EVALUATION OF HARUM MANIS TREE HEIGHT AND CROWN DIAMETER EXTRACTED FROM 3D POINT CLOUDS DERIVED FROM UNMANNED AERIAL VEHICLE (UAV) IMAGERY AT PLANTATION AREA OF UITM PERLIS

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ABSTRACT

Size of a tree crown is strongly correlated with the growth of the tree. It also displays the leaves to allow capture of radiant energy for photosynthesis which, the measurement of the tree crown is often made to assist in the quantification and understanding of the growth of the tree. The aim of this research is to determine the tree height and tree crown diameter of Harum Manis tree using 3D point cloud derived from Unmanned Aerial Vehicle (UAV) and access an accuracy for both tree crown and tree height in comparison with the tree parameter ground measurement. In this research, ArcGIS software used to determine tree height extracted using Canopy Height Model (CHM) method. While, for the determining tree crown segmentation, Object Based Image Analysis (OBIA) was used in eCognition software. Total 30 number of ground sample is used to evaluate the accuracy of tree parameter determination which measured using total station and tape. It was found that, the determination of tree height and crown diameter using UAV is significant with the RMSE value for tree height is 0.230 and for the tree crown is 0.980 respectively. In addition, R^2 for both determinations were more than 0.80 which is at 0.834 and 0.811, this show the result of both determination with using UAV is significant. Thus, the approach used in this research proposes a platform of UAV for measuring tree crown diameter which useful for tree growth analysis.

Keywords: *UAV, CHM, OBIA, Harum Manis, Tree height, Tree Crown.*

INTRODUCTION

Tree height determination is the one of indicate to estimating tree biomass, tree life history (age), and the growing of the tree (Panagiotidis, Abdollahnejad, Surovy, & Vasco, 2016). Which also important to ensure the stability of ecological trait and give impact in reducing the global warming. The diameter of a tree crown is also correlated with the growth of the tree and the crown means the multipurpose of ecological indicators such as wind-break, shading, and ability to capture carbon.

Traditionally, tree height measurement using yardstick must have same and fixed length (Schardt et al., 2015). Laser rangefinder also can be used for tree height measurement (Leverett & Bertolette, 2015). While, for a canopy of tree basically determine using diameter tape (Pretzsch et al., 2015). This method is quite difficult and challenging which also time consume and costly. Then it's also may cause a human error during measurement precession.

LiDAR (Light Detection and Ranging) alternative remote sensing technology which can emit a high frequency of laser pulses and able to penetrate tree canopies with high accuracy of measurement (Su et al., 2016). Tree Parameter (tree height, crown, and species) can easily determine and three-dimensional (3D) of tree canopies can be derived. Although, CHM (Canopy Height Model) can be created to determine the tree height and canopy (Su et al., 2016).

With the latest development, UAV (Unmanned Aerial Vehicle) is modern's technology of aircraft that operates without a human pilot on board. UAV also has a vision-based detection technique that has advantages of supplying intuitive and highly real-time information, large detection range, as well as convenience for a record and this has become a key of a component in the UAVs-based (Larjavaara & Muller-Landau, 2013). UAV is compatible and small drone also its accessibility. Many kinds of research can be done with UAV like for engineering, cadastral, forestation, and others. Lately, this technology of UAV gives many advantages in any field of works and helps in making works more ease.

CANOPY HEIGHT MODEL

Canopy height model (CHM) is the process of subtracting Digital Elevation Model (DEM) from Digital Surface Model (DSM) to extract the information of actual tree height for forest inventory parameter (Khosravipour, Skidmore, Isenburg, & Hussin, 2014). The CHM is available in raster format that shows the difference between top and ground surface which is can derived forest inventory parameters (Zhao & Popescu, 2007). Normally, CHM is derived from the LiDAR data but UAV can provide this CHM with using point cloud. The data derived from the CHM can be used for tree height extracted as individual tree detection, improved forest biomass inventory and carbon stock estimation. Other than that from CHM, the crown diameter can be determined and estimate. Figure 1 shows the visualities of DSM, DEM and CHM.

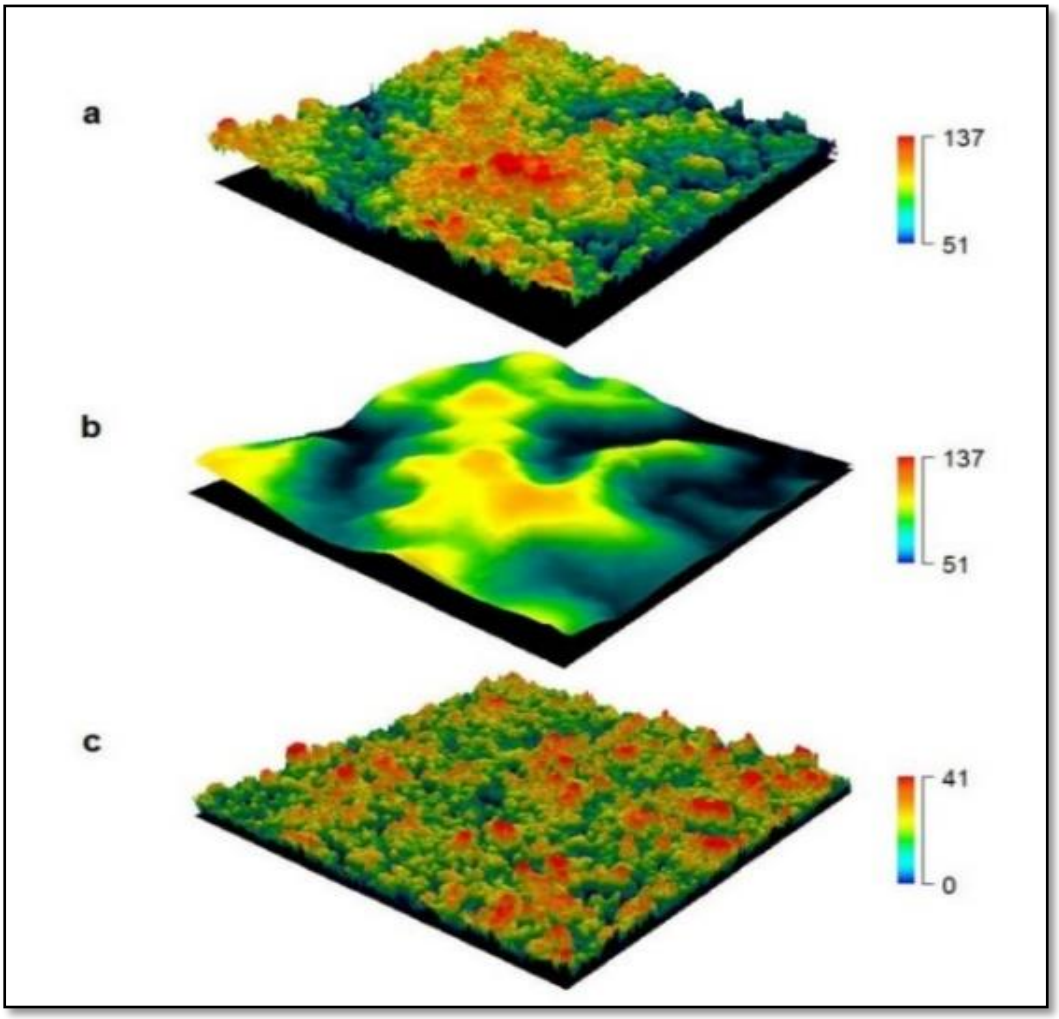


Figure 1: Visualization of DSM (a), DEM (b), and CHM (c).

OBJECT BASED IMAGE ANALYSIS (OBIA)

Object-Based Image Analysis (OBIA) is a required of image segmentation and classification through the characteristic of spatial, spectral, texture and temporal scales in order to produce a meaningful image object (J.Torres-Sánchez et al., 2018). The fundamental of OBIA includes image segmentation, image classification, attribution, query, and linking individual segmented objects in space and also time (O'Neil-Dunne et al.,2013). The process of image segmentation can be defined as the approached partition of remote sensing image in order to search the homogenous regions for object classifications (V. Lebourgeois et al., 2017).

Generally, the image segmentation can be categorized into three methods such as pixel or point-based segmentation, edge-based segmentation and region-based segmentation depend on difference application analysis (M. Parkan & D. Tuia, 2018). OBIA is an algorithm which applied for image segmentation algorithm. This image has been segmented into object with using multiresolution. For a batter delineation of tree, the image segmentation is used . The algorithm that been used (1) is to different the colour, shape, smoothness and compactness (Torres-sánchez, López-granados, Serrano, & Arquero, 2015).

$$\boldsymbol{ExG = 2g - r - b; being\ g = \frac{G}{(R+G+B)}; r = \frac{R}{(R+G+B)} b = \frac{B}{(R+G+B)}} \qquad (1)$$

MATERIAL AND METHODS

Study Area

Plantation area of UiTM Perlis is one of the areas that have a variation of plant either fruit tree, vegetables, and crops commodities that has in Perlis with the total area is 197 acres. This plantation area is located at 6°27'15"N and 100°16'56"E and managed by Faculty of Planting Industry Management as a site project. Harum Manis tree is been chosen in this research with total number of Harum Manis is 1000 trees that been planted at the plantation area and produced over 12 metric tons throughout in a year (Figure 2).

Unmanned Aerial Vehicle (UAV) image

UAV is used in this research in determine the tree height and tree crown.. UAV is used in this platform is to manage the agriculture production as UAV can focus on a small crop of the field on agriculture either other field such as engineer, cadastral and others. The uses of UAV in agriculture is productive in measuring, crop monitoring and counting, know soil and field analysis, and health assessment (Sinha, Kushwaha, & Kushwaha, 2016). In this study, the camera sensor of this UAV is with 3.5mm focal length and been applied with Red, Green, Blue (RGB) sensor. These specifications in capturing an image of the study area are enough in the detection of Harum Manis tree in order to get a high-resolution image (D. Panagiotidis et al. 2017). The projection that used in capture this image of the study area is in GDM2000 and being register with 8 ground control point covering entire of study area. High resolution of a camera with pixel size 5cm can get a clear image of the study area and can increase the accuracy of the result (Figure 3).

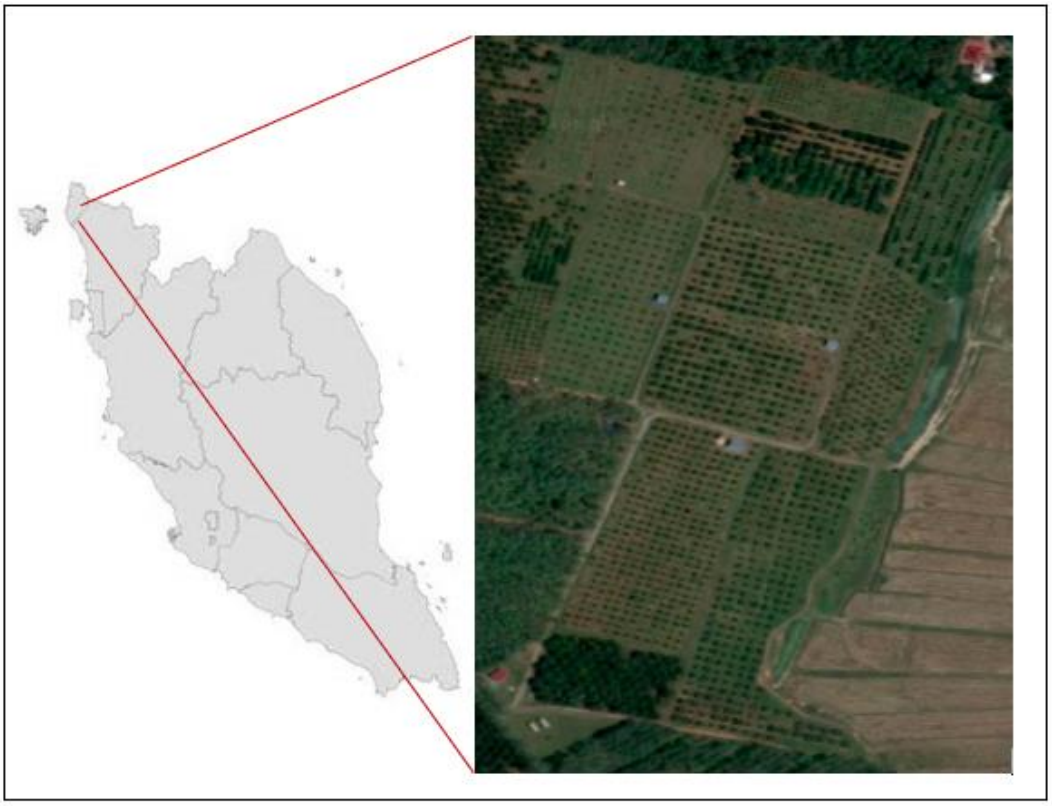


Figure 2: Location of Study Area

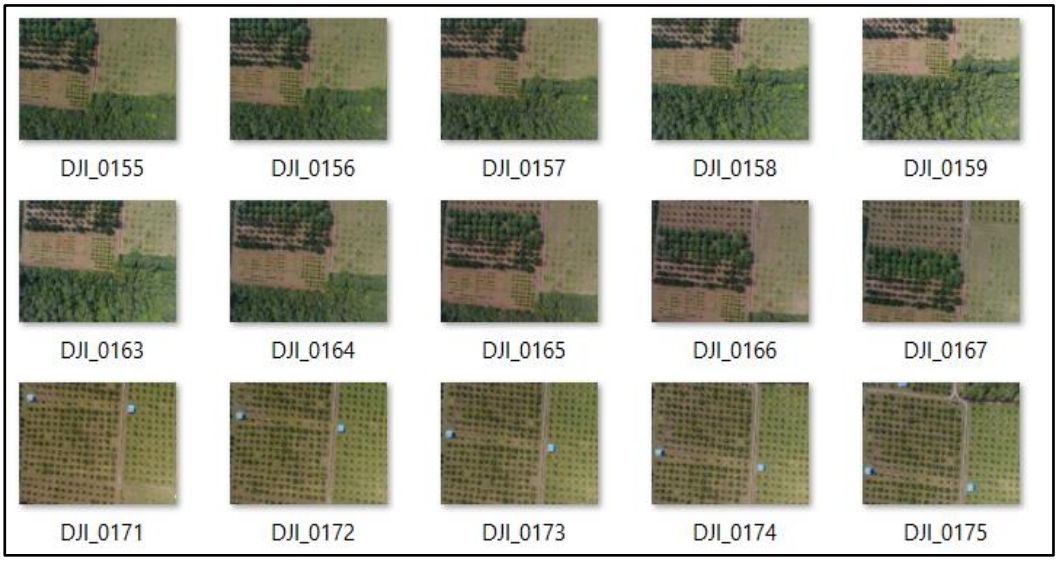


Figure 3: UAV Imagery

Field Inventory

Tree measurement is required in this research study to comparing and verify the data of the ground truth with the UAV data collection. This tree measurement is separated into two which is a measurement of tree height and measurement of crown diameter (figure 4a). Tree measurement is needed to know the actual ground of tree height and crown diameter, then be compared with the UAV data. Tree height is measured with using Total Station (TS) and crown diameter is measured by using diameter tape. All the measurement is in meter (m). In this research, 30 sample of tree is been selected randomly and been divided into two (2) different location with 15 sample for each location. The different area is been chosen due to the characteristic of location which is variation in height. Location of red area is located at sloping area, while location of blue area is at flat surface area (Figure 4b)

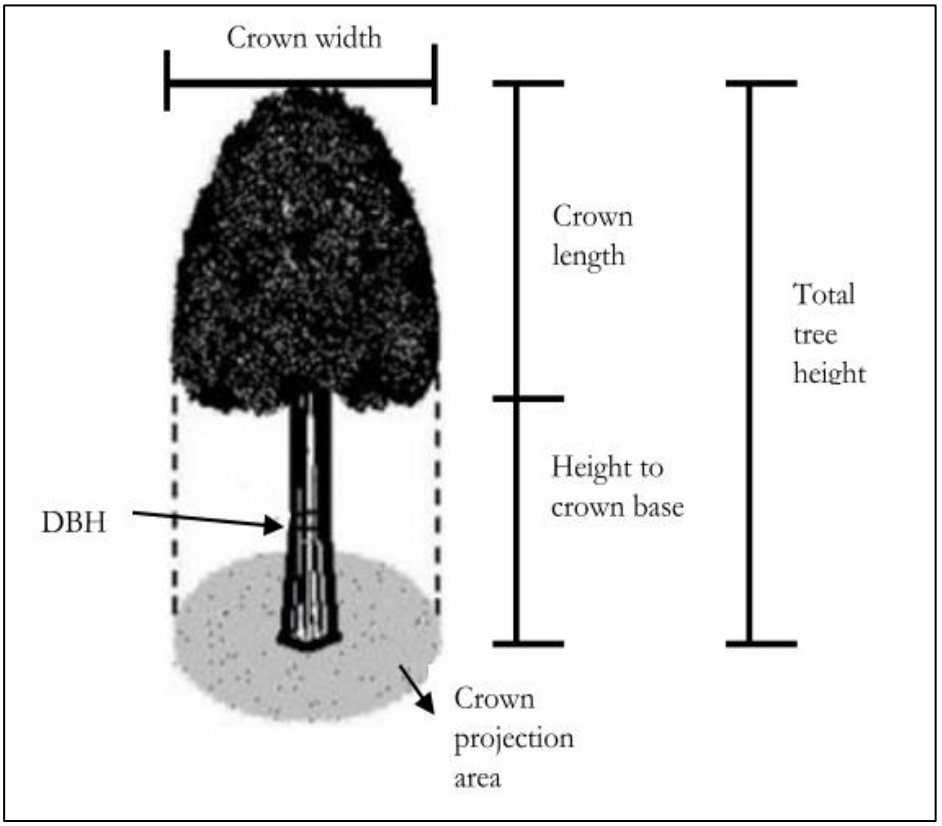


Figure 4a (left): Measurement for Field Inventory



Figure 4b: Tree sample location

Tree height determination from CHM and crown delineation using OBIA method

Photogrammetry fields its uses multiple of a photograph that has been surveyed, then a combination of multiple photos that taken from any angle is used to create a point cloud (Kim, Kim, & Kim, 2018). Each point has its own coordinate of X, Y, and Z. This point cloud can show some interesting features when many points are brought (Stålberg, 2017). The geometry of point cloud allows for quick and efficient processing and involve of thinning, splitting and combining to produce a set of vertices on point cloud.

In this study, the starting process to identification of tree height and crown delineation is producing point cloud from UAV image. The point cloud is derived from AgiSoft Photoscan software. Image of study area is insert into Photoscan and been align automatically by using Align Photos, followed by build dense cloud, build mesh, build texture, build tiled model, then insert the coordinate of 8 GCP and finally being export the point cloud into a format (.las) as shown in figure 5.

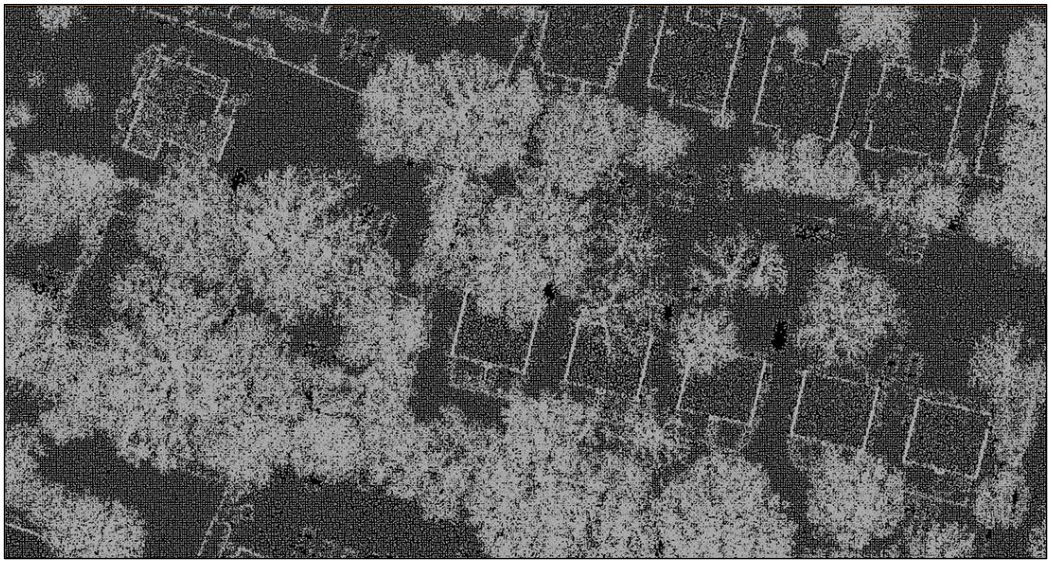


Figure 5: 3D Point Cloud from UAV

To produce DEM and DSM, UAV point cloud been classified in the AgiSoft software by manual classification method. Point cloud that had been classify has been assign into a specific class including ground, tree, building and water classification. CHM is been produce by using the "MINUS' tools that have in the ArcGIS, value of DSM is minus to the value of DEM to determine the CHM value. This tool does an automatic subtract the value of DSM to the DEM, which can be used to determined actual height for the tree.

Crown delineation is been determine with using eCognition software for determination of tree crown diameter. Firstly, segmentation process is done, after the segmentation is been creating, the brightness of the image is been determine. Its function to determine whereas the shadow and the tree based on the brightness. Brightness determination is required to know the class of tree or the shadow with threshold value less than 130 for tree determination while the shadow value is more or equal 130 brightness value. Then finally, hierarchy class is done to split the tree and shadow for crown measurement.

RESULT AND DISCUSSION

Field inventory measurement

In this research, 30 Harum Manis tree had been selected randomly to know the tree height and the crown diameter with the different of location based on the selected area of different surface. Table 1 below shows the field measurement data of tree

height and the crown diameter of the Harum Manis tree, the highest tree is 3.988m and the lowest tree is 2.535m. While, the tree crown that had been determine is 7.313m which is the widest and the smallest is 4.019m

Table 1: Field Inventory for Tree Height and Tree Crown

Trees ID	Height (m)	Crown (m)
1	2.721	4.327
2	3.501	4.733
3	2.535	4.638
4	3.721	5.180
5	2.676	4.019
6	3.298	6.129
7	3.624	7.023
8	3.746	7.313
9	3.988	5.748
10	3.428	6.694
11	3.684	5.851
12	3.642	5.958
13	3.162	5.005
14	3.162	3.125
15	3.095	4.542
16	3.032	3.963
17	3.547	4.248
18	3.697	4.645
19	4.258	4.418
20	3.958	7.798
21	3.983	7.963
22	2.254	3.267
23	3.163	5.244
24	3.288	5.797
25	3.954	6.646
26	3.495	7.551
27	3.892	6.858
28	3.345	6.372
29	2.966	5.598
30	3.545	5.919

Harum Manis Tree height from CHM

Based on the result above in Figure 6, its show the CHM of Harum Manis tree area. CHM are showing the value of actual height from the earth surface. The highest value of this CHM is around 5.7834m from the earth surface and the lowest value is -0.1m which is at the water area. Based on CHM, highest value is been colour with red colour and the lowest one is coloured with peach area. Literally, the peach area is the surface area. With using CHM technique CHM, height of Harum Manis tree can be measured. Most of the Harum Manis tree height were found at 2.522m to 4.260m (Table 2). The variation of the Harum Manis tree height is due to the difference of age the tree of Harum Manis itself.

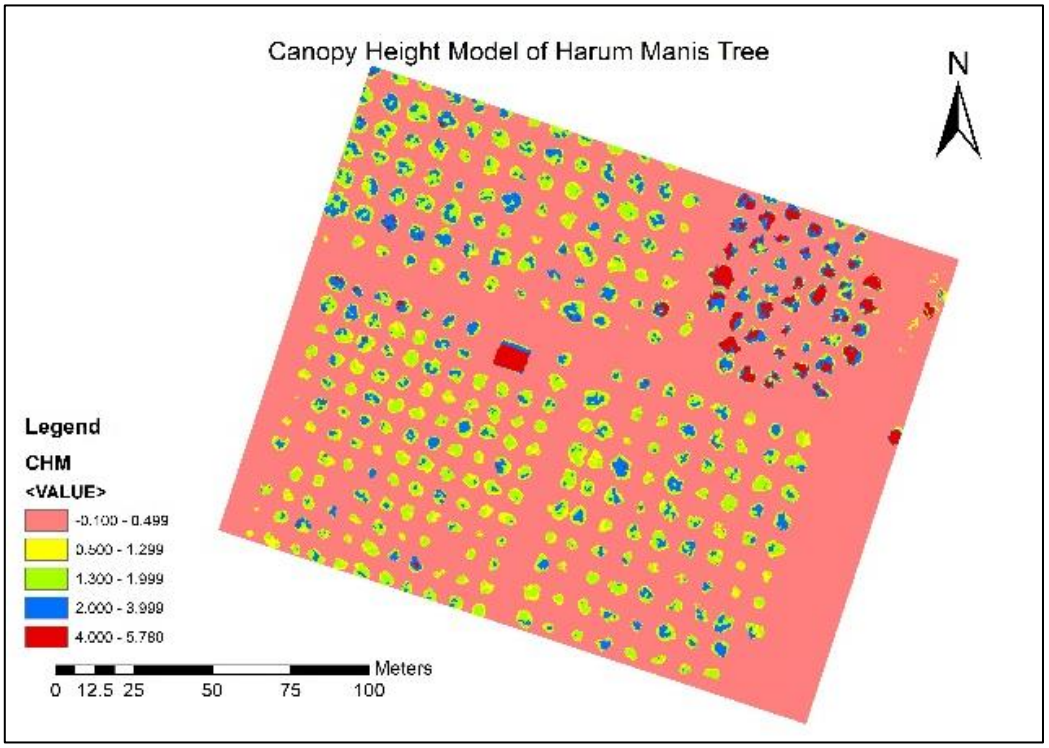


Figure 6: CHM of Harum Manis

Table 2: Tree Height Measurement from CHM

Trees ID	Tree Height CHM (m)	Trees ID	Tree Height CHM (m)	Trees ID	Tree Height CHM (m)
1	2.788	**11**	3.690	**21**	3.957
2	3.424	**12**	2.644	**22**	2.522
3	2.533	**13**	3.163	**23**	3.069
4	3.569	**14**	3.103	**24**	3.290
5	2.641	**15**	3.100	**25**	3.950
6	3.301	**16**	3.045	**26**	3.501
7	3.634	**17**	3.477	**27**	3.900
8	3.719	**18**	3.702	**28**	3.402
9	3.980	**19**	4.260	**29**	3.012
10	3.229	**20**	3.960	**30**	3.535

Harum Manis Crown Determination by OBIA

Crown diameter of Harum Manis tree is been detected with using OBIA method in eCognition software. Using eCognition software to get the crown segmentation as shown in Figure 7 and then been export into ArcGIS. In this software, orthophoto for the research area is been used because easier for detection and segmentation process in the eCognition software, then the measurement of tree crow is been measured in ArcGIS software. Indicate from Table 3, it found that the widest crown is at 8.097 and the smallest at 20954.

Table 3: Tree Crown Derived from OBIA

Trees ID	Crown (m)	Trees ID	Crown (m)	Trees ID	Crown (m)
1	4.131	**11**	4.856	**21**	8.097
2	4.523	**12**	5.147	**22**	3.59
3	2.954	**13**	6.127	**23**	5.288
4	4.882	**14**	3.407	**24**	6.657
5	4.178	**15**	4.732	**25**	6.233
6	5.226	**16**	3.763	**26**	6.742
7	6.996	**17**	4.397	**27**	6.301
8	7.019	**18**	4.823	**28**	5.408
9	5.802	**19**	4.498	**29**	5.087
10	6.088	**20**	7.905	**30**	6.346



Figure 7: Tree Crown Derivation from OBIA

Accuracy Assessment of Tree Height and Crown Diameter

Based on the Figure 8, the regression graph of tree height from ground measurement against tree height determination from CHM method. The R^2 value for Harum Manis tree height is at 0.8341 which is more than 80% the estimated result is most similar to the actual measurement of tree height. It show the strong relationship of actual measurement against the tree height determination using CHM method which the regression value near to the 1.

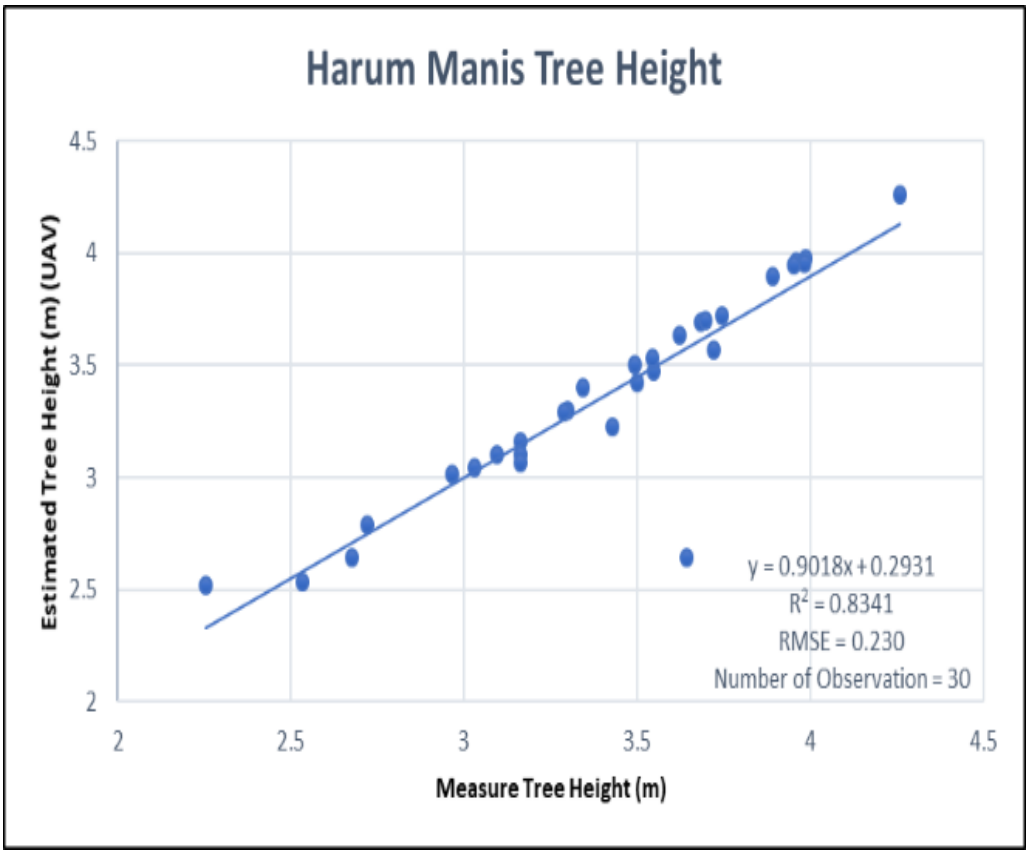


Figure 8: Regression Graph of Tree Height

Total RMSE for all 30 measurement as shown in Table 4 is 0.230 which is its shows a small in value and this result is significant in comparison to the previous research by Birdal, Avdan, & Türk, 2017 where total RMSE is at 0.280.

Tree Crown Diameter Assessment

Figure 9 show the regression graph for the Harum Manis tree crown. Based on the graph below, estimated tree crown from UAV is been validate to the existing measurement of the tree crown. The R^2 for the Harum Manis tree crown is found at 0.8110. it show the strong relationship of actual measurement of tree crown of Harum Manis towards the crown determination using OBIA method.

Table 4: RMSE of Harum Manis Tree Height

Trees ID	Conventional-Derived Height (m)	CHM-Derived Height (m)	Residual (Error) (m)
1	2.721	2.788	-0.067
2	3.501	3.424	0.077
3	2.535	2.533	0.002
4	3.721	3.569	0.152
5	2.676	2.641	0.035
6	3.298	3.301	-0.003
7	3.624	3.634	-0.010
8	3.746	3.719	0.027
9	3.988	3.980	0.008
10	3.428	3.229	0.199
11	3.684	3.690	-0.006
12	3.642	2.644	0.798
13	3.162	3.163	-0.001
14	3.162	3.103	0.059
15	3.095	3.100	-0.005
16	3.032	3.045	-0.013
17	3.547	3.477	0.070
18	3.697	3.702	-0.005
19	4.258	4.260	0.198
20	3.958	3.960	-0.002
21	3.983	3.957	0.026
22	2.254	2.522	-0.268
23	3.163	3.069	0.094
24	3.288	3.290	-0.002
25	3.954	3.950	0.004
26	3.495	3.501	-0.006
27	3.892	3.900	-0.008
28	3.345	3.402	-0.057
29	2.966	3.012	-0.046
30	3.545	3.535	0.010
Mean Error (m)			0.42
Standard Deviation (m)			0.190
RMSE (m)			**0.230**

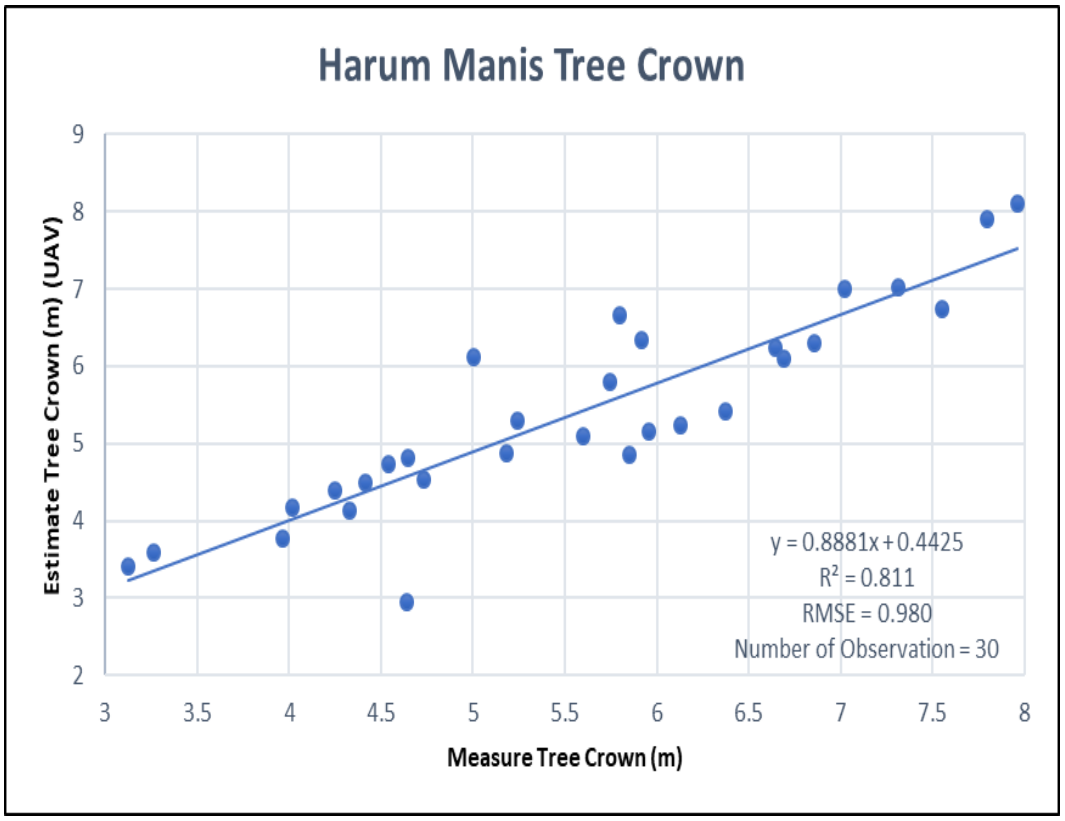


Figure 9: Regression Graph of Tree Crown

Indicate from Table 5, total RMSE for Harum Manis tree crown is at 0.980. This RMSE result is been achieve more better compared to the previous research of Panagiotidis, Abdollahnejad, Surový, & Chiteculo, 2017 which the RMSE value is at 1.040, this mean 0.060 more better and this is show the estimated measurement from this research is more significant

CONCLUSION

In conclusion, the relationship between actual measurement of tree height and tree crown of Harum Manis from ground measurement against CHM and OBIA determination are obtained and examined. It is seen that the tree height RMSE is at 0.230 and RMSE value for crown determination is at 0.9802. It can also be concluded through this study that the integration of UAV technology and GIS application in agriculture or plantation may contribute a lot of benefits not only on the productivity and growth monitoring of plantation but also to the officers or manpower

Table 5: RMSE of Harum Manis Tree Crown

Trees ID	Conventional-Derived Crown (m)	OBIA Derived Crown (m)	Residual (Error) (m)
1	4.327	4.131	-0.196
2	4.733	4.523	-0.210
3	4.638	2.954	-1.684
4	5.180	4.882	-0.298
5	4.019	4.178	0.159
6	6.129	5.226	-0.903
7	7.023	6.996	-0.027
8	7.313	7.019	-0.294
9	5.748	5.802	0.054
10	6.694	6.088	-0.606
11	5.851	4.856	-0.995
12	5.958	5.147	-0.811
13	5.005	6.127	1.122
14	3.125	3.407	0.282
15	4.542	4.732	0.190
16	3.963	3.763	-0.200
17	4.248	4.397	0.149
18	4.645	4.823	0.178
19	4.418	4.498	0.080
20	7.798	7.905	0.107
21	7.963	8.097	0.134
22	3.267	3.59	0.323
23	5.244	5.288	0.044
24	5.797	6.657	0.860
25	6.646	6.233	-0.413
26	7.551	6.742	-0.809
27	6.858	6.301	-0.557
28	6.372	5.408	-0.964
29	5.598	5.087	-0.511
30	5.919	6.346	0.427
Mean Error (m)			0.179
Standard Deviation (m)			0.9582
RMSE (m)			**0.9802**

REFERANCE

Birdal, A. C., Avdan, U., & Türk, T. (2017). Estimating tree heights with images from an unmanned aerial vehicle. Geomatics, Natural Hazards and Risk, 8(2), 1144–1156. https://doi.org/10.1080/19475705.2017.1300608

Khosravipour, A., Skidmore, A. K., Isenburg, M., Wang, T., & Hussin, Y. A. (2014). Generating Pit-free Canopy Height Models from Airborne Lidar. Photogrammetric Engineering & Remote Sensing, 80(9), 863–872. https://doi.org/10.14358/PERS.80.9.863

Kim, S., Kim, H. G., & Kim, T. (2018). Mesh modelling of 3D point cloud from UAV images by point classification and geometric constraints. In International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives (Vol. 42, pp. 507–511). https://doi.org/10.5194/isprs-archives-XLII-2-507-2018

Larjavaara, M., & Muller-Landau, H. C. (2013). Measuring tree height: A quantitative comparison of two common field methods in a moist tropical forest. Methods in Ecology and Evolution, 4(9), 793–801. https://doi.org/10.1111/2041-210X.12071

Lebourgeois, V., Dupuy, S., Vintrou, É., Ameline, M., Butler, S., & Bégué, A. (2017). A combined random forest and OBIA classification scheme for mapping smallholder agriculture at different nomenclature levels using multisource data (simulated Sentinel-2 time series, VHRS and DEM). Remote Sensing, 9(3), 1–20. https://doi.org/10.3390/rs9030259

Leverett, B., & Bertolette, D. (2015). Measuring Guidelines Handbook, 61–65.

O'Neil-Dunne, J. P. M., MacFaden, S. W., Royar, A. R., & Pelletier, K. C. (2013). An object-based system for LiDAR data fusion and feature extraction. Geocarto International, 28(3), 227–242

Panagiotidis, D., Abdollahnejad, A., Surový, P., & Chiteculo, V. (2017). Determining tree height and crown diameter from high-resolution UAV imagery. International Journal of Remote Sensing, 38(8–10), 2392–2410. https://doi.org/10.1080/01431161.2016.1264028

Panagiotidis, D., Abdollahnejad, A., Surovy, P., & Vasco, C. (2016). High resolution airborne UAV imagery to determine tree height and crown diameter. Good Educational, 1–20. Retrieved from http://www.frameadapt.cz/coajdfadlf/uploads/2016/11/5-clanek.pdf

Pretzsch, H., Biber, P., Uhl, E., Dahlhausen, J., Rötzer, T., Caldentey, J., … Pauleit, S. (2015). Crown size and growing space requirement of common tree species in urban centres, parks, and forests. Urban Forestry and Urban Greening, 14(3), 466–479. https://doi.org/10.1016/j.ufug.2015.04.006

Schardt, M., Granica, K., Hirschmugl, M., Deutscher, J., Mollatz, M., Steinegger, M., … Linser, S. (2015). The assessment of forest parameters by combined LiDAR and satellite data over Alpine regions - EUFODO S Implementation in Austria. Forestry Journal, 61(1), 3–11. https://doi.org/10.1515/forj-2015-0008

Sinha, J. P., Kushwaha, H. L., & Kushwaha, D. K. (2016). Prospect of Unmanned Aerial Vehicle (UAV) Technology for Agricultural Production Management

Robotic Precision Planter View project SOP project View project, (December). Retrieved from https://www.researchgate.net/publication/312589716

Stålberg, M. (2017). Reconstruction of trees from 3D point clouds, 62.

Su, W., Liu, R., Liu, T., Huang, J., Zhang, X., & Liu, J. (2016). The estimation of tree height based on LiDAR data and QuickBird imagery. IFIP Advances in Information and Communication Technology, 393 AICT(PART 2), 472–482. https://doi.org/10.1007/978-3-642-36137-1_55

Torres-Sánchez, J., de Castro, A. I., Peña, J. M., Jiménez-Brenes, F. M., Arquero, O., Lovera, M., & López-Granados, F. (2018). Mapping the 3D structure of almond trees using UAV acquired photogrammetric point clouds and object-based image analysis. Biosystems Engineering, 176, 172–184. https://doi.org/10.1016/j.biosystemseng.2018.10.018

Torres-sánchez, J., López-granados, F., Serrano, N., & Arquero, O. (2015). High-Throughput 3-D Monitoring of Agricultural-Tree Plantations with Unmanned Aerial Vehicle (UAV) Technology, 1–20. https://doi.org/10.1371/journal.pone.0130479

Zhao, K., & Popescu, S. (2007). Hierarchical Watershed Segmentation of Canopy Height Model for Multi-Scale Forest Inventory. ISPRS Workshop on Laser Scanning and SilviLaser, XXXVI(3/W52), 436–441. https://doi.org/10.1016/j.immuni.2016.04.014