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Abstract. Assessing tree biomass is essential for observing carbon stock and forest biodiversity which are an important indicator in climate change monitoring. The most accurate assessment involved ground data collection, including its data processing. In certain condition, it is extremely challenging, due to the difficulties of accessing dense forest and variation of terrain, tedious and time-consuming. Therefore, due to these limitations, remote sensing might become a better approach in measuring this information. The focus of this study is to estimate the tree stump height for biomass estimation after selective logging practices. In this study, we utilize remotely sensed canopy height model (CHM) derived from Unmanned Aerial Vehicle (UAV) to quantify tree stump height after felling logs at a local scale. This study aims to investigate the feasibility of utilizing UAV imagery to derive a canopy height model (CHM) for preparing parameters in assessing timber tree biomass. CHM is the reference surface to derive statistics that will be used to estimate the forest variables. Data was obtained through UAV which flown at the logging compartment in Ulu Jelai Forest Reserve, Pahang, Malaysia. The estimated stump height obtained from this technique was compared with a measured stump on the ground. Based on scatterplot regression, it showed a significant relationship with a strong coefficient, R^2 of 0.8368. At this stage of the study, the performance of the result was not assessed since it is an only preliminary result and the study only focused on producing CHM for stump height estimation using the UAV platform only.

1. Introduction

Tropical forest plays an important role in balancing the global ecosystem, carbon cycle and climate change [1]. Based on a report from[2] and review by [3], the tropical forest has been endangered and disturbed by rapid deforestation and forest degradation process over the past few decades. The Major impact resulted from this, is forest carbon emission. Information from the canopy height model (CHM) is fundamental in forestry analysis, especially in quantifying forest biomass and forest carbon analysis [4]. Recent advancement in remote sensing technologies allows us to generate a height profile and terrain information remotely. UAVs are an advanced technique and capable of obtaining information from aerial perspective [5]; [6]. A remote sensing-based platform such as an Unmanned Aerial Vehicle (UAV) which equipped with high resolution aerial digital camera permit 3D geometric structure information that is needed for CHM generation [7]. This data had been extensively used in various dynamic geographic-based disciplines. Remote Sensing has been used in the estimation of tree canopy structures such as tree height, canopy extent and plant projection area for decades and commonly derived from satellites and aerial photogrammetry which sometimes has time and weather constraints [8]. [9]and [10] had clarified that many researchers utilized optical imagery in this kind of study, but usually these optical imageries might have clouds, shadow, high saturation, low in spectral variability and only 2D in nature and it will provide the necessary information. High spatial resolution data might be a better solution, but it will be very costly. In previous study, a process of extracting elevation value via Digital Elevation Model (DEM) usually done using satellite-based active remote sensing data and aerial-based active remote sensing system such as Shuttle Radar Topographic Mission (SRTM), ASTER Global Digital Elevation Model (GDEM), Light Detection and Ranging (LiDAR) and USGS National Elevation Dataset (NED) [11];[12];[13]. These datasets had been extensively used in various dynamic geographic-based disciplines. However, some of these data are highly cost consuming, especially LiDAR which produced a most accurate elevation model [1]. For biomass and carbon budget estimation, information from CHM is crucial, and as an alternative to these expensive data, UAV derived CHM will be the best option. The data acquisition using the UAV platform is just practical and flexible in terms of cost, time, accessibility, platform and repetitive coverage. The UAV is capable of providing high spatial- temporal data which useful in assessing biomass and carbon stock effectively [10];[14]. The data obtained from the UAV system is used to generate Digital Terrain Model (DTM), Digital Surface Model (DSM) and orthophoto based on structure from motion (SfM) technique [10];[15]. According to [10] and [16], 3D modelled structure from SfM is a time and cost-effective in estimating above ground biomass (AGB) and SfM approach is capable to generate DSM and DTM , that represent the top of the canopy in case of forest and terrain model.

CHM represents the height of the tree in a forest area. Before proceeding to generate CHM, DTM and DSM are needed. DTM and DSM generated from UAV imagery provide satisfactory accuracy to manage forest resources. In the context of forestry, CHM is defined by tree height resulted from the difference between DTM and DSM on a surface. Tree height can be extracted from CHM and recent studies from [10];[16] and [17] mentioned that, tree height is an essential parameter in the timber resource management and critically needed in quantifying biomass and carbon stock. Typical or conventional measurement of tree parameters that essential in biomass and carbon calculation is quite tedious, time costing and limited by the accessibility to access the forest area. [13] generalized the conventional method to extract the tree parameter by using ground survey equipment such as measurement tape, laser device, total station and Global Positioning System (GPS) instrument. As for calculating biomass, it may require falling the tree and weighting it according to certain procedures. Numerous study discovered the method of extracting the 3D structure and parameters of trees is effective using remote sensing based technology such LiDAR, photogrammetry, Airborne Laser Scanning (ALS) and Digital Aerial Photograph which extracted from UAV [1];[17];[18]. In this study, we focused on RGB sensors from UAV to provide digital DTM and DSM in order to generate CHM as an alternative to those techniques.

This study will explore the methodology used in generating CHM in order to identify tree stump height for biomass and carbon estimation. The general procedure might involve the processing of UAV multispectral data and producing the required result. Some samples of tree stump height obtained from UAV will be regressed with the sample data collected on the ground to evaluate the relationship and its accuracy. In this study, only stump height is generated, and information used to be regressed with ground data is stump height, which generated from UAV images since the study area is located at a logging compartment where some of the trees were already harvested. Software used in this study is Agisoft Metashape Professional 1.5.1 for imagery processing and ArcGIS 10.5 for mapping and analysis. Therefore, further analysis should be done in the future to identify the accuracy of the technique.

1.1. Study Area

The Study area selected in this study is logging compartment number 159 and 124 licensed by Pahang Forest Department, which had applied selective logging practices under Sustainable Forest Management (SFM). This compartment located approximately from 4˚ 34’ 25.17” North, 101˚ 52’ 25.08” East to 4˚ 32’ 54.21 North, 101˚ 53’52.64” East at Ulu Jelai Forest Reserve, in the forest district of Lipis, Pahang.

IOP Conf. Series: Earth and Environmental Science **540** (2020) 012015 doi:10.1088/1755-1315/540/1/012015

The location of the study area is in the equatorial zone, with a humid climate and experienced rainfall throughout the year. Elevation of the forest area range from 60 - 800m above mean sea level and annual precipitation recorded between 1500 - 2000mm with a temperature range from 15.5-24.5˚C. The area of the compartment is approximately 84 hectares. But only part of the area was collected via UAV. Figure 1 and Figure 2 show the compartment plan and location map of the study area.

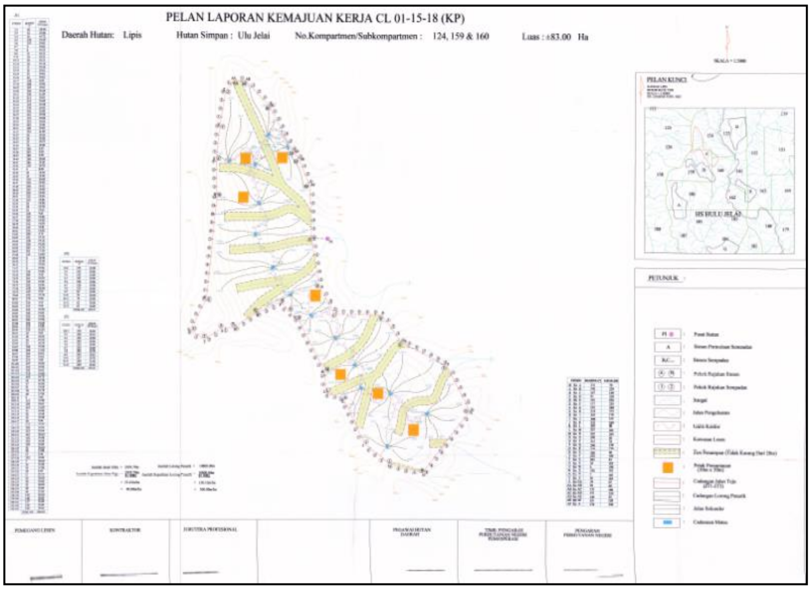

Figure 1. Compartment Plan of Study Area

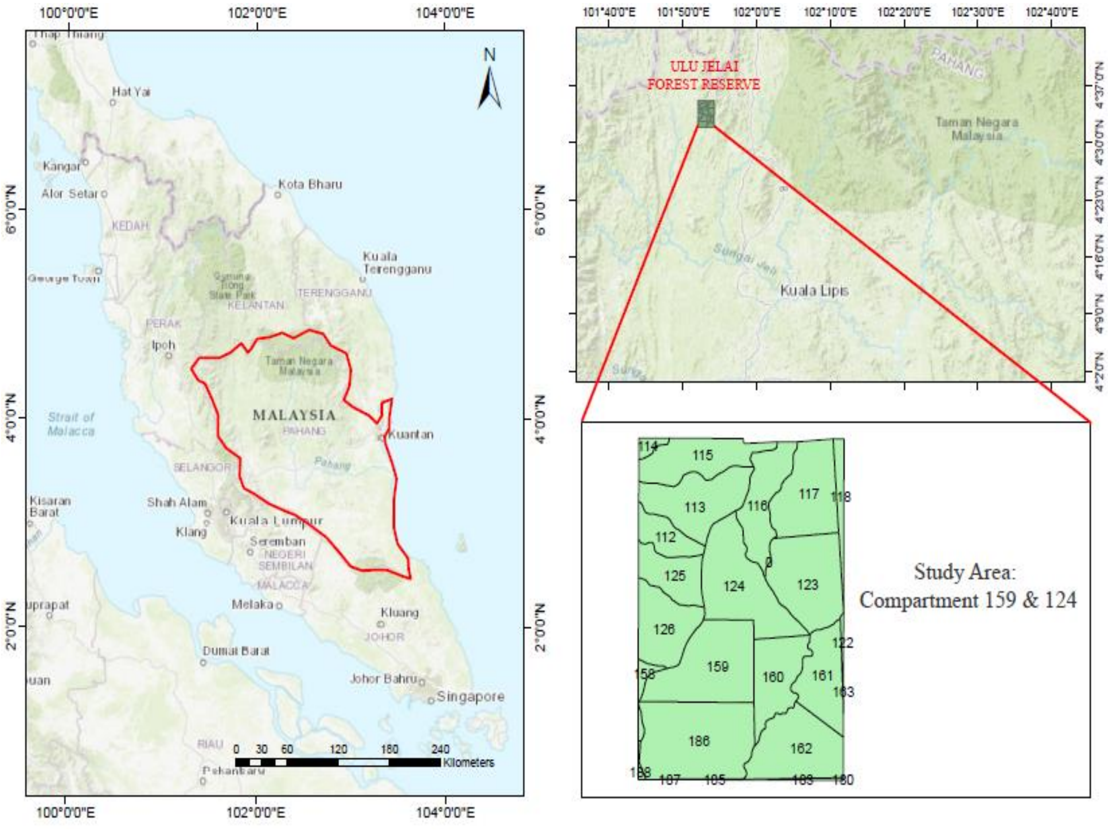

Figure 2. Location Map of Study Area

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2. Methodology

2.1 Data

Data used in this study divided into two (2) category, which is ground data and UAV data. Both UAV and ground data are collected on the same date, from 19 August 2019 to 23 August 2019. The UAV was flown over the study area on 19 August 2019 using DJI Phantom 3 device. The flight was controlled using Drone Deploy Software. The UAV was launched from the open space near the sample plot area. Flying altitude was adjusted to 90-110 m above ground level because the terrain condition of the study area for this research is hilly, there are no accurate topographic data is available and the actual ground sample position is difficult to estimate. However, it will not interfere very much with this study since the analysis of forest biomass and carbon may not require a very accurate topographic position. Flight front lap was 75% and the side overlap was 89%.

Ground data collection involved measuring stump and buttress height and a parameter related to felled log such as length of the log and its branches, the incidental damage due to the felled log and logging infrastructures and were recorded in the field data sheet.

2.2. Overall methodology

The Overall methodology adopted in this study was illustrates based on the flow chart in Figure 3.

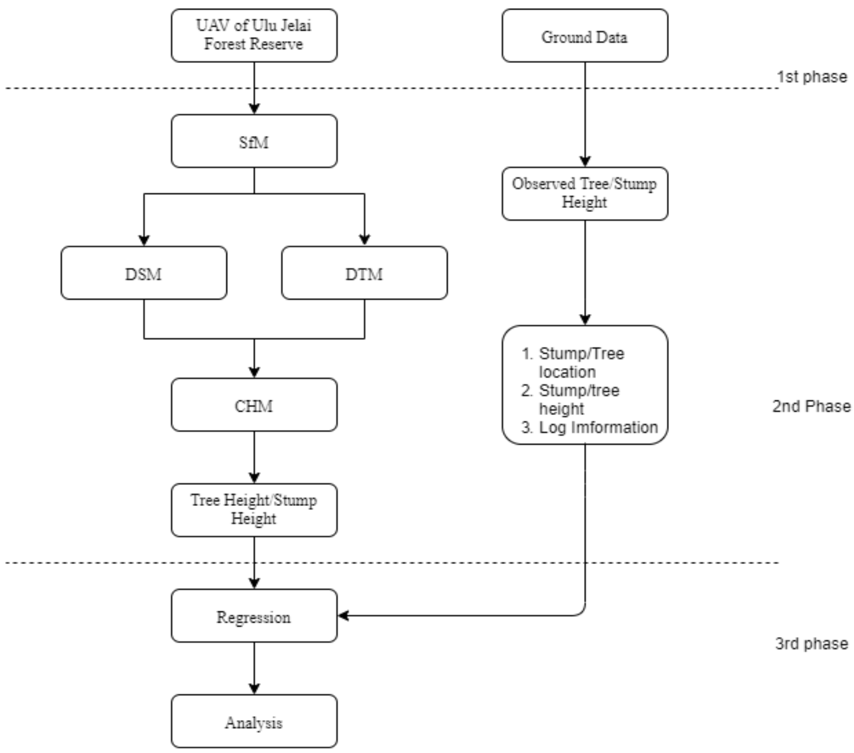

Figure 3. Overall Research Methodology

2.3. UAV Processing

We used the Agisoft Metashape Professional version 1.5 to generate photographic point cloud (PPC) and orthophotograph. The workflow that included in this process was “align photos”, Built a dense point cloud”, Build digital elevation model (DEM)”, and “Build orthomosaics”. The Result obtained from this process, which is DTM, DSM and orthophoto will then be exported to ArcMap 10.5 for further processing. In Arc Map, trough the raster calculator operation, value of the canopy height model was calculated in order to estimate tree and stump height based on the following equation:

$$Canopy\ height(CHM) = DSM - DTM \tag{1}$$

In this study, generating CHM from UAV data was based on the concept described by [19] as illustrated in figure 4 below.

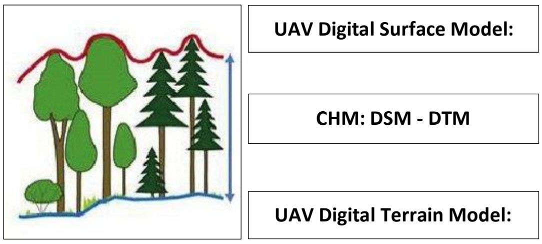

Figure 4. Schematic diagram of generating CHM

2.4. Data Processing
In August 2019, fieldwork was conducted at Ulu Jelai Area. The plot area was fixed first, then the measuring tape was used to measure the height of the stump. The height of stump is measured from ground surface to the end cut of the tree as shown in Figure 5. Trimble GPS registered the XY coordinate of the middle of the plots and the position of the stump. Breast height diameter (DBH) was measured using tape diameter.

Figure 5. Process of measuring stump height on the ground

Detail processing for identification, tree stump and analysis on height generated from the UAV and the ground was done in ArcMap 10.5 software. A regression analysis was carryout to verify the relationship between the height of the stump or tree from the UAV and ground by producing a scatter plot. The performance was presented in terms of the model fit coefficient (R^2) and root means square error (RMSE).

3. Result and Discussion

3.1. Biometric Data
Biometric data and distribution of the data based on the ground and UAV were structured in the form of descriptive statistic as shown in Table 1. This biometric data focused on stump height of 21 stumps on the logging compartment for the year 2019.

Table 1. Descriptive Statistic of Observed Height and UAV Height

Nature of Statistic	Observed Height (m)	UAV Height (m)
Minimum	0.586	0.527
Maximum	2.338	2.623
Median	1.112	1.155
Average	1.118	1.173
Standard Deviation	0.411	0.467
Sum	23.479	24.637
Number of points	21	21

From the result above, the average observed stump height on the ground was 1.118 m and the predicted height from UAV was 1.173 m. The minimum height of both observed and predicted is 0.586 m and 0.527 m respectively, while the maximum is 2.338 m in observed height and 2.623 m predicted by UAV.

3.2. Generation of Orthophotograph, DSM, DTM and CHM

In this study, 4 (four) main result has been produced which are orthophotograph, DSM, DTM and CHM**.** The orthomosaic, DTM and DSM were generated using Agisoft Metashape Professional 1.5.1 software and ArcGIS 10.5 is used to classify the range of elevation and to map the DTM, DSM and CHM. A total of 252 UAV images used to produce an orthophoto, DTM and DSM. An overall UAV coverage of the study area during the flying process was approximately 0.483 km^2. An orthophotograph generated from the UAV processing and location of the stump was mapped (Figure 6). Figure 7 show the result of DSM generated from UAV and Figure 8 show result DTM.

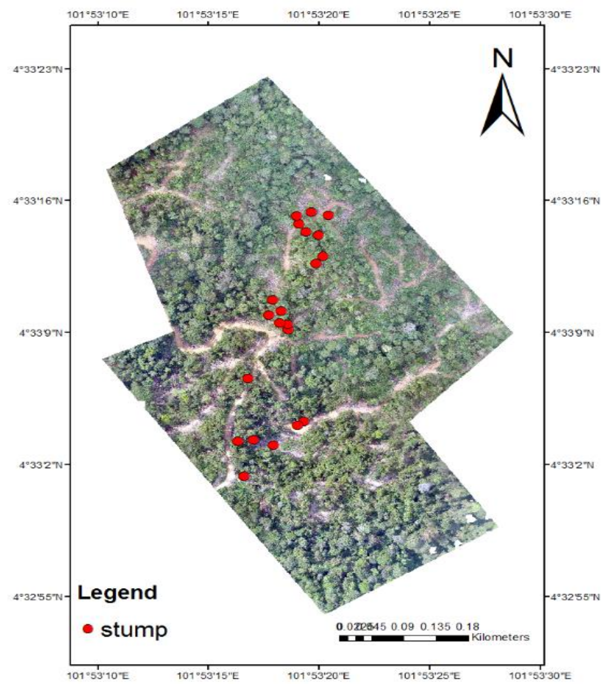

Figure 6. Orthophotograph

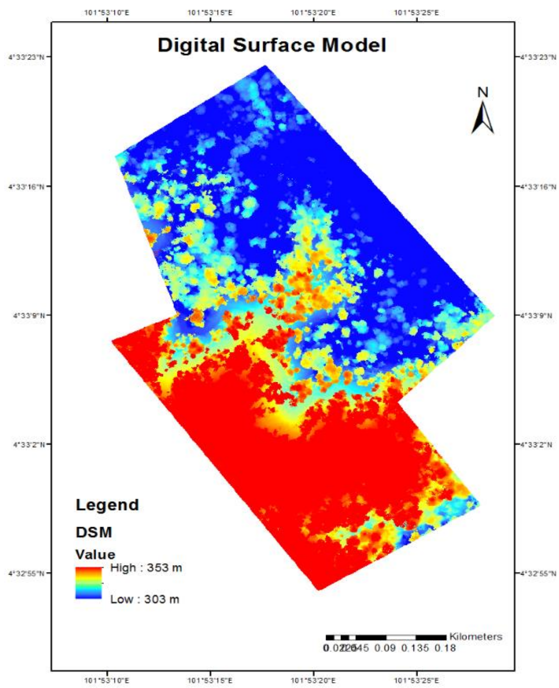

Figure 7. DSM

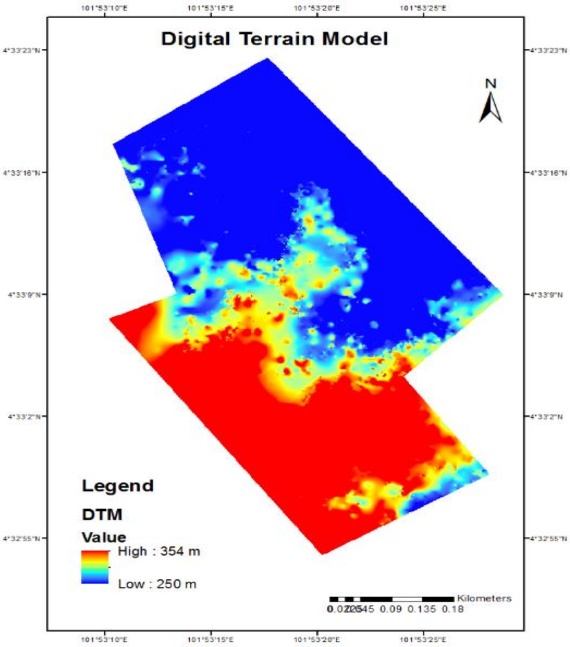

Figure 8: DTM

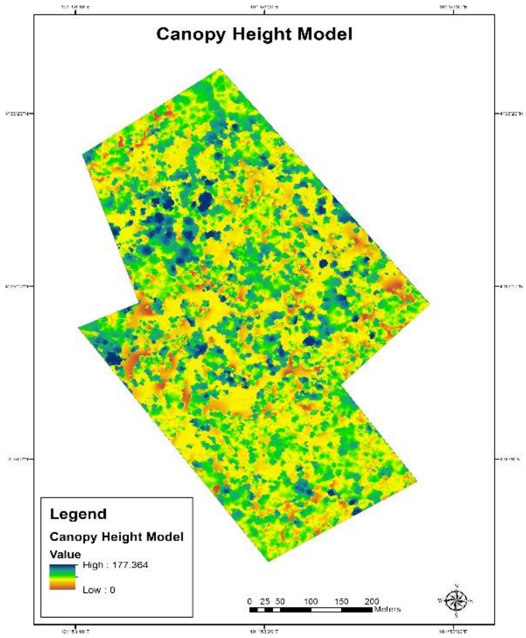

Figure 9: CHM

By visual assessment of the selective logging location, stump location was visually detected and correlated with registered location from GPS data. However field stump location had some associated error due to the accuracy of GPS instrument [1]; [20]. In some cases, tree stump was covered and hidden under the tree canopy, therefore, we assumed it was at the end of the fallen trunk and compared it by checking the elevation of the terrain. Detection of tree stumps used to determine the stump height based on the terrain elevation that resulted from the process of subtraction between DSM and DTM.

The CHM was produced using a raster calculator in ArcGIS 10.5 software. The result of the CHM was shown in Figure 9. The minimum of CHM was 0 (zero) and the highest was 177 m. In this study, analysis of CHM was done to identify the height of stump since it will be used in further biomass assessment. A total of 21 stump height was identified and compared with the same stump measured on the ground. There is a slight difference between stump height obtained from the UAV and stump height from the ground measurement. The average accuracy is might be due to flying altitude, ground control point (GCP) and environmental limitation such as canopy coverage. The maximum difference of stump height is 37 cm and the minimum difference is 0.5 cm. The result is considered acceptable for this kind of study since its focus on felled tree which is hard to identify in the dense forest and it is not critical in carbon analysis [1].

A scatter plot was used to regress stump height from the UAV and ground measurement to validate the accuracy of derived stump height (Figure 10).

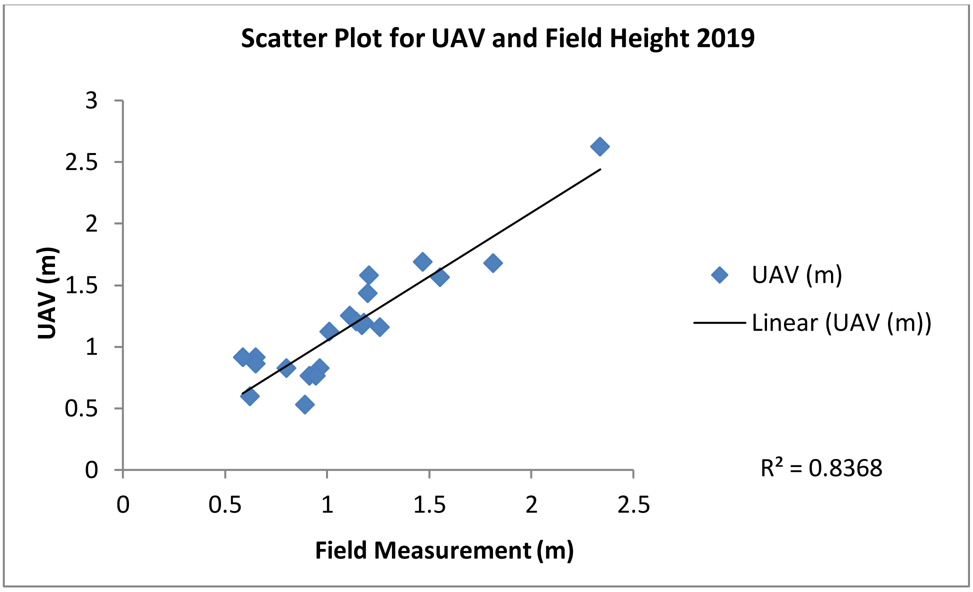

Figure 10. the Scatterplot for UAV and Field Height

The scatter plot demonstrates a strong relationship between UAV derived stump height and ground measured stump height with coefficient of determination, R^2 of 0.8368. This plot suggested good agreement between those two variables. The RMS error of the result is 0.1979 and it is acceptable.

4. Conclusion

In this study, we investigated the potential of Digital Aerial Photo (DAP) obtained from the UAV platform to estimate tree stump height after selective logging of tropical forest in Ulu Jelai, Pahang, Malaysia. UAV image was obtained after selective logging to analyse the impact of selective logging on the forest area. The image was processed to produce orthophoto, DSM, DTM and CHM which provide vertical canopy structure of forest stand to enable us to estimate tree stump height. Estimated stump height from UAV was compared with stump height, which measured directly on the ground and validated by the scatter plot with the acceptable accuracy. The difference of observed and measured stump height also at the tolerance range with the maximum difference only approximately 37 cm. Therefore, this method might provide a cost-effective approach to estimate forest structure information, especially the height of the stump or tree height and helps in forest biomass and carbon monitoring and sustainable forest management.

5. Acknowledgment

This study was supported by a research grant, DIP-2018-030 and GUP-2018-132. The authors are grateful to the Pahang Forestry Department, Forest Research Institute Malaysia (FRIM), and the Earth Observation Centre, Institute of Climate Change, Universiti Kebangsaan Malaysia (UKM) for providing the equipment and additional data.

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