Tree Height and Crown Extraction From UAV-Based Multispectral Imagery

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Abstract
Conventional methods in measuring tree height and crown diameter are time consuming compared to the advanced technology of unmanned aerial vehicle (UAV) multispectral imagery. UAV multispectral imagery is widely used in vegetation analysis such as crop analysis, vegetation monitoring, precise farming and vegetation health assessment. Thus, the purpose of this research is to extract the individual tree height and crown diameter from UAV-based multispectral imagery using the integration of geospatial techniques. Altogether, the total of 395 individual trees were extracted from the study area of Section U11, Shah Alam using the Support Vector Machine (SVM) classifier. Tree height values were extracted from normalized digital surface model (nDSM) using the zonal statistics tool with the tree height range between 1.568m to 27.850m. The range for derived crown diameters is between 0.919m to 24.506m. The final map shows the distribution of tree height and tree crown extraction from the UAV-based multispectral imagery. The spatial distribution data of tree height and crown diameter are beneficial especially in landscaping and identifying the potential of tree hazard in the urban area.

Keywords: Multispectral, Support Vector Machine Classifier, Tree Crown, Tree Height, UAV

1. Introduction

Trees beautify the urban landscape and also promotes a healthy community, economy, and environment. Furthermore, trees are essential components of any city or town urban design [1]. The primary function of tree is to improve the ecosystem in the urban areas [2]. In the other words, nature belongs in a city but must be designed for people. As known trees provide the most important things to humans and all living things in our daily life in the term of psychological and physical well-being [3]. It means that urban trees are the vital element of health and social development due to the urbanization that rapidly increases by year. Amongst the health and social benefits of trees in the urban landscape are as improving human health, providing shade to the communities, enhance the visual, improving neighbourhood values, and also creating the shaded streets.

Numerous benefits of trees to society such as increased property value, enhanced sense of the place, storm water runoff reduced, reduced cooling cost, longer pavement life, economic stability increased and the expenditure on grey infrastructure reduced with the increase of the green infrastructure. With the huge amount of heat energy released, absorbed and transferred in the urban areas, trees will act as cooling tools in providing the cooling mechanisms to reduce the heat and land surface temperature [4]. Canopy settings, which contain tree trunks, branches, and leaves, serve as a conduit for the entire ecosystem's exchange of water and carbon with the atmosphere through affecting transpiration and photosynthetic activity [5]. For a good tree management, pruning is often practiced to cut the hazard and old branches and making the safety of the community. However, crown thinning and crown reduction may result in increasing light penetration and air flow throughout a tree's crown [6] and [7].

The common practice in identifying tree height and crown diameter is using direct measurement. However, the individual process is time consuming, especially for large areas. This is due to the time limit during the measurement for collecting the data. Specifically, data needs to be collected during days of good weather.

With the advancement of technology, it is easier and processing time can be reduced but it needs to be an expertise to run the analysis correctly [8]. Recent unmanned aerial vehicle (UAV) based multispectral imagery technology has the ability to obtain accurate tree heights semi-automatically [9]. This demonstrates that, rather than the traditional surveying method in estimation the parameters of tree height and crown diameter, the advancement in UAV-based multispectral imagery and digital image processing offers a great potential in deriving the accurate tree parameters especially for identifying the tree hazard for the safety of urban areas.

Identifying the tree information is important for further actions. Trees spatial information helps recognize the trees that need to be inspected, mitigated, pruning and more to prevent the trees from falling and causing incidents to the people and environments. By using the recent technology of UAV Multispectral, the parameters can be extracted, analysed and stored in a database [10]. The technology reduces the time taken, work force and cost.

2. Materials and Methods

2.1 Study Area

Shah Alam covers a vast area of 290.3 km2 consisting of three zones which are north, middle and south zones. Middle zone is from section 2 to section 25, south covers section 26 to section 36 and the north zone consists of section U1 to U20. Figure 1 shows the area cover for this study in section U11, Shah Alam. The area covers the residential area with various tree species such as *Mimosup elengi*, *Tabebuia rosea* and *Khaya senegalensis.*

2.2 Flow of Methodology

This study consists of four main phases as shown in Figure 2. First phase is the preliminary study which includes planning and preparation. It includes site reconnaissance before obtaining the aerial images and determining the specific software and instruments to be used in this study. This phase is important to ensure that this study will run smoothly within the budget and time allocation. Equipment used in this study is the DJI P4 Multispectral sensor which consists of 6 bands attached to the drone. The Agisoft software used to generate the digital elevation model (DEM), digital surface model (DSM) and orthomosaic. Then, ArcMap is used to generate a normalized digital surface model (nDSM) which is to be used to extract tree height and tree crown were extracted from orthomosaic using Support Vector Machine (SVM) classification method. The final step is analysis and map visualization.

2.3 Preliminary Study

In the preliminary study, site reconnaissance is done to inspect the study area in terms of the suitability to fly the drone. The area chosen is in Section U11, Shah Alam which is also known as Bukit Bandaraya. The area is mostly residential with a greenery view. Next the DJI P4 Multispectral was chosen in this study due to its suitability and also cost effective. The UAV has six (6) cameras with one (1) RGB camera and a multispectral camera array with five (5) cameras covering Blue, Green, Red, Red Edge, and Near Infrared bands. The captured images will then be processed to produce the orthomosaic using Agisoft software and ArcMap used for the further processes.

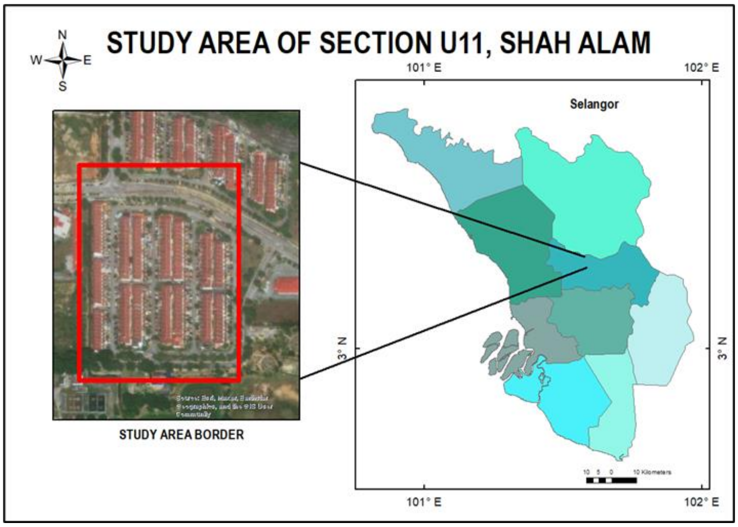

Figure 1: Study area of section U11, Shah Alam

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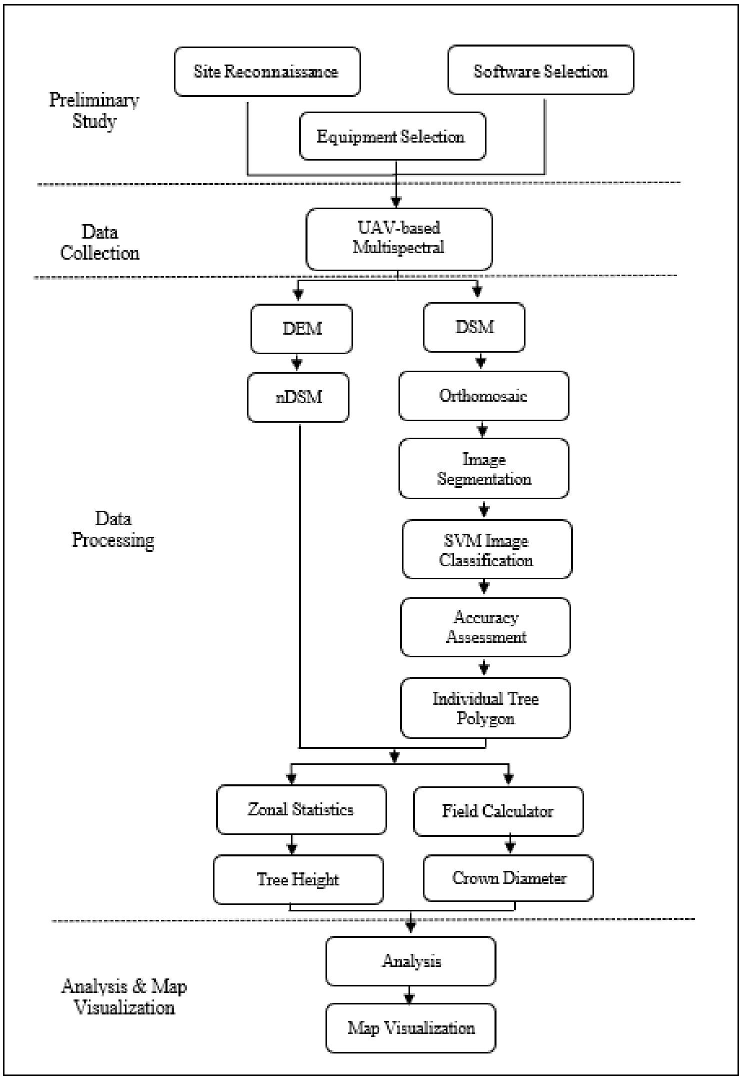

Figure 2: Research workflow

2.4 Data Collection

Planning for aerial photography is critical to the success of projects. Flight planning is essential to ensure that the area to be mapped is covered at the required scale with no gaps and that stereo models are provided by an efficient design. A flight plan will specify the spacing between successive photographs, the locations of flight lines, and the beginning and ending points of each flight line. For this study, the flying height was set to 60 meters with the 90% overlap and 80% sidelap. The mission ended within 24 minutes. Altogether, the total of 3966 images for section U11 were collected with each image have 6 sets representing each spectral band.

2.5 Data Processing

The most crucial part in the research is the data processing which consumes a lot of time and effort. UAV imagery is processed in Agisoft software. Several processes are conducted to produce the output from the imagery.

2.5.1 UAV multispectral imagery processing

Orthomosaic were derived from UAV DJI P4 Multispectral. The images were processed using Agisoft to produce digital surface model (DSM) and digital elevation model (DSM). The first processing shown in Figure 3 is the classification process. The classification process is done to classify the ground point which was used to produce Digital Elevation Model (DEM) and also Digital Surface Model (DSM).

Classification can be done automatically and manually. Figure 4 Shows the process of building the output of Agisoft. DEM are produced with the features on it. DSM are produced using the build DEM process but all the classes are included except the noises, this is because DSM are the model of all the surface of the earth including all the features. The last output is the orthomosaic. Figure 5 shows the process of classifying the individual trees from UAV multispectral imagery using the SVM classification method. The spectral and spatial details selected for this study are 18 and 15 respectively. This step is crucial since the image may be under segmented or over segmented. After completing the image segmentation process, the training samples were obtained for four classes and were trained using the SVM classification process.

2.6 Tree Height Extraction

Individual tree height is extracted from the generation of the normalized digital surface model (nDSM). nDSM represents the height of the features on the surface of the earth. This is based on the expression of DSM minus with DEM to produce the nDSM.

$$DSM - DEM = nDSM$$

Equation 1

Where: *DSM*: Digital Surface Model
DEM: Digital Elevation Model
nDSM: Normalized Digital Surface Model

Zonal Statistics tool is used to calculate the tree height based on the nDSM and tree polygon. Zonal statistics tools produce a table of minimum, mean, maximum, sum, variety and more based on research suitability. The maximum value of the raster that falls within the polygon is considered as the tree height.

2.7 Tree Crown Extraction

In order to extract the tree crowns, individual tree polygons need to be extracted by using image segmentation and image classifications. Segmentation of the orthomosaic image is based on its spectral and spatial details. For this study, spectral details of 18 and spatial details of 15 are used. Then the features were classified into four classes; trees, built up, road and ground using the Support Vector Machine (SVM) classifier. The classified trees were then extracted and converted into polygon to obtain the individual tree polygon. The equation (2) could be utilized for homogeneous tree patterns since the crown diameter of homogeneous trees has a nearly same pattern, making it simple to calculate the tree crown diameter. The crown diameter is extracted from the tree polygon which consists of the crown area and calculated as expression 2.

$$r = \sqrt{\left(\frac{area}{\pi}\right)}$$

Equation 2

Where: *r*: Radius
area: Crown Area

r multiplies the radius by two (2) to get the diameter of the tree crown [8].

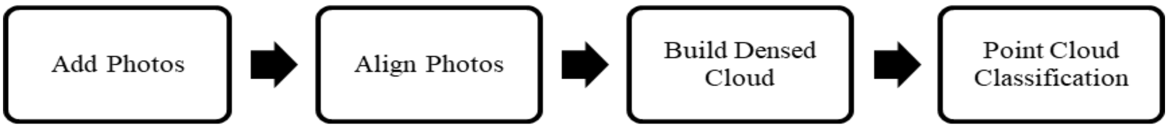

Figure 3: Point cloud classification process

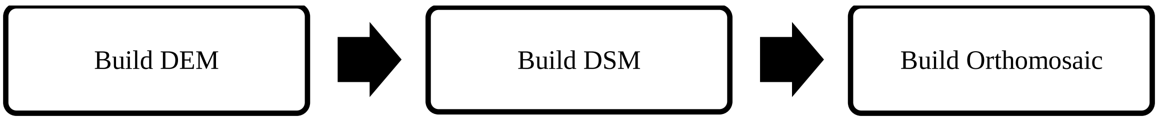

Figure 4: Building output process

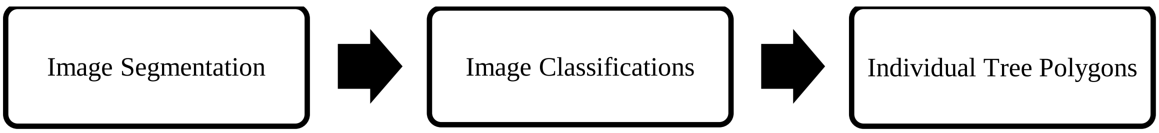

Figure 5: Individual tree polygons process

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3. Result and Analysis

Results for this research consists of point cloud extraction, DEM, DSM and nDSM, orthomosaic, tree height and crown diameter.

3.1 Dense Cloud

Dense cloud is produced from the UAV Multispectral imagery and process in Agisoft. the process required a lot of time due to thousands of images. Figure 6 and Figure 7 show the point cloud extracted which consists a lot of noises. The noises are excluded in the research by classify it into high noise classes.

3.2 Digital Elevation Model (DEM)

DEM obtained from Agisoft with a range of 7.409m to 24.926m. Figure 8 shows the elevation of section u11, Shah Alam. The elevation of the area is not too high since it is a flat surface area except at the white area which is a high area since the area is a hilly residential area.

3.3 Digital Surface Model (DSM)

DSM range for the study area 7.409m to 39.932m which include the features on the earth surface. Figure 9 shows the DSM for the study area. Some of the trees in the study area are in white colour class which represents the high features. Brown class are mostly the residential and green are the surface and the road.

3.4 Normalized Digital Surface Model (nDSM)

Figure 10 shows the nDSM of section U11 shah Alam with the range of 0m to 28.128m. This is the height of the features on the surface which are used to calculate the tree height.

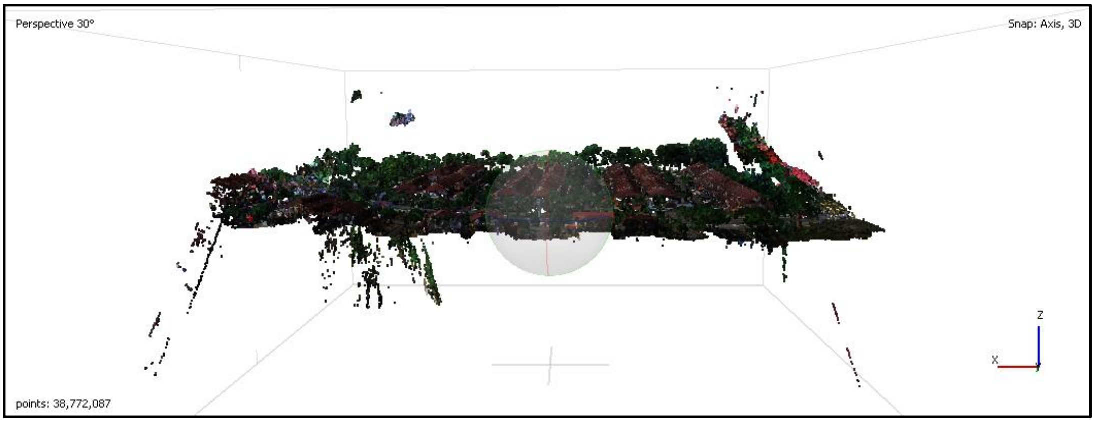

Figure 6: Dense cloud extraction from UAV Multispectral imagery side view

Figure 7: Dense cloud extraction from UAV Multispectral imagery top view

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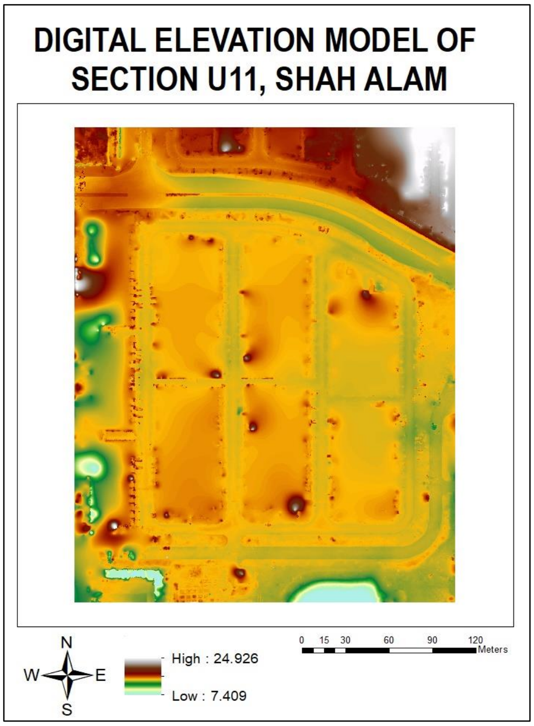

Figure 8: Digital elevation model

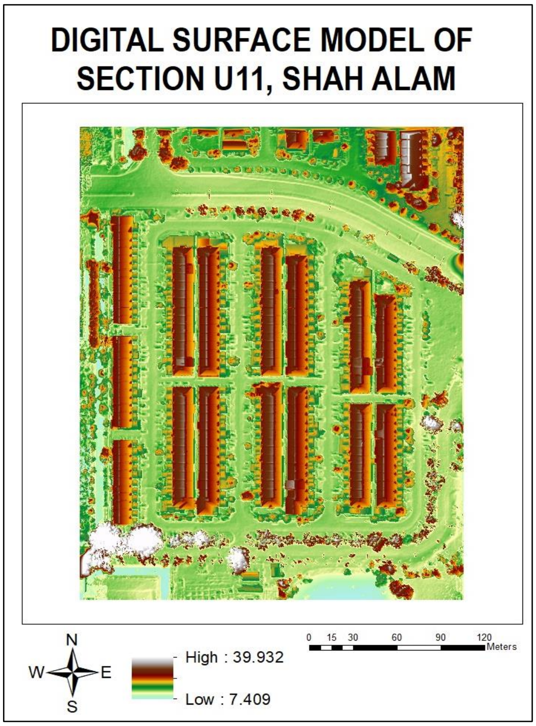

Figure 9: Digital surface model

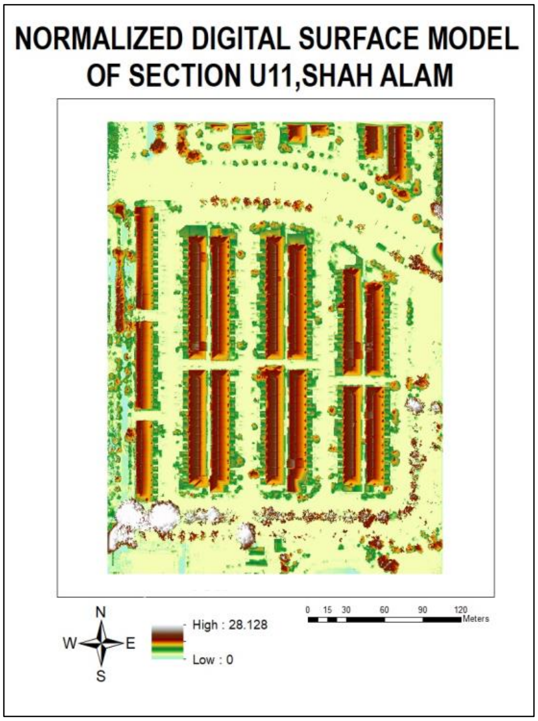

Figure 10: Normalized digital surface model

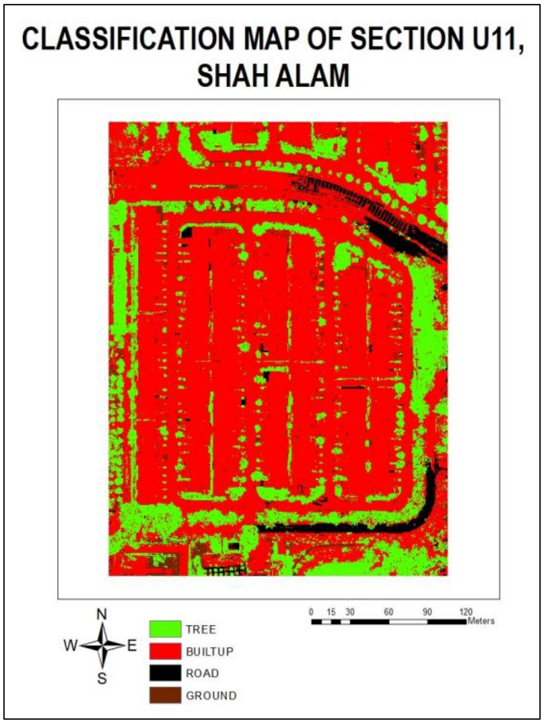

Figure 11: Image classification of section U11, Shah Alam

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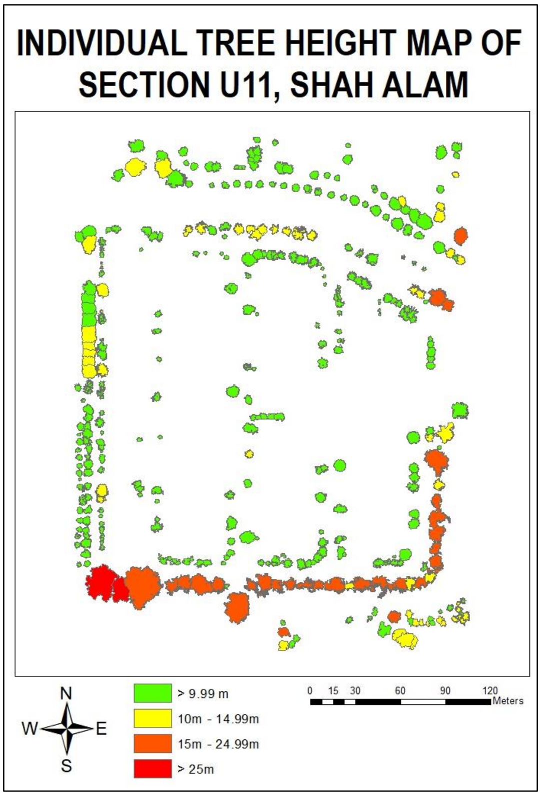

Figure 12: Tree height map of individual trees in section U11, Shah Alam

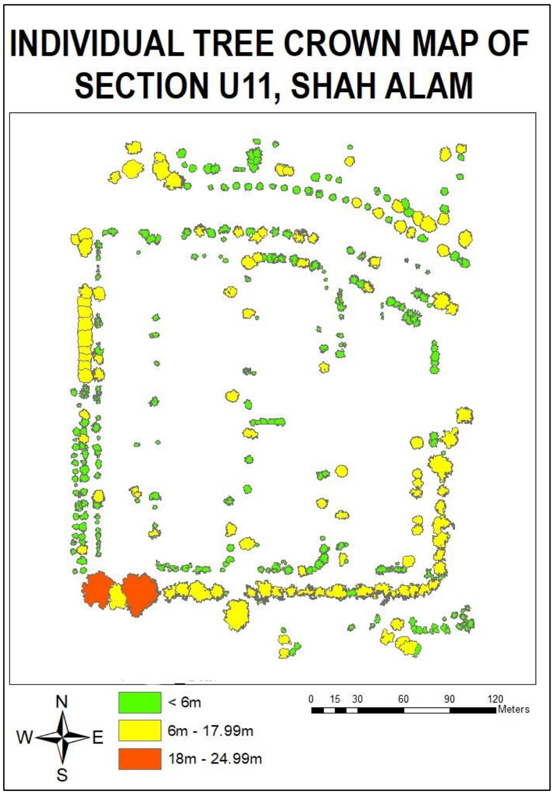

Figure 13: Individual tree crown map of individual trees in section U11, Shah Alam

Table 1: Descriptive statistics of tree height

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Tree Height	395	1.568	27.850	7.650	4.463

Table 2: Descriptive statistics of crown diameter

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Crown Diameter	395	0.919	24.506	5.123	2.734

3.5 Image Classification

Figure 11 shows the classification result, green represents tree class, red represents built-up, black represents road and brown represents ground. Most of the roads were classified as built-up areas represented in red colour. Classification accuracy derived from the error matrix is 85.45%.

3.6 Tree Height

Zonal Statistics tools is used to calculate the points that fall within the raster. Altogether, 395 trees were extracted and the tree height ranges from 1.568m to 27.850m as shown in Table 1. Figure 12 shows a map that visualized the tree height in four classes. Green label represents the classes of tree height below 9.99m, yellow label represents the classes of trees between 10m to 14.99m, orange label represents the classes of tree height between 15m to 24.99m and red represents the classes of height more than 25m.

3.7 Tree Crown

The diameter of the tree crown was calculated based on equation 2. The range of tree crown is between 0.919m to 24.506m as shown in Table 2. Minimum tree crown diameter is 0.919m and the maximum crown diameter is 24.506m. Based on Figure 13, crown diameter is classified into three classes. From the map it shows that the green label represents the diameter of the crown below 6m, yellow represents between 6m to 17.99m diameter and orange represents 18m to 29.99m diameter.

Crown diameter in section U11 is mostly in green and yellow labels, but there are two trees in the range of 18m to 29.99m which are big crown diameters.

4. Conclusion

UAV Multispectral is a technology that is rapidly increasing in vegetation analysis due to the cost effectiveness, less manpower, and time saving. The output of the imagery can be used for a large variety of analysis. The extraction of tree height and crown diameter are one of the outputs of the imagery. Total of 395 individual trees selected in this study of section u11, Shah Alam. Tree height values were extracted from the zonal statistics tool as a table shows the range between 1.568m to 27.850m. The maximum is considered as the highest tip of the trees. Tree crown diameters were extracted from the crown area with the range between 0.919m to 24.506m. The map output visualizes the individual tree height and crown diameter in classes. The parameters help in spatial databases for further decision making and action taking in reducing the rate of fallen trees.

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