The different type of rainforest are characterised according to different types of weather and the geographical location. These rainforests includes the monsoon, subtropical and the equatorial type. The rain is experienced almost every day and it lies between 1500 to 2500mm throughout the year. The temperatures vary during the day and night in that during the day, the temperatures range between 30 to 35 degrees Celsius while during the night, the temperature drops to between 19 and 24 degrees Celsius. The type of climate experienced in the tropical rainforest is the equatorial climate and it is characterized by high relative humidity ranging from 77% to 88% and this supports a variety of plant species (Martinelli et al, 1999).

The tropical rainforest is filled with green vegetation throughout the season because of the high rate of rainfall which encourages growth of trees that form canopies which provide shade to other plants and animals living in the area. Rainforests generally receive very high rainfall each year, although the exact amount varies among different years and different rainforests. The atmosphere is always humid which is hot and damp. It is because of the canopies that are formed by the trees. The rainforests acts as a shelter to variety of animals and plants. Tropical rainforests are found near the equator, between the Tropic of Cancer (23°27'N) and the Tropic of Capricorn (23°27'S). The equator receives direct sunlight. This steady flow of radiation produces consistently high temperatures throughout the year. A typical daytime temperature any time of year in tropical rainforests is in average of 27 degree Celcius, although temperatures can be much higher (Peterson, 2018).

There are various type of vegetation in tropical rainforest but the rainforest soil are not usually fertile. The soils are lack of nutrient because of continuous rain that occurs in rainforest wash the organic material from the soil. The daily weather cycle of the tropical rainforest begins in the morning when the sun shines, heats up the ground making hot and wet air rise in the atmosphere then in the afternoon, the dark clouds brings the rain and thunderstorms in the rainforest and this cycle is repeated continuously each day resulting to an ever wet area (Lewis, 2006). Although decomposition occurs rapidly in the hot and moist conditions, many of the dead, fallen leaves and other organic sediment are swept away before releasing all of their nutrients. In addition, rainwater seeps into the ground and leaches away nutrients. However, the high diversity of decomposers, such as bacteria and fungi increase the decomposition process so that the nutrients released by decomposition are taken up quickly by the plants, instead of being stored in the soil.

The rainforest is divided into four layers which is the emergent layer, the canopy layer, the understory layer and the forest floor. Firstly, the emergent layer is made up of the tallest trees, standing as high as 200 feet, towering above the canopy layer. This layer are usually occupied by butterflies, bats and large birds of prey. These trees are adapted to withstand strong winds and high temperatures from the direct sunlight. Secondly, is the the canopy layer. It is the thickest layer of the rainforest which consist of the tops of most trees. The trees exhibit particular characteristics which is it have smooth and oval leaves that form a dense maze. It covers the other two layer which acts as a roof. It contains epiphytic plants which attach themselves to tree trunks and branches for support. These plants also obtain water and mineral salts from rain and debris that is collected from the other supporting plants in the canopy region.

Next if the understory layer which is located in the region between the canopy layer and the forest floor. It is home to snakes, big cats and lizards. This region does not receive enough sunlight due to the canopy layer blocking the light. The understory layer or also known as shrub layer approximately receives up to 15% of total sunlight. The region is a very dark section and it is considerably open and are packed with leafy herbaceous plant and young trees that can survive under minimum light. Lastly is the forest floor which get below 2% of total sunlight. It is distinguished as a section with low vegetation because of low penetration of sunlight. Only plant that can adapt with low light can survive in this region. The decomposition rate in plant and animal matter increase by the presence of fungi and the availability of warm and humid conditions. Many animals in the forest consume dead animals and plant matters for survival.

2.3 Remote Sensing

Remote sensing is a process of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analysing and applying that information. (Canada Centre for Remote Sensing, 2008). Remote sensing technique for forest cover change detection and monitoring has been used to assess the differences in forest cover over two or more time periods caused by environmental conditions and human actions. Remote sensing and Geographical Information System (GIS) are practical tools in estimating and confirming ecosystem changes arising from forest use and forest management interferences.

Remote sensing data provides a means of quickly identifying and delineating various forest types which will be difficult and time consuming if traditional ground surveys are used. Data is available at various scales and resolutions to satisfy local or regional demands. Species identification can be performed with multispectral, hyperspectral, or air photo data interpretation. Both imagery and the extracted information can be incorporated into a GIS to further analyse as slopes, ownership boundaries, or roads (Canada Centre for Remote Sensing Tutorials, 2008). Remote sensing satellite is a widely used technique to study vegetation cover. Normally, data about earth's features is acquired either from air which is aerial photography or from space which is satellite imagery. Aerial photographs are in analogue form while images are basically in digital form.

Remote sensing is based on the measurement of electromagnetic energy. The remote sensing sensor measures the energy that is reflected or backscattered by the earth's surface. The measured energy is converted and stored as a digital number (DN) value, which ranges from 0 to 255. Each pixel has a single DN value. Most sensors measure reflected sunlight which is the passive remote sensing. However, some sensors detect energy emitted by the earth itself or provide their own source of energy which is active remote sensing (Lillesand and Kiefer, 2000).

The reflective characteristics of vegetation are different from those of bare soil or water and are dependent on the properties of the leaves including the orientation and the structure of the leaf canopy. The proportion of the radiation which is reflected in the different parts of the spectrum depends on leaf pigmentation, leaf thickness and composition and on the amount of free water in the leaf tissue. The reflectance is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis. However, it is high at the green region. In the near infrared region (NIR), the reflectance is much higher than that in the visible band due to the cellular structure in the leaves. Thus, vegetation can be identified by the high NIR but generally low visible reflectance. The reflectance of bare soil generally depends on its composition. However the reflectance of clear water is generally low.

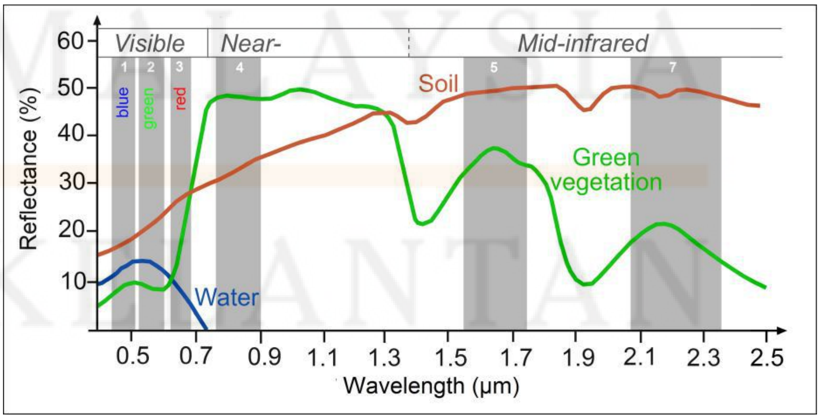

Figure 2.1 : The typical spectral reflectance curves for vegetation, bare soil surface and clear water. (Source : EuMeTrain)

Digital or visual image interpretation techniques are applied to extract information from the satellite image data. For an accurate image classification, data collected from ground truthing or ground survey is linked to image data. In this way a map showing various land cover types of the area is produced. This study uses satellite imagery to detect and map areas of forest cover by taking advantage of unique reflective characteristics of forest vegetation.

2.3.1 Unmanned Aerial Vehicle (UAV) System

Unmanned aerial vehicle (UAV) can make a practical maps. Light, handy drones are rapidly deployable. They convey lightweight digital cameras that can take great quality pictures. These cameras can be set to capture images at basic interims, and digital memory is economical and unlimited (Greenwood, 2015). After securing the pictures, the pictures can be stitched into geo-corrected orthomosaics. They can be geometrically corrected to a uniform scale, adapted so that they comply to a typical geographical coordinate system, and was stitched together.

Lightweight GPS system empower drones to produce spatially precise maps. Drone limit the need to convey information networks that will include weight and unpredictability to the device (L. Gupta , 2016). It is because the drone doest not need to use information in real time. Such drones can be utilized at a beginner stage to produce maps instead of depending upon integrated mapping governance. They balance with other mapping mechanism and replace imaging division left by satellite mapping and classic inspection.

While drone mapping is one of the latest system, experts have just begun to merge this new diversity of aerial imagery into their project (I. Colomina, 2014). In Borneo, indigenous Dayak community have start working with how to use UAV imagery to record unlawful operation on their property and to draw limits. This practice empower them to improve and protect themselves against the land grabbing act that are familiar in Southeast Asia. In any case, drone administrator should have a high resistance for hazard and a readiness in problem solving. There is space for critical advancement, yet in addition for unexpected problems and specialized difficulties. Other than that, changing and unverifiable control of drones can also be challenging.

There are different type of maps which are produced by UAVs which is geographically ortho- rectified 2D maps, elevation model, thermal maps and 3D maps or model (Pradeep et al., 2017). 2D map is the most familiar products made from imagery gathered from UAV. The easiest approach to make a mosaic from aerial imagery is by utilizing photograph stitching software such as Agisoft software. It blends a series of overlapping aerial image into a specific photo. But, without a geometric adjustment, it is hard to measure distance accurately. Geometric adjustment is a procedure that separate the angle misinterpretation from the aerial photograph. Image that have been knitted are continuous along the boundaries. However, it do not have perspective distortion corrected. It is challenging to determine the geographical references accurately in the absence of ground control point and overviewed location which is recognizable in the image.

An ortho mosaic photograph is a progression of overlaying flying photo that have been geometrically amended to give them a consistent scale. This step dispose angle misinterpretation from the airborne photograph, making the subsequent "mosaic" of 2D image free from any misrepresentation. Orthomosaic photos can be utilized in creating GIS compatible maps for application of archaeological, construction and many mores (RJ Raczynski, 2017) .

Next is the 3D models. It allows experts to make volume estimation from an arrangement of airborne photo. It is a progressively basic yield from UAV technology as a latest equipment and programming have made it accessible than ever to make them. Rather than plane, 2D result made by standard image knitting methods, 3D models look like a virtual world which allow to explore from inside. By collecting UAV imagery, data can be produced from it is digital elevation model (DEM), thermal and NDVI maps which needed particular processing software.

Digital elevation models are different from 3D model but it is similar to the topographical maps. There are three types of elevation model which is digital elevation model (DEM), digital terrain model (DTM) and digital surface model (DSM) (A. Balasubramanian, 2017). A DEM is a bare-earth raster grid referenced to a vertical datum. When non ground point was taken out, smooth DEM will be produced. DTM is similar to DEM. It is an elevation surface representing the bare earth referenced to an average vertical datum. DSM captures the natural and built features on the Earth's surface.

NDVI maps are usually utilized for applications of rural. Normalized Difference Vegetation (NDVI) photo produced the map. The image was taken with cameras that can see in both the visual and the near-infrared spectrum. Based on the amount of infra red light reflected by living plants, NDVI imagery is utilized to determine if a specific region has green vegetation or not (Shunlin Liang, 2008). To catch the wavelength needed, standard simple camera can be modified for the creation of NDVI image. This will remarkably cut down the expense of collection of the data.

Lastly, thermal maps illustrate the condition of a mapping territory. It is helpful for applications such as recognizing structural damage to roads, detecting the origin of groundwater release and locate hidden archaeological remains (Omar, 2017). Many of these systems remain quite expensive, and some are exposed to export restrictions.

2.3.2 Application of UAV System On Forest

Remote sensing data has been a rise in the use of forestry. The data has been collected from satellites or airborne sensor. However, unmanned aerial vehicles (UAV) are now a new method that have been used widely in the last few years in the application of forestry. It benefits the sector from the added values such as flexibility, low cost, reliability and effectiveness of timely supplying of high resolution data (T Lagkas, 2018). Nevertheless, UAV are currently have limited flight times and payload size, restricting the possible range of operations and the type of sensors that can be carried. The image are mainly based on technologies such as red green blue (RGB), multi-spectral and thermal infra-red. LiDAR sensors are widely used to enhance the assessment of particular plant's characteristics (K Omasa, 2006).

To compare forest with other ecosystem, forest are specifically be affected by climate change due to endurance of trees and the main objective is to conserve and protect the forest. However, forestry and agriculture relate with the development of renewable raw materials. The distinction is that forestry sector is less related to economic aspect and it reflect the delay in using new monitoring technologies. The main forestry application of UAV is aiming to reserve resources, map diseases, species classification, fire monitoring and spatial gaps estimation (C Torresan, 2017).

Other than that, some potential utilization of UAV on the sector is the recognition and mapping of wind damaged forest to plan forest value recovery plan. UAV also can identify and mapping the cutover areas. Next, it can assessed post planting stocks and survival.

2.3.3 Classification System

Before the classification process, it is necessary to prepare images for the study area. Proper geo-reference and standardize for the effects of temporal and atmospheric differences between images as well as account for system errors must be taken care. It is also necessary to define the classes to group the landscape. Construct characteristics must be defined in terms of units and scales that the sensor detected.. There are two ways to characterize the classes. Firstly, the method is called supervised classification that requires the user to locate the desired classes on an image which can be used to train the computer to look for other pixels with similar characteristics. The user selects representative samples for each vegetation cover class in the digital image. Then, the image classification software uses the training sites to identify the vegetation cover classes in the entire image. Secondly, the method is unsupervised classification which is a statistical algorithm that separates the image pixels into clusters of similar spectral characteristics. Pixels are grouped based on the reflectance properties of pixels. These groupings are called clusters. The user identifies the number of clusters to generate and which bands to use. With this information, the image classification software generates the clusters (Sowmya et al., 2017)

2.3.4 Classification Algorithm

2.3.4.1 Minimum Distance Classifier

Minimum distance classification technique is one of the techniques used for classifying the images. Among the various techniques used for classifying the images, minimum distance classification is used for classifying the images according to the closest region of interest (Ukrainski, 2017). In minimum distance classification technique initially the mean value for all classes of images is calculated in each band of data. The minimum distance is initialized to be the high value. The Euclidean distance from each unknown pixel to the mean vector for each class is calculated. All pixels are classified to the closest region of interest class. The distance is defined as an index of similarity so that the minimum distance is identical to the maximum similarity. Selecting the minimum distance value among all distances does the classification of pixel. When a pixel is assigned to a corresponding class the number of pixels classified to that class is incremented. It is to indicate that the pixel is classified under this class. After all the pixels are classified it will be possible to conclude how many pixels are associated to a particular class.

The minimum distance classifier is used to classify unknown image data to classes that minimize the distance between the image data and the class in multi-feature space (Madhura et al., 2013). The distance is defined as an index of similarity so that the minimum distance is identical to the maximum similarity. The distances between the pixel to be classified and each class center are compared. The pixel is assigned to the class whose center is the closest to the pixel.

2.3.4.2 Maximum Likelihood Algorithm

The maximum likelihood classifier is among one of the most used algorithm of classification in remote sensing, in which a pixel with the greatest probability is characterized into the corresponding class. The likelihood *Lk* is defined as the posterior probability of a pixel belonging to class *k* Eq. (2.1).

$$Lk = P(\frac{k}{x}) = \frac{P(k) \times P(\frac{x}{k})}{\sum P(i) \times P(\frac{x}{i})} \tag{2.1}$$

where $P(k)$: prior probability of class k

$P(\frac{x}{k})$: conditional probability to observe x from class k, or probability density function

Usually P(k) are assumed to be equal to each other and $\Sigma P(i) \times P(\frac{x}{i})$ is also common to all classes. Thus, *Lk* depends on P($\frac{x}{k}$) or the probability density function.

For numerical reasons, a multivariate normal dispersion is applied as the likelihood density function. In the case of normal dispersion, the probability can be expressed as below, Eq. (2.2) :

$$L_k(X) = \frac{1}{(2\pi)\frac{\pi}{2}\left|\Sigma_k\right|\frac{1}{2}} \exp\left|-\frac{1}{2}(X-\mu_k)\Sigma_k^{-1}(X-\mu_k)^t\right| \qquad (2.2)$$

where n: number of bands

X: image data of n bands

Lk(X) : likelihood of X belonging to class k

μk : mean vector of class k

Σk : variance-covariance matrix of class k

$|\Sigma_k|$: determinant of Σ_k

In the case where the variance-covariance matrix is symmetric, the likelihood is the same as the Euclidean distance, while in case where the determinants are equal each other, the likelihood becomes the same as the Mahalanobis distances. The maximum likelihood method has an advantage from the view point of probability theory, but care must be taken with sufficient ground truth data should be sampled to allow estimation of the mean vector and the variance-covariance matrix of population (Efron, 1982). Next, inverse matrix of the variance-covariance matrix becomes unstable in the case where there exists very high correlation between two bands or the ground truth data are very homogeneous. In such cases, the number of bands should be reduced by a principal component analysis. When the distribution of the population does not follow the normal distribution, the maximum likelihood method cannot be applied.

2.3.4.3 Mahalanobis Distance Classifier

Mahalanobis distance is a distance measure between two points in the space defined by two or more than two correlated variables. Mahalanobis distance takes the correlations within a data set between the variable into consideration. If there are two non-correlated variables, the Mahalanobis distance between the points of the variable in a 2D scatter plot is same as Euclidean distance. In mathematical terms, the Mahalanobis distance is equal to the Euclidean distance when the covariance matrix is the unit matrix. This is exactly the case then if the two columns of the standardized data matrix are orthogonal. The Mahalanobis distance depends on the covariance matrix of the attribute and also accounts for the correlations. It can also be explained as the covariance matrix is utilized to correct the effects of cross covariance between two components of random variable. The Mahalanobis distance is the distance between an observation and the centre for each group in *m*-dimensional space defined by *m* variables and their covariance. Thus, a small value of Mahalanobis distance increases the chance of an observation to be closer to the group's centre and the more likely it is to be assigned to that group. For each feature vector, the Mahalanobis distances towards class means are calculated. This includes the calculation of the variance-covariance matrix V for each class Eq. (2.3) (Madhura et al, 2015).

d_k^2 = (X-μk) TV (X-μk) -- (2.3)

Where X is vector of image data

μ*k* is the mean vector of the k^{th} class

V is the variance covariance matrix

2.3.5 Accuracy

The standard summaries for the accuracy assessment are the error matrix, the overall accuracy and the Kappa coefficient. Error matrices quantitatively compare the relationship between the classified maps and reference data. Overall accuracy, user's and producer's accuracies, and also the Kappa statistic were then derived from the error matrices. The Kappa statistic incorporates the off diagonal elements of the error matrices and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance. Expert Systems use a combination of remotely sensed and other sources of georeferenced data (Stefanov et al., 2001) to increase the information about mixed pixels to make better classification decisions. Accuracy assessment was critical for a map generated from any remote sensing data. On the other hand, classification accuracy can be improved by using multi-source data (Li et al., 2011).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

The study area is in Gunung Basor Reserve Forest as in Figure 3.1. According to Kelantan Forestry Department (2003), Gunung Basor had been a logging area by selective management system in 1980s. The area of Gunung Basor is approximately 40,613 ha and 34,763 ha of Gunung Basor was gazetted as permanent forest reserve. Another 5,850 ha of Gunung Basor was targeted as production forest (Kelantan Foresty Department, 2003). The soil type varies according to the terrain conditions. The average maximum and minimum temperature of Gunung Basor is 32°C and 25°C respectively with mean annual rainfall of 2750 to 3000 mm. Generally, there are three types of vegetation zonation in Gunung Basor, namely lowland dipterocarp, hill dipterocarp and montane forests. Figure 3.1 also show the area where the drone was flew.

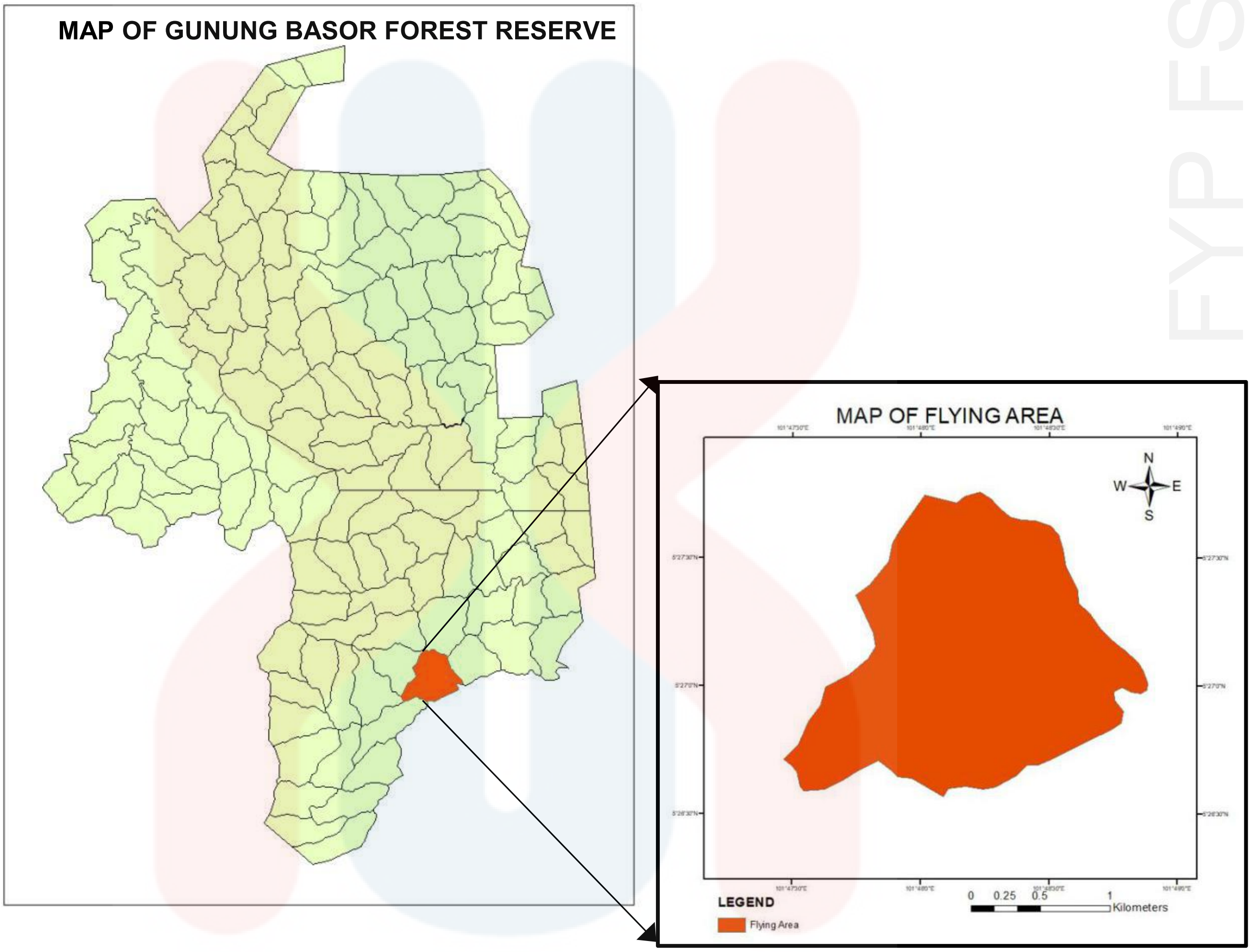

Figure 3.1 : Map of Gunung Basor Forest Reserve and the flying site of drone

3.2 Materials

- UAV image data
- Remote Sensing Software

1) ENVI Software

ENVI or the Environment for Visualizing Images is used to process and analyze all types of imagery and data such as multispectral, hyperspectral, LiDAR, and SAR (Harris Geospatial,2011)

2) Agisoft Software

Stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data to be used in GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales (Agisoft, 2018)

3.3 Methods

3.3.1 Image Acquisition and Pre-processing

Data used in this study were an optical drone data. The drone data acquisition was performed on 18 April 2018 by scanning from a drone with the DJI FC6310 system. The entire area was scanned at 170 m from ground level. The measurement densities were at least 10 measurements per square metre from a 170 m altitude above ground level. From the images taken by unmanned air vehicles (UAV), we made an orthomosaic photo and a digital elevation model (DEM) using Agisoft Photoscan Professional v1.3.4 software have been developed (Agisoft, 2018). An orthomosaic photo is an image that is composed of multiple overhead images and is corrected for perspective and scale. Resolutions of an orthomosaic photo and a digital surface model (DSM) were about 4.15cm and 16.6cm, respectively. Pre-processing was carried out to prepare the image for further procedure.

Figure 3.2 : DJI FC6310 drone

Table 3.1 Camera specification

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC6310 (8.8 mm)	5472 x 3648	8.8 mm	2.41 x 2.41 µm	No

3.3.2 Data Analysis

Data processing, analysis and also interpretation were determined by using ENVI and ArcGIS 10.3 software. From digital surface model, slope model was produced by using ArcGIS 10.3 software. Slope model showed the maximum rate of elevation change between each cells and its neighbour so the border of trees are emphasized. From orthomosaic photo, DSM and slope model, tree segmentation was performed in ENVI software using the minimum distance classifier, Mahalanobis distance classifier and maximum likelihood algorithm. The red, green and blue (RGB) bands were adjusted by try and error.

After segmentation, the segmented images were classified to four classes : Non-forest area, Broad leaved forest area, Fern forest area and Unclassified. The unclassified included the shadow in the image and the background of the image. In ENVI software, some images were chosen as a training sample visually and was applied the algorithms to the overall tree crown map.

The pre-processing and post image processing and also analysis were carried out to enhance the quality of the images and the readability of the features using spatial analysis tools of ENVI. The image analysis is obtained by calculating the changes and percentages which is showed by the portion of colour.

3.4 Research Flowchart

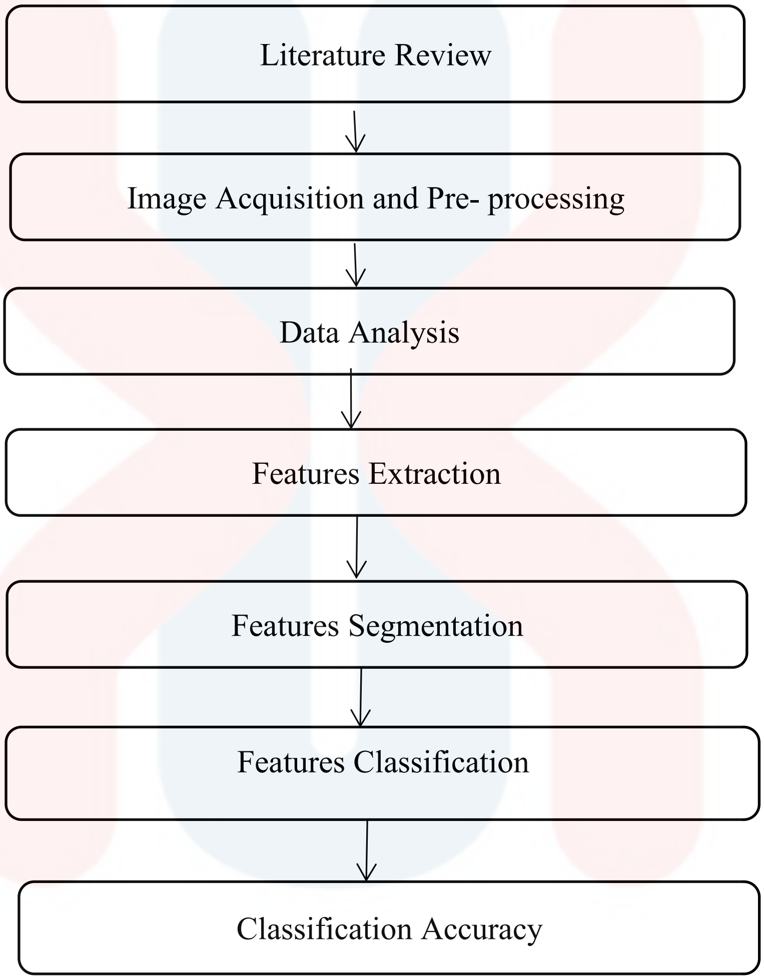

Figure 3.3 : Research Flowchart of study

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter discussed on the results that were produced based on orthomosaic photo of Gunung Basor. The data were produced with the accuracy assessment by using three algorithm which are supervised minimum distance classifier, Mahalanobis distance classifier and maximum likelihood algorithm that gives the results from operator and user accuracy. The classification is made to provide a differences between three algorithm. The objectives is to run data through three algorithm and to differentiate the classification from the algorithms. Table 4.1 shows the classification scheme with description.

Table 4.1: Image Classification

Class	Description
Non- forest area	Areas with no vegetation cover and uncultivated agricultural land.
Forest area (Broad leaves area)	Area that have green tree crown area density.
Forest area (Fern)	Area that have only have fern.
Unclassified	Area that can't be classified by computers.

(Source : Onishi et al., 2018)

4.2 Image Pre-processing

Preprocessing process was done to align the images captured by the drone with the DJI FC6310 system.

4.2.1 Image Mapping and 3D Modelling

There are total of 122 images was captured by FC6310 drone model for this study. The images undergo pre-processing process in Agisoft Software. 65 cameras station have been aligned through this process.

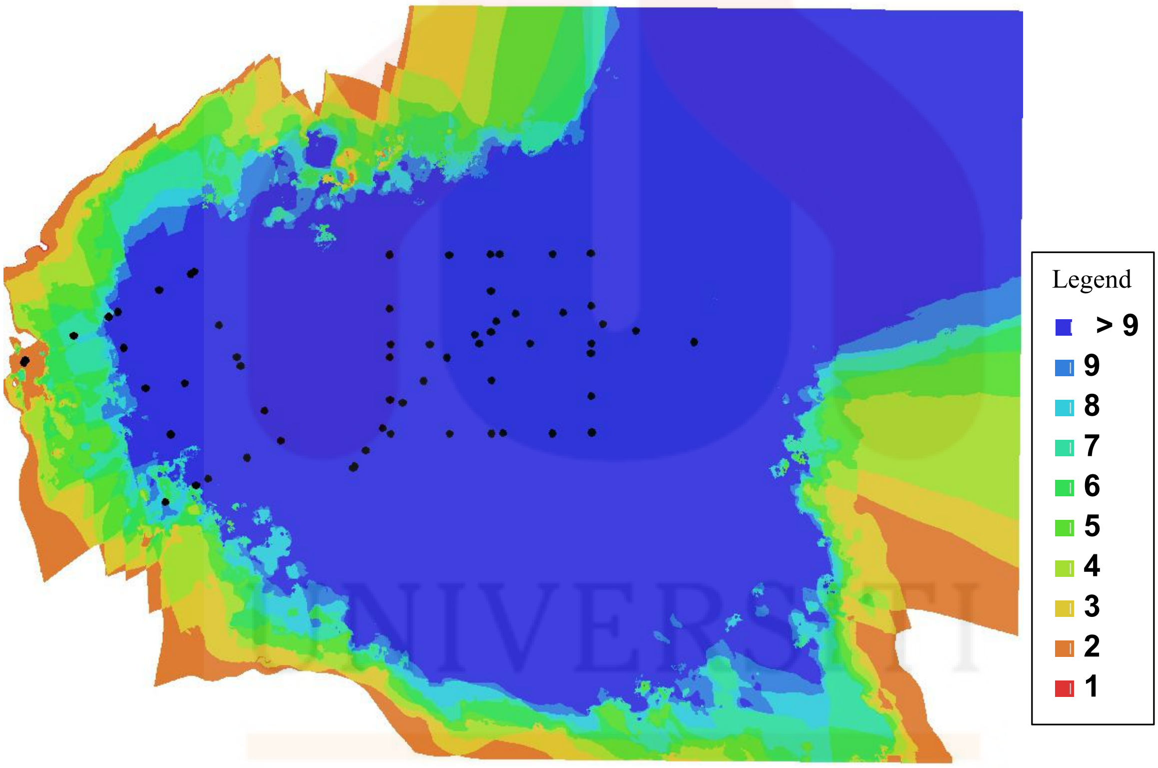

Figure 4.1 : Camera location and image overlaps 100 m

Table 4.2 : Point Cloud Specification

Number of images:	122	Camera stations:	65
Flying altitude:	170 m	Tie points:	70,745
Ground resolution:	4.15 cm/pix	Projections:	192,182
Coverage area:	0.218 km²	Reprojection error:	1.25 pix

Through process in Agisoft software, an orthomosaic photo and Digital Surface Model (DSM) was produced. Resolutions of an orthomosaic photo and a DSM were about 4.15cm and 16.6cm, respectively.

4.2.2 Orthomosaic photo

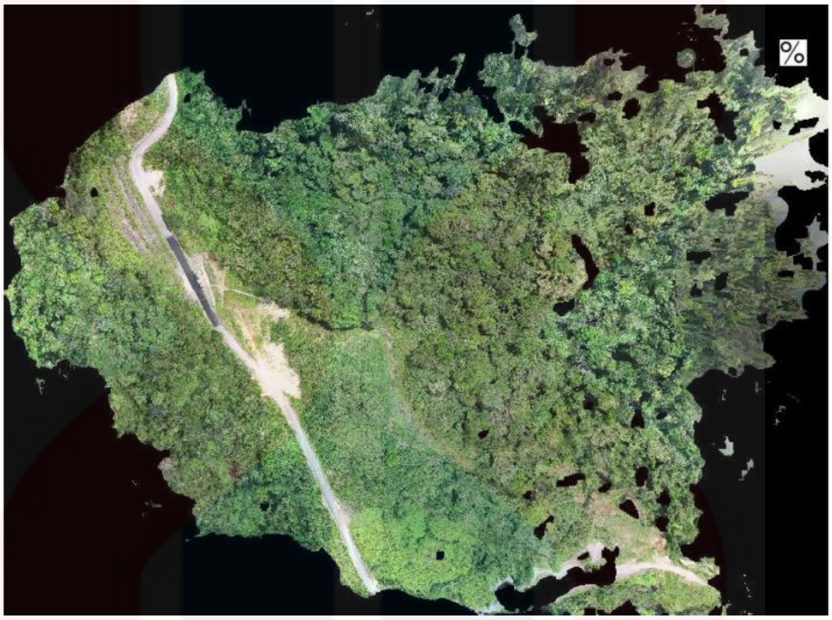

Figure 4.2 : Orthomosaic photo of Gunung Basor Reserve Park

4.2.3 Digital Surface Model (DSM)

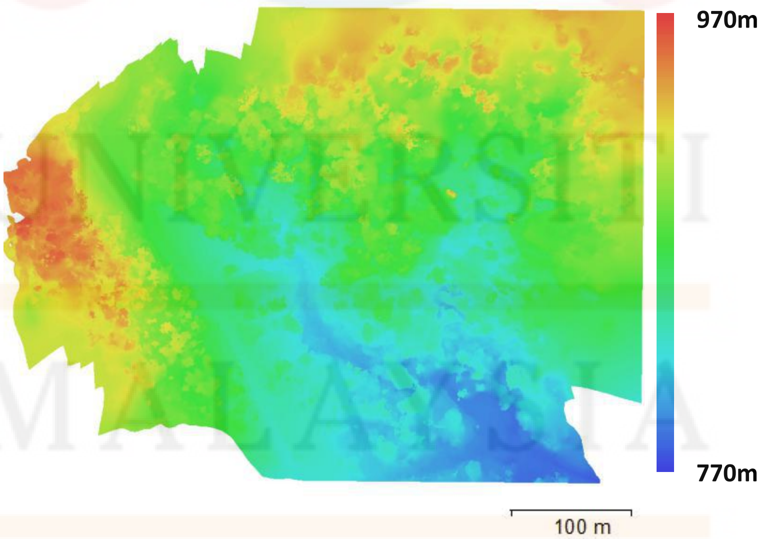

Figure 4.3 : Digital Surface Model of Gunung Basor Reserve Park

Resolution: 16.6 cm/pix

Point density: 36.3 points/m²

From DSM, slope model was produced by using ArcGIS 10.3 software. Slope model showed the maximum rate of elevation change between each cells and its neighbour so the border of trees are emphasized.

4.2.4 Slope Model

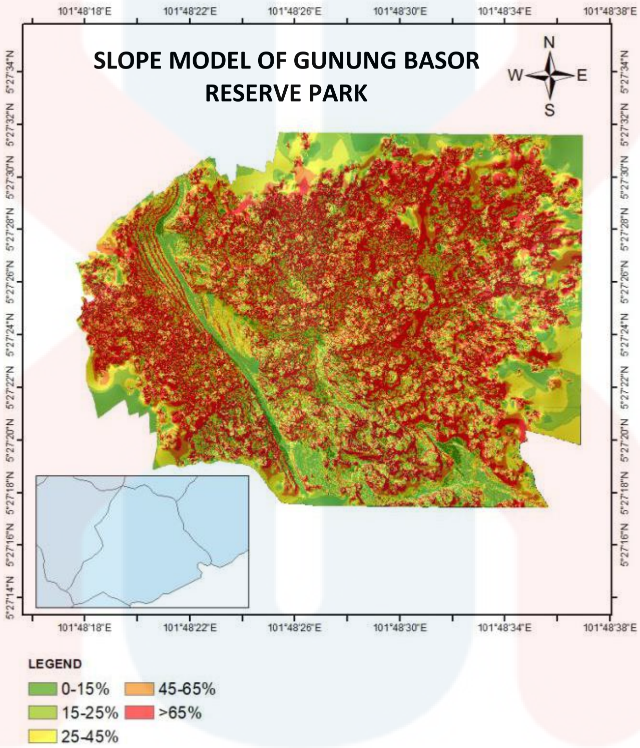

Figure 4.4 : Slope model of Gunung Basor Reserve Park

From orthomosaic photo, DSM and slope model, tree segmentation was performed in ENVI software using the minimum distance classifier and maximum algorithm.The RGB bands were adjusted by try and error method.

After segmentation, the segmented images were classified to 4 classes : Non-forest area, Broad leaved forest area, Fern forest area and Unclassified. The unclassified included the shadow in the image and the background of the image.In ENVI software, some images were chosen as a training sample visually and was applied the algorithms to the overall tree crown map. Three different classification was produced.

4.3 Results

The objective of this study is to develop a forest tree recognition techniques based on remote sensing imagery data. The supervised classification method was able to classify three to four classes which is non forest area, broad leaves forest area, fern forest area and unclassified. The unclassified was due to the background of the orthomosaic photo during the segmentation in Agisoft software. The result means the system is able to classify the image.

Figure 4.5 to 4.7 shows the application of three different supervised classification method on Gunung Basor. It can be noticed that maximum likelihood and Mahalanobis distance classifier's prediction of distribution of broad leaves forest, fern forest and non- forest area were reasonable. Maximum likelihood algorithm has been one of the most used algorithm. Its has the best accuracy as it assumes that the statistics for each class in each band are normally distributed and the probability that a given pixel belongs to a specific class was calculated. The pixel with the greatest probability is characterized into the corresponding class that was assigned by user. Mahalanobis distance classifier overpredicted the fern forest area. However in minimum distance classifier, the prediction of broad leaves forest is overestimated. Generally, these fern areas was recognized as poor resources for many browsers and grazers and may even be tipping forest succession away from healthy, stable climax ecosystems. However, in Gunung Basor Reserve Park has high density of forest because the study area is in area with remote mountain elevation. Fern favour areas under the forest canopy, along creeks and streams and other sources of permanent moisture.

4.3.1 Classification using Minimum Distance Classifier

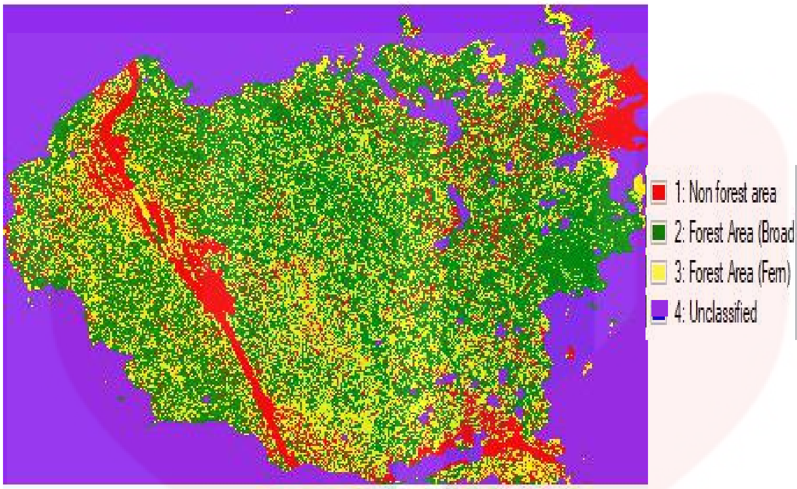

Figure 4.5 : Supervised classification image of Gunung Basor using minimum distance classifier

4.3.2 Classification using Maximum Likelihood Algorithm

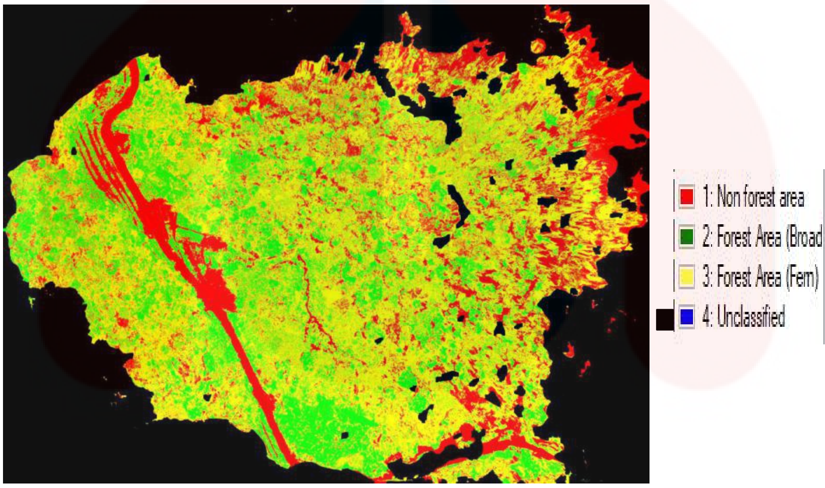

Figure 4.6 : Supervised classification image of Gunung Basor using maximum likelihood algorithm.

4.3.3 Classification using Mahalonabis Algorithm

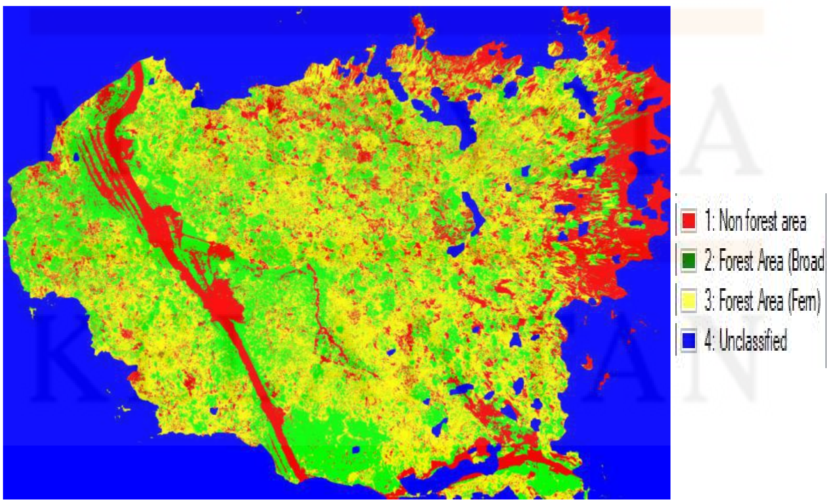

Figure 4.7 : Supervised classification image of Gunung Basor using Mahalanobis distance classifier.

4.4 Accuracy Assessment

Based on the accuracy assessment done after the classification (Table 4.3), maximum algorithm has highest accuracy compared to Mahalanobis algorithm and minimum distance classifier with, 82.90%, 76.63% and 58.33% respectively. Maximum likelihood algorithm gave the best result compared to minimum distance classifier and Mahalanobis distance classifier which overestimated fern forest area and broad leaves forest area.

Table 4.3 : Accuracy Assessment

Algorithm	**Overall Accuracy (%)**	**Kappa Coefficient**
Minimum Distance Classifier	58.33	0.37
Maximum Likelihood Algorithm	82.90	0.73
Mahalanobis Distance Classifier	76.63	0.68

Accuracy assessment of classification are the process of comparing the classification with geographical data that are assumed to be true, in order to determine the accuracy of the classification process. The training data were derived from ground truth data. A set of reference pixel is used where points on the classified image for which the original data are known. The relationship between two compared data is commonly summarized in a confusion matrix. The number of rows and column in the confusion matrix should be the same as the number of categories whose classification accuracy is being assessed.

Table 4.4 : Confusion matrix for minimum distance classifier

Class	Unclassified	Non- Forest Area	Forest Area (Broad leaves)	Forest Area (Fern)	TOTAL	Commission	Omission	Producer Accuracy	User Accuracy
Unclassified	0	0	0	0	0	0	100	0	0
Non-forest Area	11.89	86.93	9.51	12.15	31.49	24.48	13.07	86.93	75.52
Forest area (Broad leaves)	59.49	2.67	51.17	45.29	36.12	40.02	48.83	51.17	59.98
Forest Area (Fern)	28.62	10.40	39.32	42.56	32.39	60.23	57.44	42.56	39.77
TOTAL	100	100	100	100	100				

Table 4.5: Confusion matrix for Maximum Likelihood Algorithm

Class	Forest Area (Broad leaves)	Forest Area (Fern)	Non-Forest Area	TOTAL	Commission	Omission	Producer Accuracy	User Accuracy
Forest area (Broad leaves)	16.36	75.91	9.47	36.12	44.86	16.61	83.39	55.14
Forest Area (Fern)	0.25	3.92	90.33	32.39	15.23	24.09	75.91	84.77
Non-forest Area	83.39	20.18	0.20	31.49	4.58	9.67	90.33	95.42
TOTAL	100	100	100	100				

Table 4.6 : Confusion matrix for Mahalonabis distance classifier

Class	Forest Area (Broad leaves)	Forest Area (Fern)	Non - Forest Area	TOTAL	Commission	Omission	Producer Accuracy	User Accuracy
Unclassified	0	0	0	15.71	50	0	100.00	50.00
Forest Area (Broad Leaves)	76.62	20.97	4.41	18.22	52.12	23.38	76.62	47.88
Forest area (Fern)	23.05	73.80	3.93	31.99	12.50	26.20	73.80	87.50
Non Forest Area	0.33	5.24	91.66	34.08	5.94	8.34	91.66	94.06
TOTAL	100	100	100	100				

In confusion matrix, the pixel located along the diagonal represent the pixel that are are classified in proper category. Table 4.4 to 4.6 shows the confusion matrix table of the three algorithms. The non diagonal value in the column represent the omission error. The non diagonal value in the row represent the commission error. Omission error calculate the probability of a pixel being accurately classified which is also known as producer's accuracy. This results from dividing the number of correctly classified pixels in each category by the number of training pixels used for the total of column. This indicates how well training set pixels of the given cover type are classified. Commission error determines the probability that a pixel represents the class for which it has been assigned which is also known as user's accuracy. This is computed by dividing the number of correctly classified pixels in each category by the total number of pixels in the total of row. The total accuracy is computed by dividing the total number of of major diagonal by the total number of tested pixels (Lillesand and Kiefer, 2000). Another characteristic coefficient that can be obtained from confusion matrix is Kappa coefficient which is an indicator of the extent to which the percentage correct values of an error matrix are due to "true" agreement versus "false" agreement, and it ranges from 0, false to 1, true.

The performance is notable as the data used is acquired from easily available drone UAV photography. Compared to satellite images, UAV image has a limited range of viewing. Most of previous studies used expensive hardware such as multispectral images to improve performance. In the matter of scale, UAV can be very limited compared to satellite image. But, UAV is a low cost and easy to feature image. Thus, the vision system is cost effective and usable tool for forest remote sensing.

Some misclassification were also exist. The main error is because of the classification between broad leaves forest area and non forest area. This may be cause by the non forest area included some understory vegetation. The understory vegetation mainly consist of broad green leaves tree. The method of separating each of the class is one of the parameter which can affect the result.

From the method, there are two variable that can create a good images. First is the the process of object based classification. Previous study showed that object based classification has a higher accuracy than pixel based classification (Tarabalka et al. 2010). for this study, the segmentation could not segment each tree crown apart perfectly, so by improving the segmentation method can lead to high accuracy classification. Thus, the study are able to identify each of the tree species.

Secondly is the training data. This study picked up training data and test images from the same area and at the same time. Tree shapes are vary in different environment and weather. Making a good use of DSM can enhance the classification accuracy. For further study, we need a trained images of various site and time by considering its practicability.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Vegetation cover change over time due to natural and human made causes. Information about the type of any changes in the vegetation cover is important for assessing the status of regenerating forests and estimating the size of the forest area, hence will support the natural forest management.

Based on the study, a supervised classification method was run. With the minimum distance classification algorithm, mahalanobis distance classifier and maximum likelihood algorithm, the images were classified into three to four classes which is non forest area, forest area with broad leaves, forest area with fern and unclassified. The accuracy for each of the algorithms are 58.33%, 76.63% and 82.90% respectively. Thus, maximum likelihood algorithm gave the best result compared to the other two. Mahalanobis algorithm produce a good classification result but overpredicted the broad leaves forest area. Minimum distance classifier has the least accurate result with, 58.33% which it predicted more fern forest area compared to the original image.

Besides that, accuracy assessment is one of major problem as UAV photograph has low accuracy compare to satellite image. But UAV photograph is low cost and easy to get images. Moreover, inexperienced user to identify and classify the classes can contribute to the misclassified classes. Therefore, supervised method by using maximum likelihood was suggested as the accuracy of the image is higher compared to accuracy assessment of minimum distance classifier.

5.2 Recommendation

Firstly, further research would be important to help to understood more about different classification using different algorithm. Thus, we can get a better picture of the future classification pattern and trend of the area. Classification of vegetation area is important to forest study as it can evaluate the health of the forest.

Besides that, it is recommended to use satellite images such as pleiades satellite image. Satellite images of different spatial resolutions can be used too to produce more accurate classification maps.

Next, additional data such as tree parameters, Digital Elevation Model (DEM) and also NDVI value of the satellite imagery should be included to improve the classification map. There will be more information of the area as data was compared for the study.

Lastly, to improve the accuracy assessment of classification, field study need to be conducted for reference as it can eliminate any bias implicated by researchers.

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