UNIVERSITI PUTRA MALAYSIA

A LOW COST AERIAL REMOTE SENSING PLATFORM FOR COUNTING OIL PALM TREES

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APPROVAL SHEET

This project report hereto entitled "**A LOW COST AERIAL REMOTE SENSING PLATFORM FOR COUNTING OIL PALM TREES**" was prepared and submitted by MOHD FARIS MURSHIDI BIN MD NOOR in partial fulfilment of the requirement for the degree of Bachelor of Engineering (Agricultural and Biosystems) is hereby accepted.

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ABSTRACT

Unmanned Aerial Vehicle (UAV) System has gained popularity in the field of photogrammetry, remote sensing and geospatial engineering for civilian application. Its impact on society and the speed of project delivery has undeniably present users with varieties of choice and producers with very attractive competitiveness. In large scale or area for vegetation and agricultural application, satellite remote sensing has been widely used for collecting the data. However for small to medium scale enterprise or medium farm, UAV very idea to use for space and airborne platforms are very economical due to budget constraints. In this study, an RGB image was captured by UAV and used to estimate the palm tree in the interested area. To estimate trees inside the interested area, Training Rule Method was used. The value of the interested area and the factor of area were multiplied by number of trees in the training area. This method was also compared to the Trimbler eCognition Developer software, in order to compare the accuracy of trees estimated. On eCognition Developer the values of threshold used were (0.5) and (0.4). The Training Rule method gives the result of first image 94% and second image 96% of accuracy. Meanwhile, eCognition method gives the result of threshold (0.5), on first image 92% and second image 85% of accuracy. For threshold (0.4), on first image 95% and second image 99% of accuracy.

ABSTRAK

Sistem Pesawat Udara Tanpa Automatik (UAV) telah mendapat populariti di bidang fotogrametri, penginderaan jarak jauh dan kejuruteraan geospatial untuk aplikasi awam. Impaknya terhadap masyarakat dan kelajuan penyampaian projek tidak dapat dinafikan hadir pengguna dengan pelbagai pilihan dan pengeluar dengan daya saing yang sangat menarik. Dalam skala besar atau kawasan untuk aplikasi tumbuh-tumbuhan dan pertanian, penderiaan jauh satelit telah digunakan secara meluas untuk mengumpul data. Walau bagaimanapun untuk perusahaan kecil atau sederhana atau ladang sederhana, UAV sangat idea untuk digunakan untuk ruang dan platform udara adalah sangat menjimatkan kerana kekangan bajet. Dalam kajian ini, imej RGB ditangkap oleh UAV dan digunakan untuk menganggarkan pokok sawit di kawasan yang berminat. Untuk menganggarkan pokok di dalam kawasan yang berminat, Kaedah Kaedah Latihan telah digunakan. Nilai kawasan yang berminat dan faktor kawasan didarabkan dengan bilangan pokok di kawasan latihan. Kaedah ini juga dibandingkan dengan perisian Pemaju eCognition Trimbler, untuk membandingkan ketepatan pokok yang dianggarkan. Pada Pemaju eCognition, nilai ambang yang digunakan ialah (0.5) dan (0.4). Kaedah Latihan memberikan hasil imej pertama 94% dan imej kedua 96% ketepatan. Sementara itu, kaedah eCognition memberikan hasil ambang (0.5), pada imej pertama 92% dan imej kedua 85% ketepatan. Untuk ambang (0.4), pada imej pertama 95% dan imej kedua 99% ketepatan.

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LIST OF ABBREVIATIONS

UAV - Unmanned Aerial Vehicle

UAS - Unmanned Aircraft System

GIS - Geographic Information System

NN - Nearest Neighbour

RGB – Red Green Blue

CHAPTER 1

1. INTRODUCTION

1.1. History of oil palm

The oil palm tree (*Elaeis Guineenis Jacq.)* can live in a wild, semi wild and cultivated condition. This oil palm can live in three land areas of equatorial tropics; in Africa, America and south-east Asia. The name of *Elaeis Guineenis* came from two different words, where "Elaeis" was derived from Greek word "Elion" meaning oil and word "Guineenis" came from attribute its origin to the Guinea Coast.

Elaeis Guineenis has a large feathered-palm having solitary columnar stem with short internodes. This species have two reproduction systems where male-inflorescence and female-inflorescence exist in one tree. Besides, there are three type of palm; Dura, Pisifera and Tenera. The Dura has big kernel and thick shell with thin mesocrup of it fruit, for Pisifera has a very small kernel and thin shell with thick mesocrup of it fruit. Tenera is the combination of both two type palm Dura and Pisifera, where it producing small kernel and thin shell with thick mesocrup.

1.2. Introduction of UAV

UAV or Unmanned Aerial Vehicle or commonly known as a drone, is an aircraft without a human to be a controller or pilot aboard that aircraft. To be more understand, that UAV are the component of the Unmanned Aircraft System (UAS), where inside it, include the UAV (drone), a ground-based controller (human that remotely control at ground) and a system of communication between aircraft and ground-based controller (radio wave transmitted). Today UAV not only for military purpose it also includes the application in:-

1. Agricultural
2. Aerial Photography
3. Commercial
4. Surveillance/ Mapping

1.2.1. UAV in military

UAV was earlier used are in military sector, where the UAV were used in surveillance and mapping of the area either for enemy activities or planning on moving the troops in efficient and safe way.

1.2.2. UAV in survey and mapping

UAV also play important role in survey and mapping due to its ability where it quickly deploy in any condition and situation, but also because it is cheaper in terms of costing. Besides, UAV can collect highly detailed data of smaller area or temporal data where it prove to be efficient in term of surveying and mapping the situation, such as crime situation, forest fires, estimation of damage after flood or storms. Due to this, it becomes a critical factor in making decision and right action to be implemented.

1.2.3. UAV in agricultural

The use of UAV in agriculture in order to increase crop production and also help in monitoring the crop growth. This is because UAV can be attach or mounted with variance advance sensor and digital imaging sensor, due to this ability farmer are able to use UAV in gathering whole picture of their fields, gathering information of crop, improving crop production and preventing disease.

1.2.4. Impact UAV in agricultural

UAV or drone can be used in mapping or surveying. These drones are equipped with near-infrared camera sensor, allowing to see the spectrum of light that plant used to absorb light for photosynthesis, either the crop health or not. UAV also used in crop spraying, where the proper amounted of fertilization and pesticide can apply. Besides, for irrigation management. UAV with mounted with thermal sensor in order to differentiate the area that receive water and not receive. Lastly, monitoring livestock, the thermal sensor are mounted to UAV in order to detect the temperature of livestock for health condition, this can help the farmer to separate the disease livestock and take further action.

1.3. Interaction UAV in oil palm counting

There was one experiment conducted in smart counting for oil palm using UAV, and it only used the RGB images to capture the images, by using fixed wing J-HAWK UAV, mounted with Canon S100 (12Mp), with GIS software in counting the oil palm tree, and the study area was at Melaka Pindah oil palm plantation . The result of the experiment showed the reduction in error of estimation from 790 tree stands to 582, with 27% error. Due to this, the purpose this project is to improve the reduction of error to less that 27%, with improving the RGB Vision to high resolution camera and improving the type of UAV by changing it to rotary UAV.

1.4. Problem statement

i) Most of the UAV used LIDAR, Infrared and other multispectral sensor in detecting the tree, or counting the tree.

ii) LIDAR, Infrared and other multispectral sensor are expensive in terms of costing.

iii) The High Resolution RGB image will be used to count the oil palm tree.

1.5. Objective of this project

In this study there are several objectives that will be achieved. The objectives are stated as below:

i) To estimate number of oil palm trees using RGB image taken from Unmanned Aerial vehicle (UAV) platform.

ii) To create the Training Rule method using ArcGis software.

iii) To compare eCognition method and Training Rule method in terms of accuracy.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Survey on quadrotors

Unmanned Aerial Vehicles (UAVs) offer a wide range of interesting in any field of application such in military and commercial due in reducing the operation course. Furthermore they are capable of hovering and flying at high and low speed. They can move in any direction and take off but also land vertically. This small vehicles can flown either indoor or outdoor, and also offer the possibility for near-area surveillance, crop dusting, precision farming, microwave autonomous for remote sensing, geographic studies, fire monitoring, security, search and rescue, etc.

In the area of system modelling, several papers can be found in the literature treating the problem of modelling of quadrotos and aircrafts. In this survey, it is very important to note that modelling and control strategies applied to helicopter cannot be applied directly to quadrotors due to differences between these two systems. In this review, we will go through the configurations, Quadrotors models, control, Collision Avoidance System (CAS) and fault diagnosis and fault tolerant control.

2.1.1. Configuration

UAVs are subdivided into three categories; 1) fixed wing UAVs, 2) rotary wing UAVs, and 3) flapping wings. In rotary wing are superior to their fixed wing counterpart in terms on achieving the higher degrees of freedom, lower flying speeds, stationary flight ability and suitability for indoor usage.

A quadrotor is a rotary wing UAVs, that consist four rotor located at the end of X cross structure. In most of configurations, each pair of blades spins in the same direction and implemented on one of axes of the body frame coordinate system. In addition, the structure if X cross structure or cross-style, where it provide higher momentum for same desired motion, thus increasing the manoeuvrability as each move requires all four blades to vary their rotation speed where it shown in [9]. Beside for the altitude control is basically analogous in both configurations.

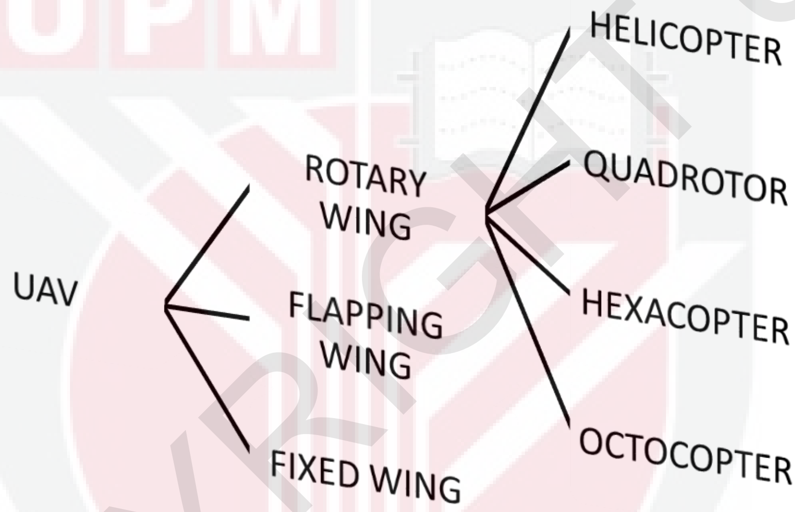

Figure 1: UAV classification

Table 1: The different of rotary wings, fixed wings and flapping wings

COMPARISON BETWEEN ROTARY WINGS, FIXED WINGS, AND FLAPPING WINGS			
	ROTARY WING	FIXED WING	FLAPPING WING
Manoeuvre	High	Low	Medium
Cost	Medium	Low	High
Construction and repairing	Medium	Low	High
Civilian application	High	Low	High
Military application	Medium	Medium	Medium
Energy consumption	High	Low	Medium
flight safety	Medium	High	Low
Range	Medium	High	Low

2.1.2. Quadrotors models

a. Nonlinear Model

The nonlinear model of quadrotor dynamics has similar development in many works. The researcher considers the force that production by four of motors, gravity gyroscopic effect and drag force and moment. Obviously, the force and moment are enough to give a realistic model for this model.

In [11], [6], the basic concepts of helicopter aerodynamic are presented. In [7] show an analysis of the Starmac model quantifies several aerodynamic effects relative to the free stream of vehicle, thus, it include the total thrust that varies with input power, the free stream velocity and the angle of attack. As the flapping of blade resulting from different inflow velocities experienced by advancing and retreating blades.

b. Linearization

The methods based on linearization have some drawbacks. Their use is often accompanied by extreme caution. The local linearization (Jacobian) is only valid on point of operation; meanwhile the exact linearization is not always possible and it is not always advantageous to eliminate all nonlinearity in a system. Therefore, recent year's researchers are oriented to methods best suited to the nonlinear nature system.

2.1.3. Control and control mission

a. The Linear Control

The quadrotor is a multivariable with highly coupled nonlinear system. However, This Linear system consist of a complicated algebraic that manipulation in state variables under certain environmental conditions. Sometime, linear control can be applied in trajectory tracking, like: trajectory and also the flying conditions for the quadrotor are not complex and difficult.

b. The Nonlinear Control

For nonlinear control there are eight components: 1) Lyapunov Criteria, 2) Sliding Mode Control, 3) Backstepping, 4) Feedback Linearization, 5) Neural Network and Fuzzy Logic, 6) Model Based Predictive Control (MBPC), 7) Adaptive Control Algorithms, and 8) Robust Control Algorithms.

1. **Lyapunov Citeria**

   The Lyapunov stability is a mathematical translation of a physical observation: if the total energy of a system dissipates, continuously decreasing with time, then the system tends to return to steady state. Some used Lyapunov functions to ensure stability in get stable result, but not always good performance and precision.

2. Sliding Mode Control

It's used in many works to stabilize the quadrotor, the quadrotors have variable structure, as is appropriate to apply the sliding mode control for this type of system. Besides, the advantage of sliding mode control is its insensitivity to modelling error, parametric uncertainties, and other disturbances, as shown in [13].

3. Backstepping

Backstepping is control approach based on Lyapunov criteria; allow formal obtainment on control that stabilizes a non-linear system. Besides, it suitable for the cascade structure of quadrotor dynamic. Several researchers have tested backstepping to design an altitude controller; the controller demonstrates the ability to control angles of orientation with relatively few large disturbances. The feedback controller performed poorly compared to backstepping and sliding mode control in [1]. The results show that the backstepping method is able to control and stabilize the quadrotor. For practical purposes, however, saturation limits need to be imposed to prevent instability [4]

4. Feedback Linearization

The feedback linearization is to algebraically transform either completely or partly of nonlinear dynamic to linear, in order for linear control techniques become applicable in this system. Beside, other researchers have associated feedback linearization the inner with h-infinity controller.

5. Neural Network and Fuzzy Logic

The neural network creates a nonlinear mapping of inputs to outputs that can help make an image of quadrotor dynamics and create controller. With this mapping, it helps and improves the robustness of the controller, where the [10] show the Cerebellar Model Articulation Controller.

The fuzzy logic allows the qualitative knowledge of designers in the control systems, with the method of complementary to conventional control. Where it able to formalize and simulate the expertise of designer to gives a simple answer to the model process such example; seamless exceptions and integrates.

6. Model Based Predictive Control (MBPC)

MBPC are designed based on dynamic model of the system that must be controlled, with mathematical optimization techniques to obtain ideal inputs to be applied in the system, this techniques include the accuracy of the dynamic model and calculation of the load of optimization in order to be executed. MBPC is an advance control techniques, thus, the process of repeated of optimization and constraints at each time of step. As the quadrotor is a nonlinear system, so it needs to be the MBPC to be nonlinear controller.

7. Adaptive Control Algorithms

Adaptive controllers are aimed to adapt the uncertain or time varying parameters with changes in system. [5], show a continuous time varying adaptive controller. In addition, it performs well with known uncertainties in mass, moment and aerodynamic damping coefficients.

8. Robust Control Algorithms

Robust controller algorithms guarantee the controller performance with acceptable disturbance ranges or unmodeled system parameters. The [2], show a robust controller is implemented and validated experimentally an attitude controller subsystem.

2.2. Smart counting – oil palm tree inventory with UAV

2.2.1. UAV-based palm tree inventory

High spatial resolution images captured with UAV offers a reliable prospect to detect the palm tree with the characteristic formation of the tree. The popular technique for detecting object from image are template matching algorithms, where it using the object's boundary as criteria. Somehow, this boundary technique can be misleading due to image problem and distortion or occlusion. Beside, template matching can be affected by the geometry and scale of the object in the image. For these reason the matching and object-based image analysis process need to integrate into single processing workflow to improve the counting accuracy.

2.2.2. Theoretical bases

The combination of template matching with the object recognition has been used in computer vision. With the algorithm searches the image to find an area within a larger image, which need to specific and smaller the template image. Other way to perform the template matching is to calculate the cross correlation between the template and the images, using the squared Eucliden distance [Equation 1-3].

$$d_{f,t}^{2}(u,v) = \sum_{x,y}[f(x,y) - t(x-u,y-u)]^{2} \qquad [1]$$

Where d is the sum over x, y under the window containing the feature positions at $, v$. In expansion of d^2 ;-

$$d_{f,t}^{2}(u,v) = \sum_{x,y}[f^{2}(x,y) - 2f(x,y) - t(x-u,y-u) + t^{2}(x-u,y-u)]^{2} \qquad [2]$$

The term $\sum_{x,y} t^{2}(x-u,y-u)$ is fixed. If the term $\sum_{x,y} f^{2}(x,y)$ is nearly constant the remaining cross correlation term,

$$c(u,v) = \sum_{x,y} f(x,y)t(x-u,y-u) \qquad [3]$$

Object-based image analysis (OBIA) is common tool for the remote sensing professionals in order to extracting useful information on the image. Compare with previous method (pixel-based methods), the OBIA consider spectral information from a set of similar pixels, where it belong to the same object.

Besides, the basic element of OBIA is segmentation which partitions an image into unclassified segment based on the colour, size, texture, shape and contextual information [3]. Mean that, the quality of segmentation and result of the object are based on colour, shape, size, and pixel neighbourhood influenced by the parameter that given by user.

2.3. Tree counting analysis using eCognition

2.3.1. Data collection

The aim of this field data collection was the validation of the results of the image processing analysis in the tree counting and LiDAR analysis projects. All the field surveys were undertaken in parallel to the aerial photography and LiDAR surveys before the start of the growing season to avoid a temporal decorrelation in the predictions of the analysis. The digital aerial photographs were orthorectified and geo referenced between MGIU and Forest Research using the LiDAR data layers as the reference points. This technique ensured a good match between the two data layers and a superior geo correction than the one normally obtained using OS 1:10,000 maps.

2.3.2. eCognition analysis

The aims of the Tree Counting project were:

1. Evaluation of the eCognition software for counting trees in mature Sitka spruce plantations.
2. The identification of sensible grounds for the implementation of a fully automated method for tree counting using the software and the three visible channels (RGB) from commercial digital aerial photography.
3. The exploration of the main issues involved in the development of a fully automated method for tree counting such as image characteristics, image acquisition, image segmentation methods and image classification. The aim was the development of a rule-based system transferable across a wide range of situations knowing the limitations of the method and data inputs.

2.3.3. Image classification eCognition

There are two methods for image classification available in eCognition:

1. The Nearest Neighbour classifier and
2. The use of membership functions.

At the moment, both methods seem to require considerable input from the user, which constrains the possibility of a fully automation of the process. The easiest and more effective method appears to be the Nearest Neighbour. It requires fewer interactions from the user and the parameters are more transparent. The use of membership functions requires a methodical analysis of each one of a long list of properties that include reflectance characteristics, topological relationships of the objects and logical operators. The program offers the possibility of selecting the most relevant properties in order to construct a rule based system that quantifies the degree of membership of the objects, obtained in the segmentation process, to a class defined as tree top.

1.3.4. Nearest-Neighbour classifier (NN)

The Nearest-Neighbour (NN) classification system is a quick method that requires the selection of sample objects within a defined feature space. This method is quite dependent upon a careful definition of classes and the selection of the most representative samples by the operator. Therefore, the method is very interactive and needs a lot of trial error attempts, which leaves very little room for automation.

The process of analysis has required a combined use of eCogniton and ArcView. This process is outlined as:

- Segmentation of the original images defines scale by the number of trees in each plot. The rest of the parameters are equal in all the 12 areas: Colour 0.8, Shape 0.2, Smoothness and Compactness 0.5 Polygons are exported to ArcView as a shape file.
- Selection of polygons classified as tree tops in ArcView.
- Location of the centroid within each polygon. Normally, this centroid will correspond with the location of the tree top in the field. The results evidence this statement.

Table 2: The table below provides a summary of the best results achieved after an

Plot ID	No of trees	Colour weight	Scale parameter	Estimated no of trees	Percentage of success
1	142	0.8	8	126	89
2	75	0.8	10	65	87
3	235	0.8	5	162	69*
4	109	0.8	10	98	90
5	270	0.8	5	223	83
6	123	0.8	9	121	98
7	96	0.8	10	90	94
8	103	0.8	10	111	108**
9	134	0.8	9	131	98
10	133	0.8	8	161	1.22***
11	167	0.8	8	152	91
12	126	0.8	9	123	98

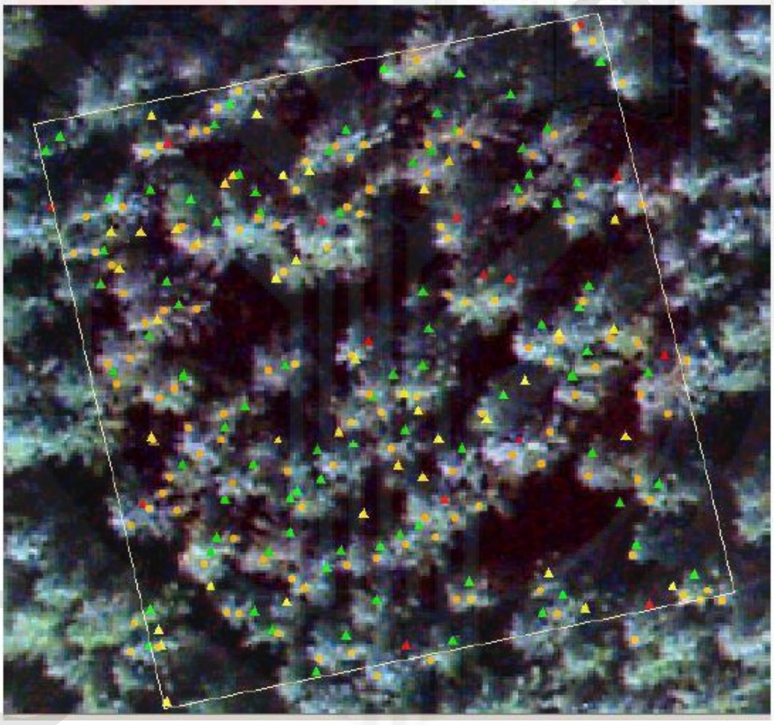

Figure 2: Plot 1; Scale 8; Colour 0.8; Shape 0.2

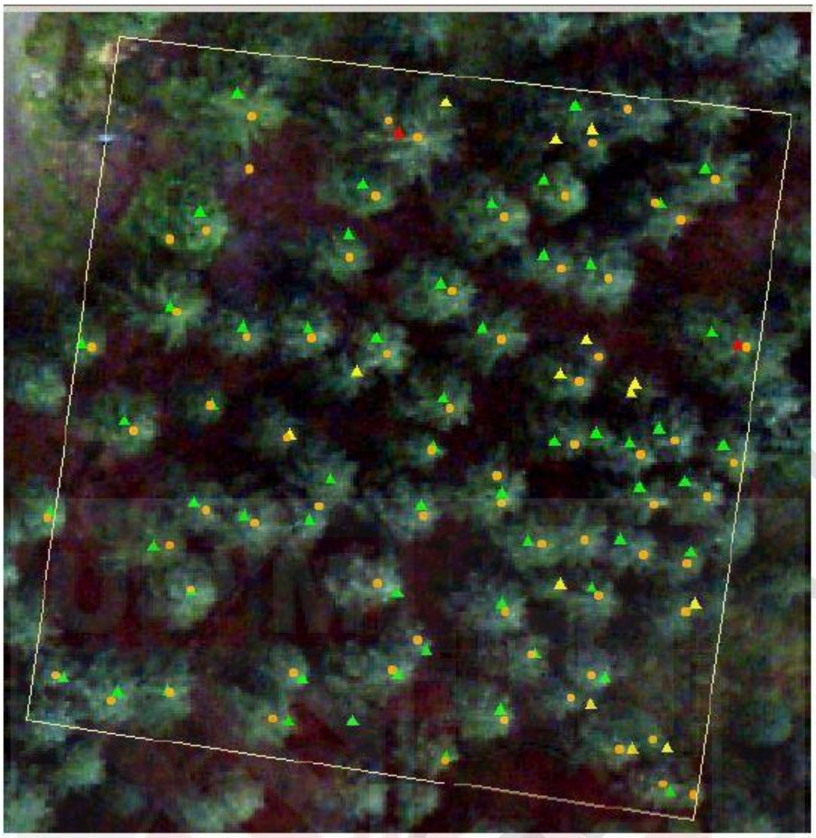

Figure 3: Plot 2; Scale 10; Colour 0.8; Shape 0.2

CHAPTER 3

3. METHODOLOGY

3.1. Introduction

This research was performed at Random Oil Palm Tree Farm (area of interest) in *Figure 6* and *Figure 7*. The first study was to Control and fly the UAV inside the oil palm plantation. Second, to study the accuracy on counting the oil palm treesusing RGB camera and process the image in order to compare between three methods:

1. Training Rule Method,
2. Trimbler eCognition Software and,
3. Human counting (manual count).

3.2. Data Collection

For data collection, the equipment used was the UAV and RGB camera. For UAV we used DJI Phantom 2 (DJI Company) that brought from www.amazon.com.my with estimation weight 1000g, maximum Ascent speed : 6m/s ; Descent speed 2m/s, the maximum flight speed 15m/s, estimation battery life when flight 25 minutes, and 2.4GHz remote control with communication distance 1000m (open area). For the RGB camera we used GOQ F60R 4K 16M Action Sport Camera, that brought from www.lazada.com.my with 4K 30fps, 1080p 60/30 fps video and 16M for images, and with estimation weight 580g.

Figure 4: DJI Phantom 2 (UAV)

Figure 5: GOQ F60R 4K 16M Action Sport Camera

Figure 6: Area of Interest capture by UAV

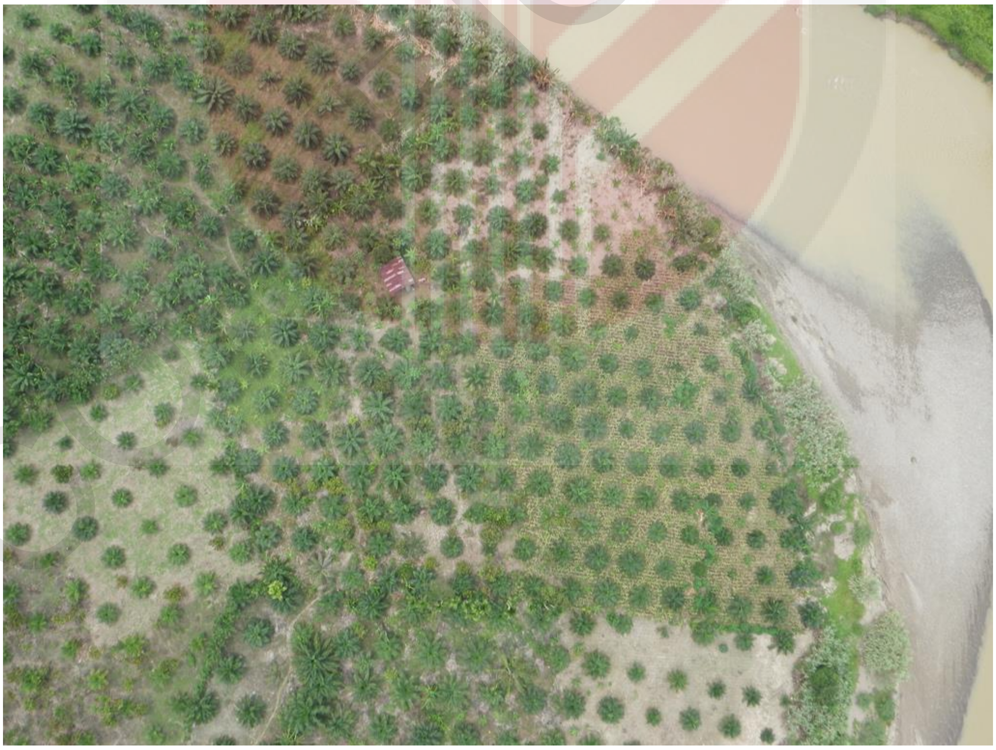

Figure 7: Area of Interest capture by UAV

1. The UAV was flown to the suitable height to get the high density of oil palm tree image
2. The UAV was flown to 70 meter height, and collected the image.
3. After the image was collected, counting of the oil palm tree was done manually and recorded.
4. By using the Training Rule software the image was refined and processed to estimate the number of oil palm trees from number of image area using Arcgis map Software.
5. By using Trimbler eCognition software the images were refined and processed to estimate the number of oil palm trees from threshold filtered image, then uploaded into Arcgis Map Software
6. The results ware compared between Training Rule Method and Trimbler eCognition software.

3.3. Overall Methodology

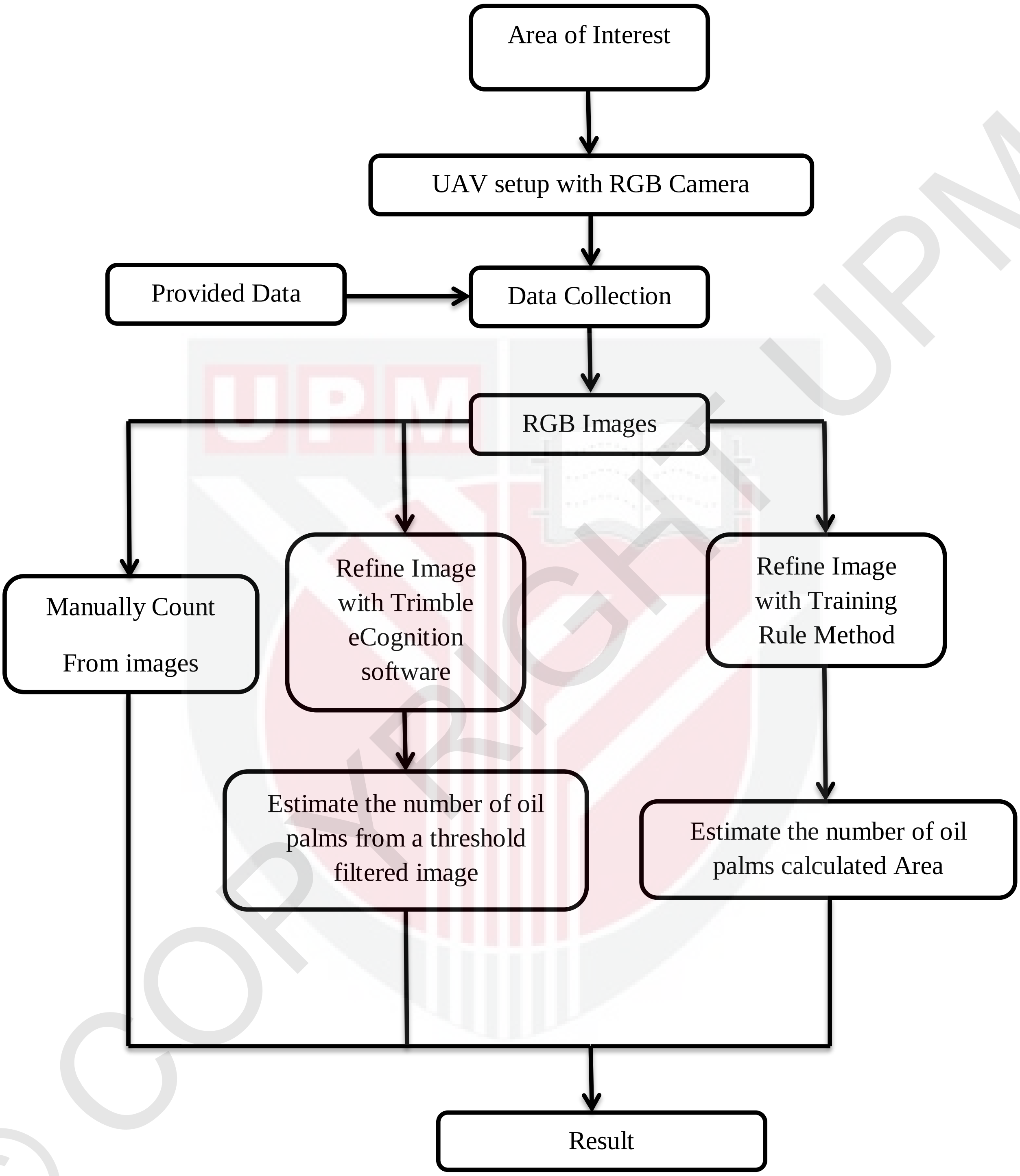

Figure 8: The flow of methodology

3.4. Data Preparation and Processing

3.4.1. Manual Counting

The images obtained by UAV were printed to make the manual counting easy and smooth. The counting process of image was done several times, as for each image the palm trees were counted four times. Before counting process each tree need to be identified, so that only Palm Oil trees were selected.

3.4.2. eCognition Developer Counting

The eCognition Developer software is very practical to use and it offers a comprehensive collection of algorithms tailored to different of image analysis. Beside user can choose from variety of segmentation algorithms such as multiresolution, quad tree or chessboard.

For this we only used the RGB Image solution to counting the trees and how to process the image by using the Template Matching method and import the matching with different threshold and determined the number of palm trees were detected.

Firstly, the eCognition Developer software was opened and, then the image to analyse was selected, for this step the first image selected is as shown in *Figure 6*. After this the Template Editor was selected. If not found, needed to go to view and go to window then needed to select Template Editor.

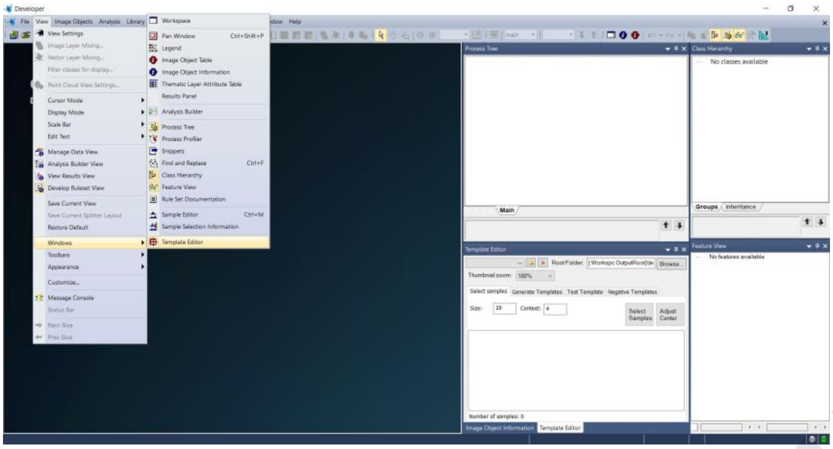

Figure 9: How to select the Template Editor

Secondly, at Template Editor, needed to go to browse that saved the output file to specific location for later use. Needed to click the Select Samples and put the name “PalmTemp”. Selected 30 samples at different locations that represent the palm oil trees in the image *Figure 6*. Needed to ensure that the samples were selected at the centre of the sample to get high sample correlation.

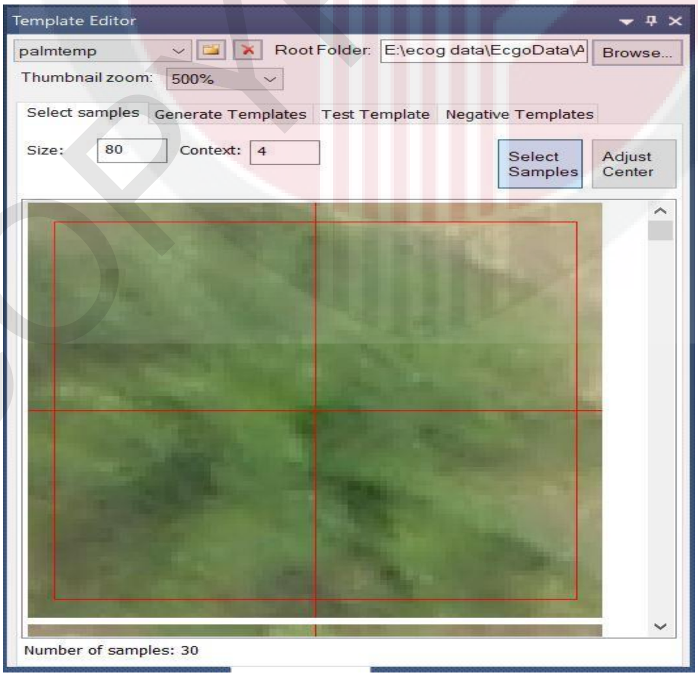

Figure 10: The selected sample

Thirdly, after 30 samples were selected, needed to go to Generate Templates window behind the Select samples window. Needed to select Layer 1 in Layer box then generate the template. Needed to repeat this step by changing the Layer box to Layer 2 and Layer 3. After all layers were generated, needed to compare each layer the value of sample correlation at the bottom of Template Editor window, the best value of Sample correlation almost to 1. As in this sample correlation Layer 1 had highest value compared to Layer 2 and Layer 3.

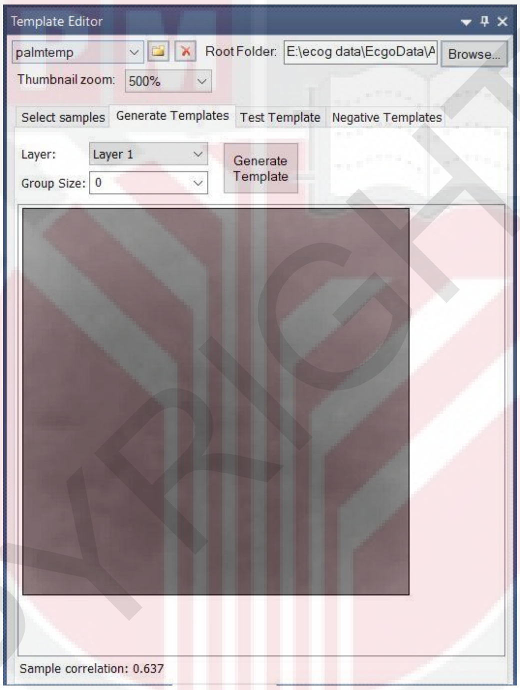

Figure 11: The sample correlation value at the bottom

Fourthly, needed to go to the Test Template window, click to Select Region, and select the region that interest in the image in *Figure 7*. Then at the Template selection in the Test Template window, Layer 1 was picked as it has the highest value of samples correlation than other layers. Next, at the Test parameter, at Threshold box the value 0.5 was inserted (since we were interested in threshold 0.5 and 0.4), then at Test tick the Update Template and Execute Test. Next step at the Process Tree window, needed to right click then chose Append New. After opening the Append New, at Algorithm box, the template matching was selected. At the Algorithm parameter on Template folder, needed to choose the folder that save three layers that have sample correlation, on Input layer rename the name of file example “CC_palm”, for the Output layer choose the Layer that have value near to 1. In this case the value that near to one is Layer 1, for the Threshold insert the value 0.5 and for the thematic layer rename it to “tempalm”. Next step is to execute the algorithm. After the algorithm process was done, then needed to show the vector point in the image. To do this needed to move the cursor to toolbar and find Show/Hide Vector layers as shown in, *Figure 17*.

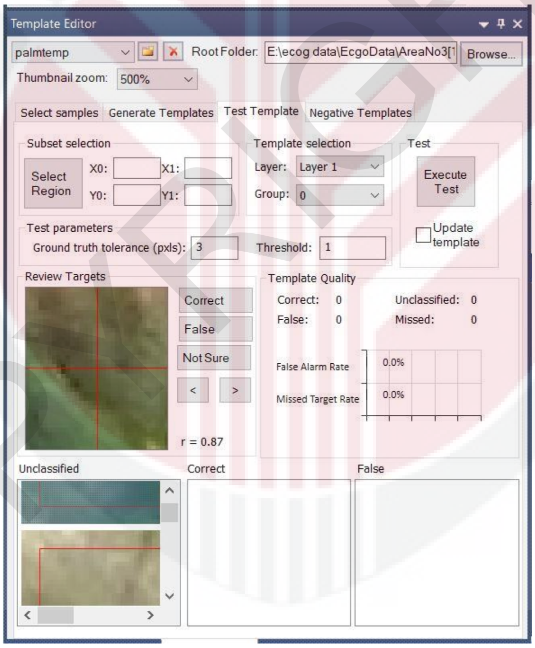

Figure 12: The template testing window

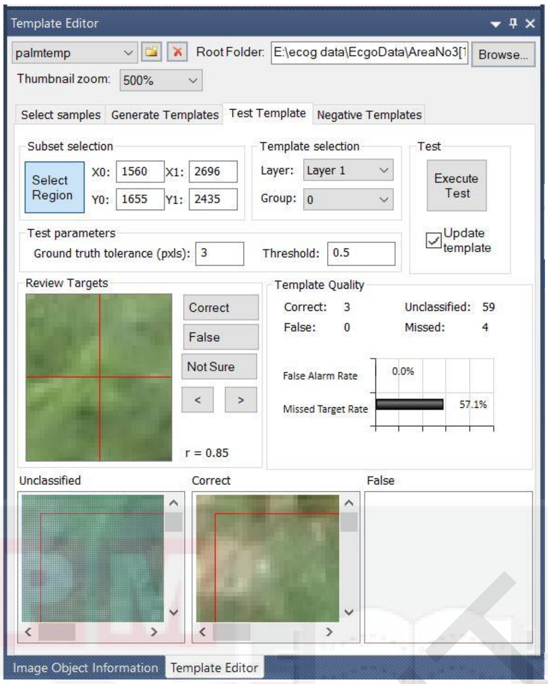

Figure 13: The result on Execute test

Figure 14: The selected Region

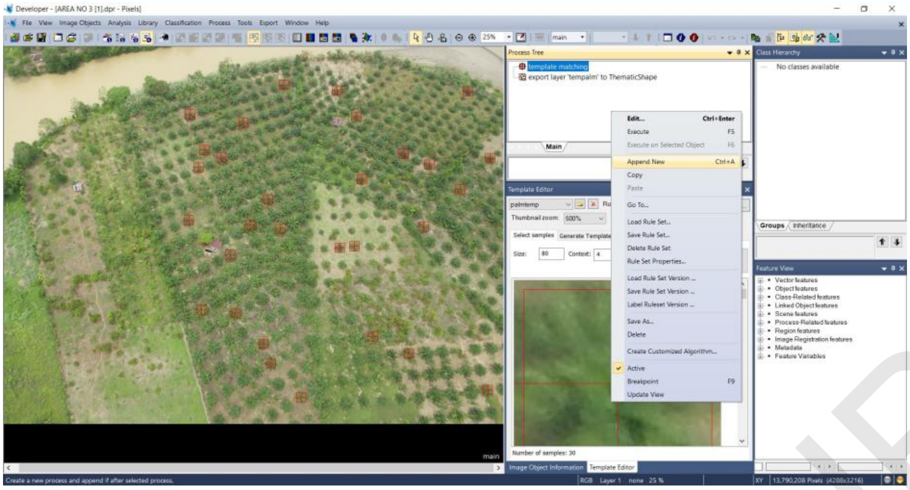

Figure 15: How to select the Append New

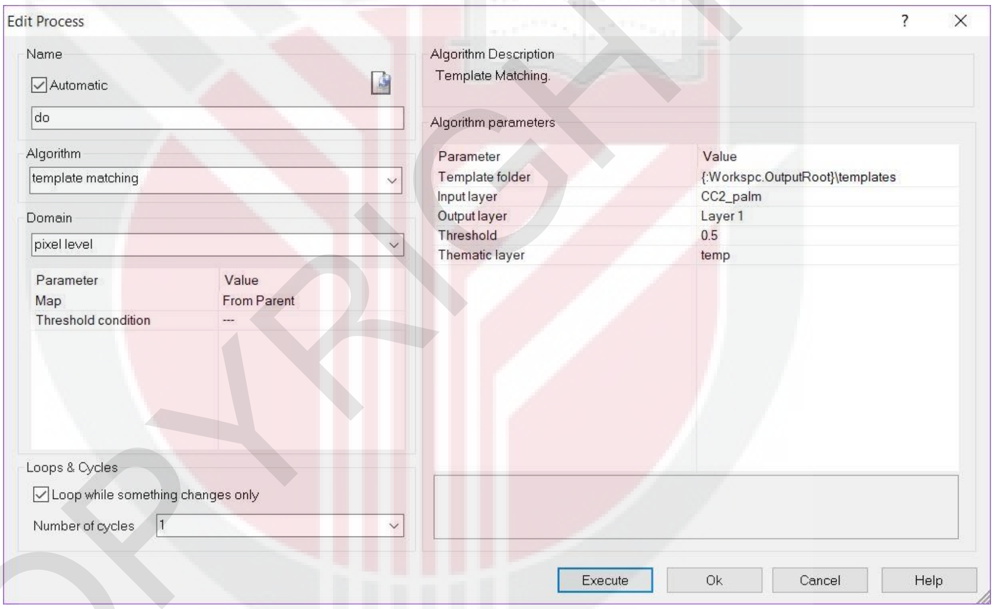

Figure 16: The executable window

Fifthly, when the vector layer already generated, next was to export the vector layer to shapefile. To do this at Process Tree window right clicked and selected the Append New. At Algorithm choose Export to existing vector layer, for the Algorithm parameter at Export Path put the export file to the folder and the end of path insert the

“**.shp** “. Needed to repeat the fourth step until the end by changing the Threshold Value to 0.4 and save the project shown in *Figure 15* and *Figure 16*.

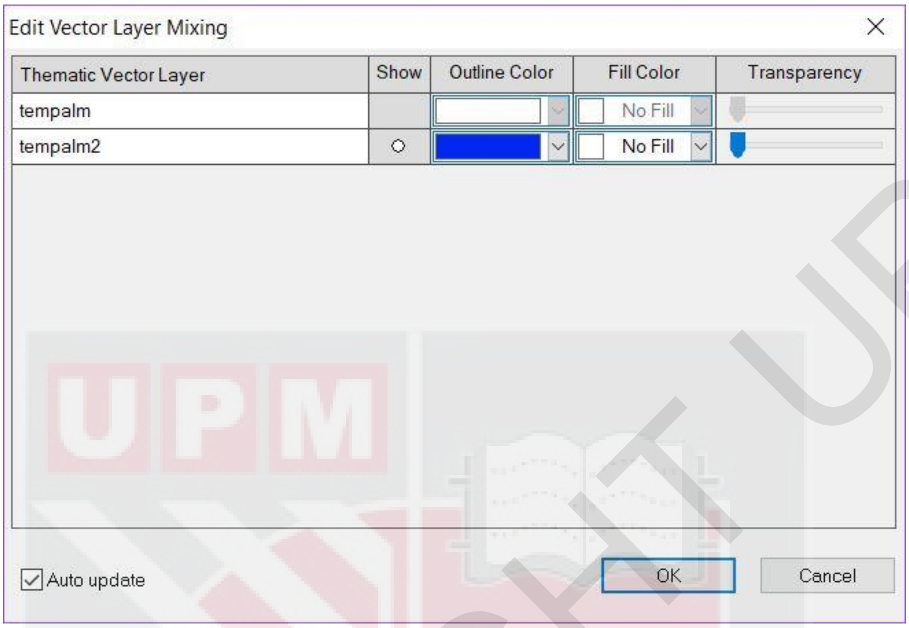

Figure 17: Window to show/hide vector layer

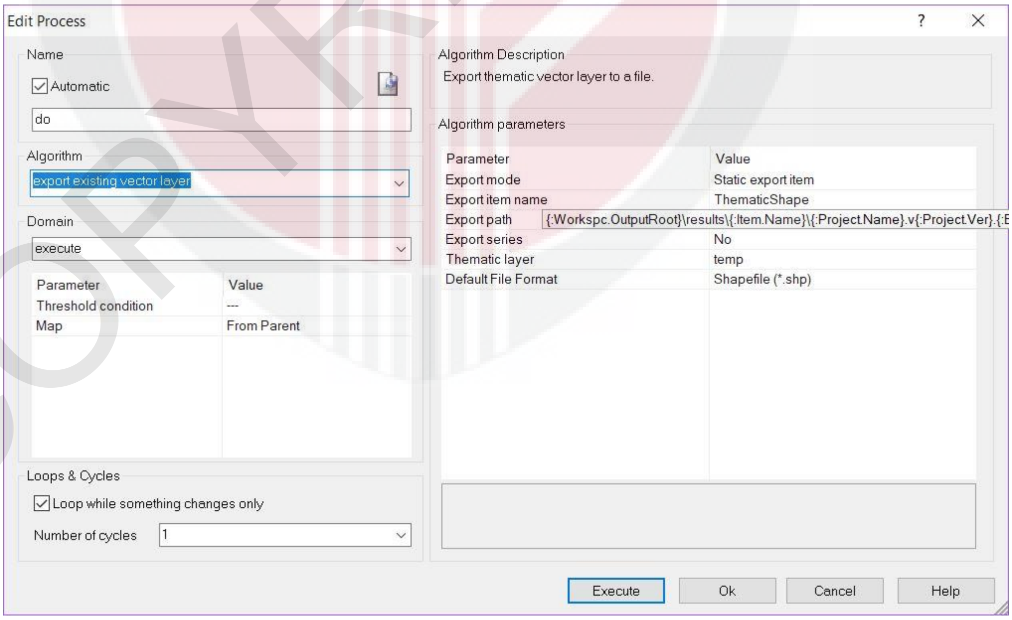

Figure 18: Step to export vector layer to shapefile

Finally, the Arcgis ArcMap software was opened, and the vector layer **".shp**" and the RGB image were inserted. Next was to Georeferencing the vector a point with the image. After the georeferencing was, next step was to start editing the vector points. In editing process, most of the point that out from the interested area were removed. Next was to remove the points that did not represent the palm trees, such as bush or the plantation tree in the image (example: banana trees). Editing process was done, then needed to open table of attribute of the point, the number palm trees would be shown. Repeat this process for the vector layer for threshold 0.4.

3.4.3. Training Rule Method Counting

Training mode method is the method to estimate the number of objects in an area. To estimate the number of the objects there are some condition to follow first, the object must be in arranged. And, the blank spot must be subtracted to get only areas that only have trees. If the object are not arrange such as if one area have two pattern of tree and not in same arrangement, it need to divide the area in to two area, in this case it will have two training mode area and each area need to subtract the blank spot to get the high accuracy estimation.

This training mode method can be done in any free software or any software that can calculate the area, for this project using the ArcGis, ArcMap software is used, due to it interface and editing area for interesting area are easy and friendly.

Firstly, go to add data, add the image of interested area shown in and the shapefile for WholeArea, TrainingArea and AreaofBlank as shown in *Figure* 19.

After the images were shown, carefully see the pattern of the arrangement of the palm tree, and divide the area if the arrangement of the palm tree was not the same. In this image the area was divided by three sections of area as shown in *Figure 20*. After the whole area had been identified, the next step was to locate the blank spot or area no palm trees or building as shown in *Figure 21*.

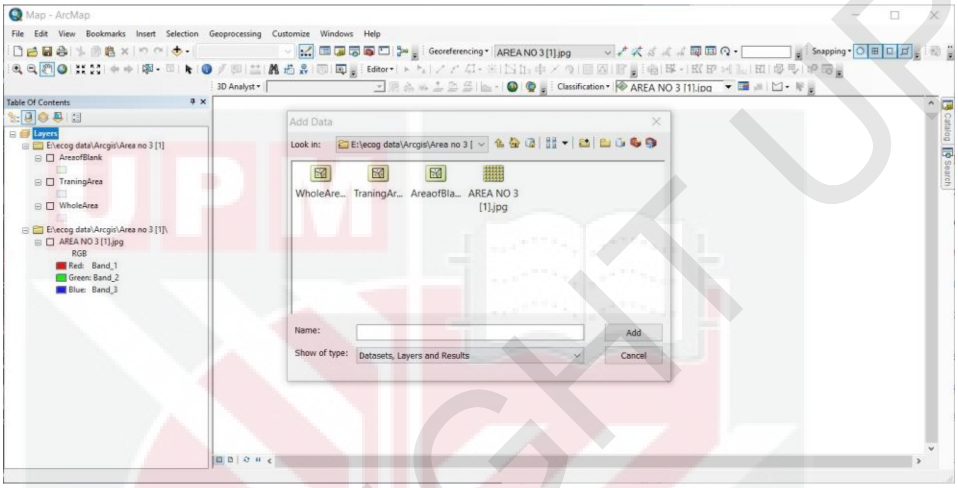

Figure 19: Selected shapefile to edit

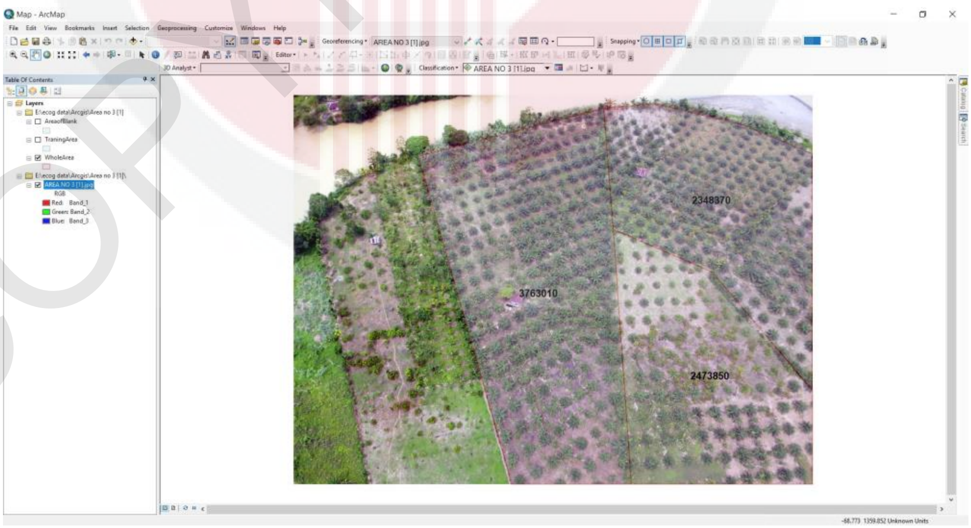

Figure 20: Three divided area

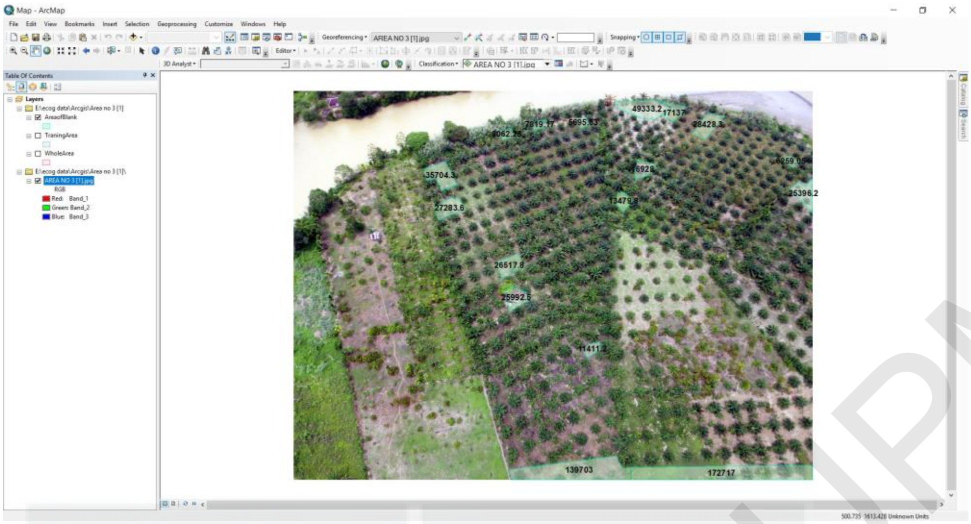

Figure 21: Show the blank area

Secondly, after all the blank areas were identified, proceed to making the training rule area. As the section of area was divides by three, the training rule area need to be three of each divided section area as shown in *Figure 22*. The training area can be placed anywhere in each section area, each training area must contain the number arrangement of tree, in case each training area consist of four palm trees as shown in *Figure 23*.

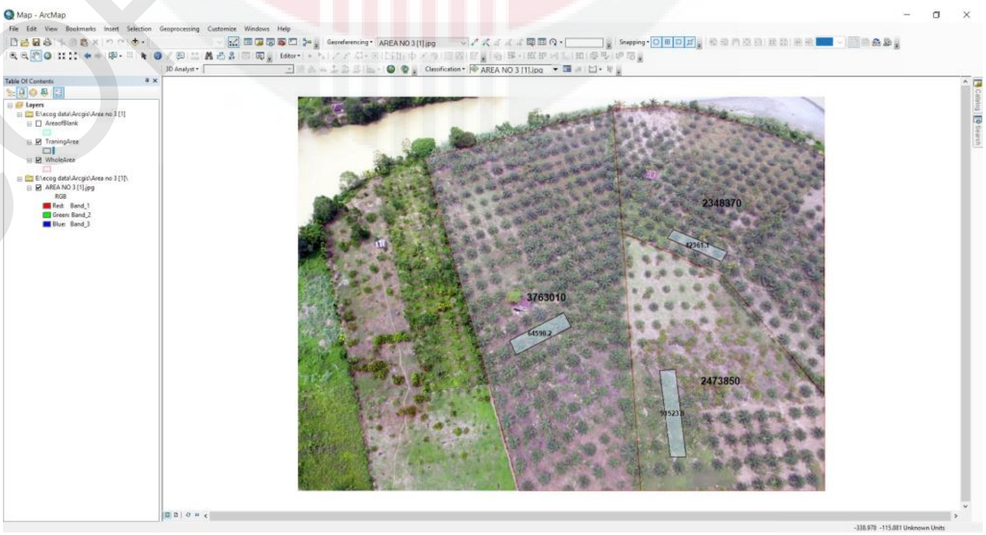

Figure 22: Each Training Area in each three area

Figure 23: The Training Area

Thirdly, this step is the calculation steps where each section area must subtract the blank area inside each section area to get the whole area. After removing blank area, next was to calculate each training area. For the benchmark of the number of trees in each section area, manual counting needed to be done for each section area for the accuracy purpose.

By using the number factor formula:

$$FACTOR = \frac{Whole\ Area - Blank\ Area}{Training\ Area}$$

Once the number of factor value obtained; proceed to find the estimation count;

By using estimation count formula:

$$Estimated\ Count = FACTOR\ \times number\ of\ trees\ in\ Training\ Area$$

3.4.4. Accuracy Assessment

The accuracy assessment plays an important role in to find the capability of each method and to make comparison between each method, to see the ability of accuracy estimation counting, with the benchmark of manual counting as the base of this accuracy assessment.

Where the percentage accuracy:

$$Percantage\ Accurracy = \frac{estimated\ count}{manual\ count} \times 100\%$$

CHAPTER 4

4. RESULT AND DISCUSSION

4.1. Result on Manual Counting

For the manual counting process, it takes a few hours to count two images. This counting process involved with hardcopy (printed) of images and also softcopy of images, this is because to avoid wrong counting of trees. Beside hardcopy of images help to make counting by hand easily to mark the counted tree, also this count process repeat for 5 times to check any miss counted tree until the value counted are the same. On the other hand softcopy help to identify and confirm the object is palm tree by using the images enhancement as a help tool. The images enhancement technic usually is done in ArcGis ArcMap software show in *Figure 32* and *Figure 34*. As the combination of the two images the counting can be more accurate and precise where the first image counted 557 trees and for the second image counted 354 trees.

4.2. Result on eCognition Developer Counting

For using the eCognition Developer software, the class algorithm in the software was based on the points generate in template matching for tagging the possible of object (palm trees) in the image. The comparison of accuracy between eCognition Developer and Training mode method are shown in *Table 3*.

Table 3: The comparison result of eCognition and Training Rule method

IMAGE NO.	First	Second
eCognition Developer		
Threshold 0.4		
Estimated Trees	532	351
Percentage Accuracy	95%	99%
Threshold 0.5		
Estimated Trees	514	304
Percentage Accuracy	92%	85%
Training Rule Method		
Estimated Trees	523	340
Percentage Accuracy	94%	96%

Form the result of eCognition on counting palm tree in first image with the threshold value (0.5) shown in *Figure 24*, the estimated counting of about 514 trees were counted. On the other hand, result of eCognition on counting palm tree in first images with the threshold value (0.4) shown in *Figure 25*. The estimated counting about 532 trees were counted.

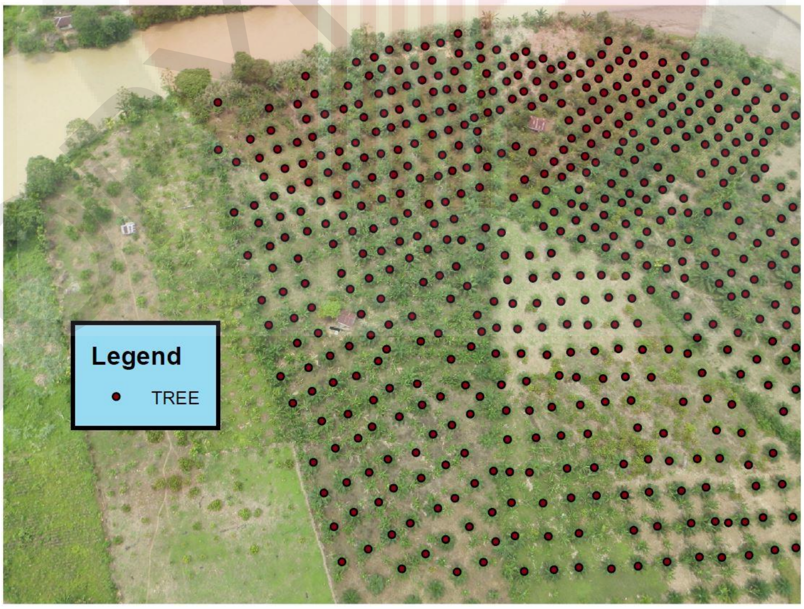

Figure 24: The eCognition result threshold (0.5) for first image

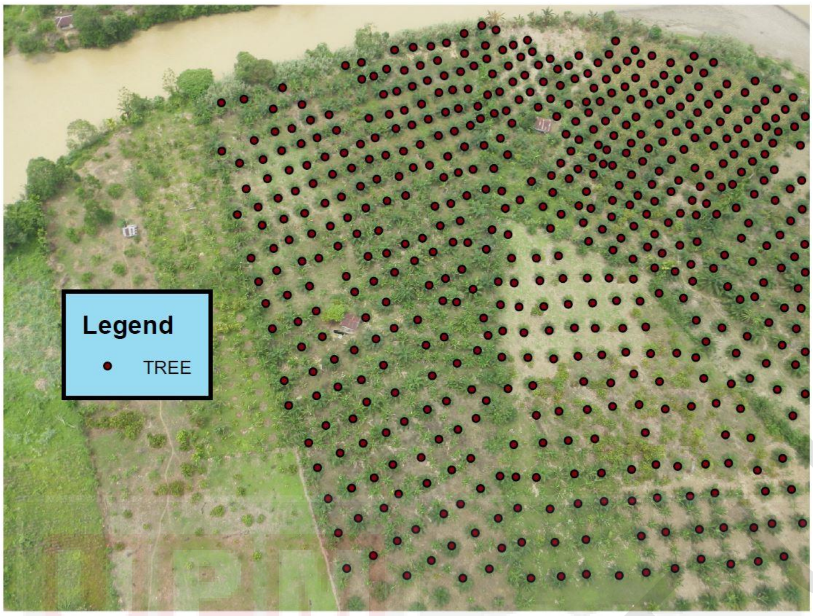

Figure 25: The eCognition result threshold (0.4) for first image

By using the percentage Accuracy formula, we found that the estimated accuracy on threshold (0.5) about 92.28% accuracy. Meanwhile for estimated accuracy on threshold (0.4) about 95.51% accuracy.

Form the result of eCognition on counting palm tree in second image with the threshold value (0.5) shown in *Figure 26*. The estimated counting of 304 trees was counted. On the other hand, result of eCognition on counting palm tree in second images with the threshold value (0.4) shown in *Figure 27*. The estimated counting of about 351 trees was counted.

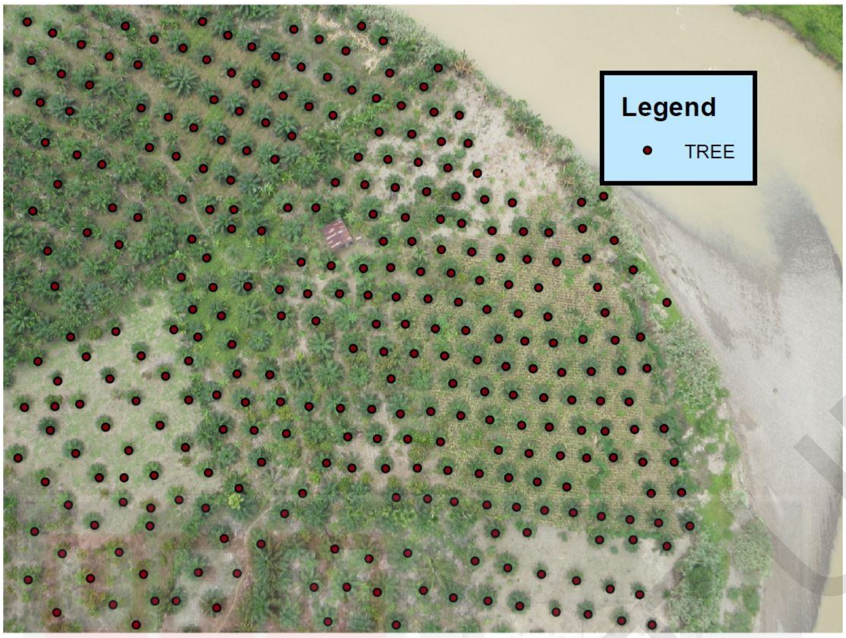

Figure 26: The eCognition result threshold (0.5) for second image

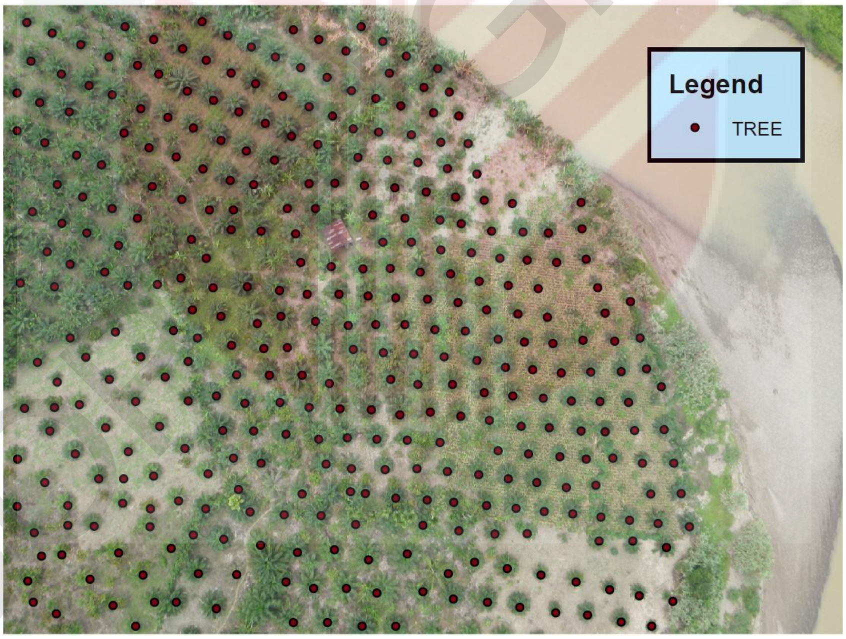

Figure 27: The eCognition result threshold (0.4) for second image

By using the percentage Accuracy formula, we found that the estimated accuracy on threshold (0.5) about 85.86% accuracy. Meanwhile for estimated accuracy on threshold (0.4) about 99.15% accuracy.

However, there were some sorts of problem during data managing and editing the point. Somehow, most of the point where shoot at something else than palm tree like other object such bush and other crop shown in *Figure 28*. In order to overcome this, vector layer had to be edited to make sure that all points in the image only pointing the palm trees. In editing process point that outside the interesting region were removed. Unfortunately, for the point that did not represent the palm trees inside the region on interest had to be removed carefully to avoid mistakenly removed of point on the palm trees. *Figure 29* shows not only points near the palm tree but also point of the other crops. This is because inside this region there were some crops planted together, like banana trees and other crops.

Figure 28: The unedited point

Figure 29: The point that miss target

4.3. Result on Training Rule Method

Training rule method is the method that estimate the number of object (trees) with the value of area. The training mode is very easy step for the inventory management to estimate the number of trees without using expensive software or complex algorithm or using any neural network method or deep learning of machine. Moreover using this method can give us the estimated value above 90% of accuracy. Same to the eCognition method, the benchmark counting are the manual count to make the value of accuracy.

From the data in first image in *Figure 6* the area are divided into three (area 1, area 2 and area 3), each of area need to underline the blank area, whole area and training area. In area 1: the value of sum of blank area is 288189.803; the value of whole area is 363009; and training area is 64590.16. In area 2: the value of sum of blank area is 172716.8; the value of whole area is 2473850; and training area is 91523.95. In area 3: the value of sum of blank area is 156961.56; the value of whole area is 234872; and training area is 42361.09. As all section area already label as shown in *Figure 30* and all the calculation of the area and estimated count shown in *Table 3*.

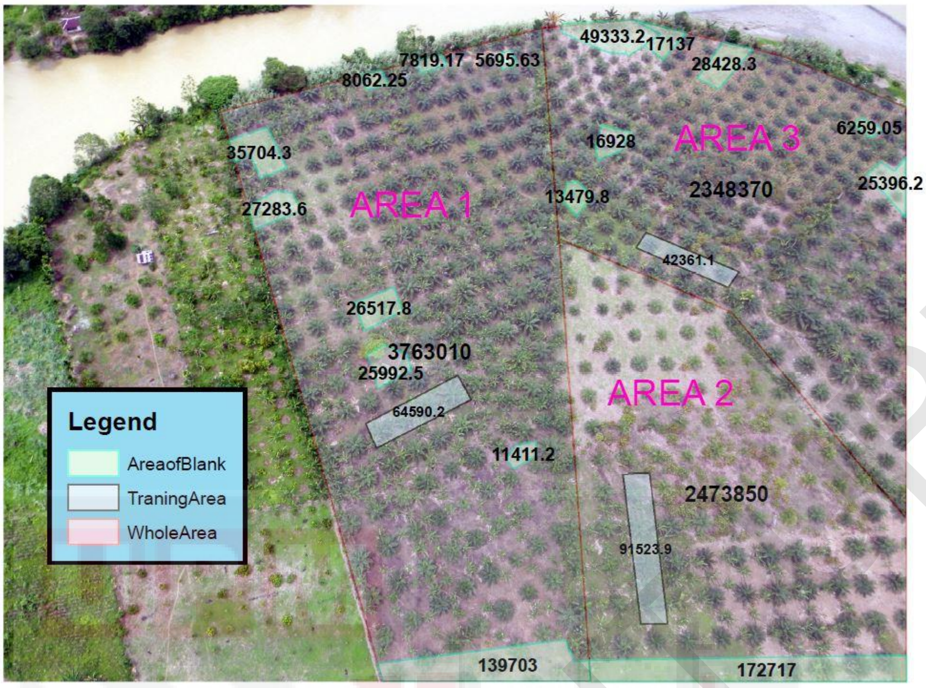

Figure 30: The Training rule result for first image

Table 4: The calculated result for first image

AREA NO.	1	2	3	1+2+3
SUM OF BLANK AREA, ab	**288189.803**	**172716.8**	**156961.56**	
WHOLE AREA, wa	**3763009**	**2473850**	**2348372**	
TRAINING AREA, ta	**64590.16**	**91523.95**	**42361.09**	
NO. OF TREE IN TRAINING AREA, nt	4	4	4	
SUBTRACTED AREA (wa - ab)	3474819.197	2301133.2	2191410.44	
FACTOR VALUE (wa - ab)/ta	53.79796546	25.14241573	51.73168207	
ESTIMATED COUNT (FACTOR VALUE * nt)	**215**	**101**	**207**	
MANUAL COUNTING	**237**	**103**	**217**	
TOTAL ESTIMATED COUNT				523
TOTAL MANUAL COUNT				557
TOTAL PERCANTAGE ACCURACY	90.79%	97.64%	95.35%	93.83%

From *Table 4* in area 1, the estimated count was around 215 trees, where the manual count was about 237 trees, the estimated accuracy of 90.79%. In area 2, the estimated count was around 100 trees, where the manual count about 103 trees, the estimated accuracy of 97.64%. In area 3, the estimated count was around 206 trees, where the manual was count about 217 trees, the estimated accuracy of 95.35%. With all total estimated count was 522 trees and total manual count was 557 trees, the estimated accuracy of 93.83%.

From the data in second image in *Figure 7* the area was divided into three (area 1, area 2 and area 3), each of area need to underline the blank area, whole area and training area. In area 1: the value of sum of blank area 870.729; the value of whole area is 133458; and training area is 6324.388. In area 2: the value of sum of blank area is 34452.59; the value of whole area is 335116.8; and training area is 5647.393. In area 3: the value of sum of blank area is 13189.015; the value of whole area is 90137.1; and training area is 7108.339. As all section area already labelled as shown in *Figure 31* and all the calculation of the area and estimated count are shown in *Table 4*

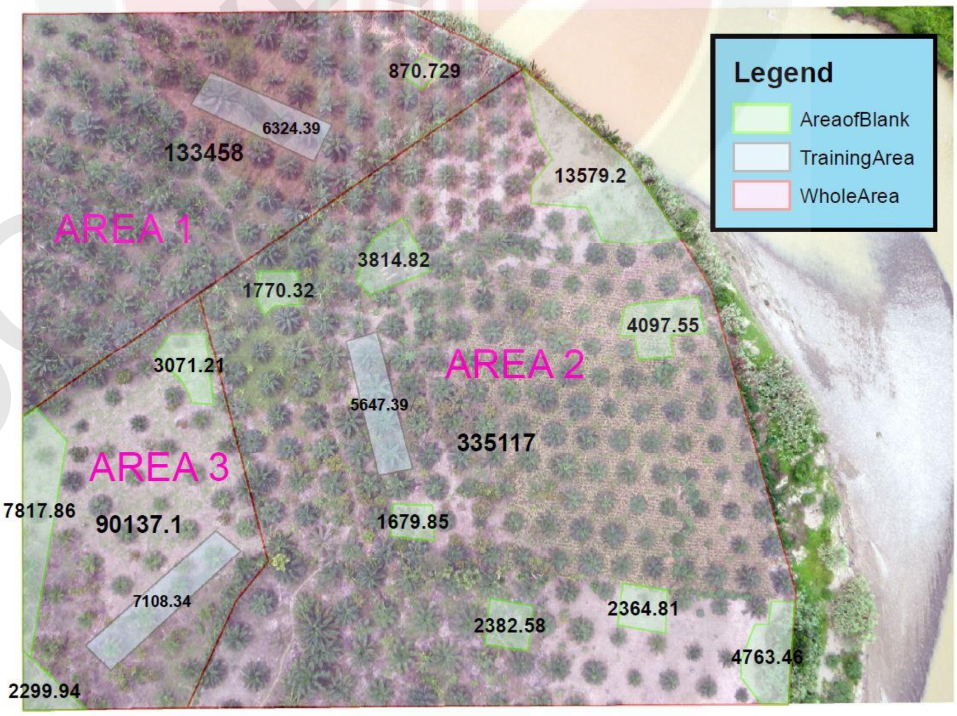

Figure 31: The Training rule result for second image

Table 5: The calculated result for second image

AREA NO.	1	2	3	1+2+3
SUM OF BLANK AREA, ab	**870.729**	**34452.59**	**13189.015**	
WHOLE AREA, wa	**133458**	**335116.8**	**90137.1**	
TRAINING AREA, ta	**6324.388**	**5647.393**	**7108.339**	
NO. OF TREE IN TRAINING AREA, nt	4	4	4	
SUBTRACTED AREA (wa - ab)	132587.271	300664.21	76948.085	
FACTOR VALUE (wa - ab)/ta	20.96444288	53.23946996	10.82504436	
ESTIMATED COUNT (FACTOR VALUE * nt)	**84**	**213**	**43**	
MANUAL COUNTING	90	221	43	
TOTAL ESTIMATED COUNT				340
TOTAL MANUAL COUNT				354
TOTAL PERCANTAGE ACCURACY	93.17%	96.36%	100%	96.07%

From *Table 5* in area 1, the estimated count was around 83 trees, where the manual count was about 90 trees, the estimated accuracy of 93.17%. In area 2, the estimated count was around 212 trees, where the manual count was about 221 trees, the estimated accuracy of 96.36%. In area 3, the estimated count around 43 trees, where the manual count about 43 trees, the estimated accuracy of 100%. With all total estimated count was 340 trees and total manual count was 354 trees, the estimated accuracy of 96.07%.

CHAPTER 5

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

From the analysis done, it is shown that in first image using eCognition Developer with threshold 0.4 give the precision accuracy about 95% higher than the threshold 0.5 with precision accuracy about 92%. Meanwhile, for Training Rule method gives the precision accuracy almost 94%. From this, the difference between eCognition with thresholds 0.4 and Training rule method around 1%, and the difference between eCognition threshold 0.5 and Training Rule method around 2%.

In the second image, the eCognition Developer with threshold 0.4 give the precision accuracy about 99% higher than the threshold 0.5 with precision image 85%. Meanwhile, for Training Rule method gives the precision accuracy about 96%. The difference between eCognition threshold 0.4 and Training Rule method around 3% and between eCognition threshold 0.5 and Training Rule method around 11%.

In conclusion, the precision accuracy between thresholds 0.4 with Training Rule between ranges 1-3%, from this Training Rule method are reliable in order to estimate the number of trees in the interested area, with the best and cheap.

5.2. Recommendation

5.2.1. eCognition Developer software

- In order to use this software the user must know and understand the operation of the software and the complex algorithm in the software.
- For better result high resolution image are needed to increase accuracy and reduce miss object target.
- For eCognition, correlation value near to 1 is better for reliable result on object counting.
- The Trimbler eCognition Developer software is not cheap software, the user need to invest some money in order to use it.

5.2.2. Training Rule method

- To use this method, user only need to understand on how to calculate the area: area of field, area of blank (no trees) and the training area.
- Simple method that only use, simple calculation and factor formula.
- Can use any free software that can help calculate polygon area.
- No need to invest on software, but only invest on drone.
- No need high resolution image, because it only area are interested.

REFERENCES

1. Adigbli, P., Grand, C., Mouret, J.-B., Doncieux, S., 2007. Nonlinear Attitude and Position Control of a Micro Quadrotor using Sliding Mode and Backstepping Techniques. 3rd US-European Compet. Work. Micro Air Veh. Syst. 17–21.
2. BAI, Y., LIU, H., SHI, Z., ZHONG, Y., 2015. Robust Flight Control of Quadrotor Unmanned Air Vehicles. Robot 34, 519.
3. Blaschke, T., Feizizadeh, B., Hölbling, D., 2014. Object-based image analysis and digital terrain analysis for locating landslides in the Urmia Lake basin, Iran. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 7, 4806–4817.
4. De Vries, E., Subbarao, K., 2010. Backstepping based nested multi-loop control laws for a quadrotor. 11th Int. Conf. Control. Autom. Robot. Vision, ICARCV 2010 1911–1916.
5. Diao, C., Xian, B., Yin, Q., Zeng, W., Li, H., Yang, Y., 2011. A nonlinear adaptive control approach for quadrotor UAVs. 8th Asian Control Conf. 223–228.
6. Footnote, S., 1996. Principles of Helicopter Aerodynamics. J. Am. Helicopter Soc. 1–5.
7. Hoffmann, G., Rajnarayan, D.G., Waslander, S.L., Dostal, D., Jang, J.S., Tomlin, C.J., 2005. The Stanford testbed of autonomous rotorcraft for multi agent control (STARMAC) 12.E.4-121–10.
8. Kalantar, B., Idrees, M.O., Mansor, S., Halins, A.A., 2017. Smart Counting – Oil Palm tree inventory with UAV. Coordinates 17–22.
9. Kalantari, A., Spenko, M., 2014. Modeling and performance assessment of the HyTAQ, a hybrid terrestrial/aerial quadrotor. IEEE Trans. Robot. 30, 1278–1285.
10. Nicol, C., Macnab, C.J.B., Ramirez-Serrano, A., 2008. Robust neural network control of a quadrotor helicopter. Can. Conf. Electr. Comput. Eng. 1233–1237.

11. Seddon, J., Newman, S., 2002. Basic Helicopter Aerodynamics Second Edition.
12. Shraim, H., Awada, A., Youness, R., 2018. A survey on quadrotors: Configurations, modeling and identification, control, collision avoidance, fault diagnosis and tolerant control. IEEE Aerosp. Electron. Syst. Mag. 33, 14–33.
13. Utkin, V., 91992). Slides Modes in Control and Optimization. Berlin: Springer-Verlag.
14. Suárez, J.C., 2003. Tree counting analysis using eCognition. For. Com.

APPENDICES

Figure 32: The enhancement of first image

Figure 33: The enhancement of second image

Figure 34: Camera setting before flies away.

Figure 35: The drone that use for flight training purpose

Figure 36: The demonstration on flying drone

Figure 37: The demonstration on flying drone controller from PhD student