EXTRACTION OF FOREST BIOMETRICS USING AIRBORNE LiDAR AND WORLDVIEW-3 IMAGERY

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ABSTRACT: Forest plays an important role in environmental stability, such as maintain the diversity, provide oxygen, absorb heat, prevent disaster and many more functions. The advance of technology and human irresponsible attitude nowadays harm forest such as illegal logging, deforestation, and forest healthy. Using the convenient method of monitoring forest is almost impossible and required a lot of time to complete while monitoring forest need continuous concentration to detect any changes in forest condition. In this study, the technology of remote sensing and LiDAR are used to help in monitoring and managing forest. This technology is used to extract forest biometric information which is tree height, Diameter at Breast Height (DBH), Leaf Area Index (LAI), and tree crown. In this study, extraction of the Diameter of Breast Height (DBH) cannot be done because there is no information such as age of tree, basal area, and tree circumference. In this study, CHM is calculated based on formula CHM=DSM-DTM. The result of the this study shows the accuracy between tree height of field measurement and LiDAR prediction is 0.666m with a graph of regression show R^2=0.99. The result of this study show regression graph between DHP and WorldView-3 has excellent relationships with R^2= 0.77.

1. INTRODUCTION

Forests are important to the well-being of humanity as they provide foundations for life on Earth through ecological functions, regulating climate and water resources, and serving as habitats for plants and animals (Latif and Blackburn, 2010). Forests consist of trees that buffer the earth and myriad of life forms. It is not just a collection of trees; they are much more than that. Forest is a complex system; it is a functional system of interacting and is interdependent biological, physical and chemical component. This complexity produces combine of climate, soil, tree and plant species unique resulting to hundreds of difference forest type around the world (Mohd Zaki & Abdl Latif, 2016). Forests in Malaysia are tropical rainforest that needs year round high temperature and abundant rainfall. Tropical rainforest are dense and lush where it's more known as vital storehouse of biodiversity on the planet and can be found near the equator (Abd Latif et al., 2011). Tree is important component of environment that function to maintain the diversity, function and services that exist mostly in forest (Blackburn et al., 2014). Forest today faces multiple of threats from fire, disease, pollution and insect outbreak. Most of the factors can negatively affect large forest areas in a short time periods. Besides that, it can create chronic stresses for long-term consequences on the species and nature of a forest ecosystem within where much of their original extent depleted (Latif & Blackburn, 2010). Forest today faces multiple threats, such as, insect outbreak, fire, disease, and air pollution. While global warming, deforestation, climate change has become serious problem in the world, these problems gives effect to forest in term of growth, biodiversity, timber, biomass, tree crown, crown spacing, productivity and carbon storing. An assessment of forest biometrics is importance to obtain quantifiable information about the resource to allow reasonable decisions on forest density, forest management and forest use (Yunfei et al., 2008)

Remote sensing is increasingly seen as an important tool for providing information to achieve sustainable and efficient forest management. Light Detection and Ranging (LiDAR) has found useful in various application such as 3D model of cities, delineation of tree crown (Abd Latif et al., 2011), analyses of vegetation cover (Latif et al., 2012), and deriving forest canopy structure (Saeidi et al., 2014). WorldView-3 satellite imagery is suitable remote sensing technology in agriculture, mining, geology and forestry industries (Mohd Zaki & Abd Latif, 2016). In this study, LiDAR data and WorldView-3 imagery were used to extract forest biometrics The estimation of tree height, tree crown, diameter of tree and leaf area index (LAI) are compare with field measurement for improvement and containment to protect and monitoring the forest for future generation. The aim of this study is to extract the forest biometrics using LiDAR and Remote Sensing at Ayer Hitam Forest Reserve, Puchong, Malaysia. The specific objectives of this study are i) to conduct field measurements of Canopy Height model (CHM), Leaf Area Index (LAI) and Tree Crown and ii) to extract Canopy Height Model (CHM), Leaf Area Index (LAI) and Tree crown using LiDAR and WorldView-3 Imagery.

2. MATERIALS AND METHODS

2.1. Study Area

The study area was Ayer Hitam Forest Reserve, Puchong, Selangor, Malaysia (3° 00' 24"N, 101° 38' 25"E) (see Figure 1). The area is a lowland dipterocarp forest managed by Faculty of Forestry, Universiti Putra Malaysia (UPM) together with Selangor State Government, Malaysia. The Ayer Hitam Forest Reserve is the only remaining forest in Klang Valley and Putrajaya with total area of 1248 ha. This secondary forest comprises of various species dominated by family tree of *Dipterocarpacaea*. The altitude that comprises in this lowland forest varies from 15 m to 233 m height, and the terrain slope undulating up to 34º.The average annual rainfall is 2178 mm while the average temperature annually is 25.3ºC with maximum 27.7º C and minimum 22.9º C .

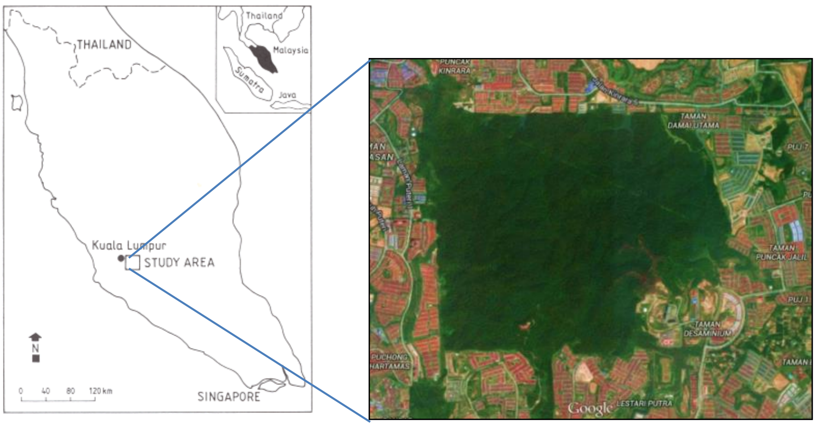

Figure 1: Ayer Hitam Forest Reserve, Puchong, Malaysia (Source: Google Map, 2015)

2.2. Remotely-sensed Data

The research is conducted based on a plot area with a size of 30 x 10 with 2 hectare total area. LiDAR data and WorldView-3 are used in this research to extract the leaf area index (LAI) , canopy height model (CHM), ITC and diameter at breast height (DBH) of the forest. The LiDAR data was acquired in August 2013 using the LiteMapper Q560 that consists of RIEGL LMS-Q560 laser scanner for LiDAR scanner was mounted in the aircraft, along with the Hassleblad digital camera (Figure 2a). Worldview-3 imagery was acquired on 9th December 2014. Figure 2b shows part of Ayer Hitam Forest Reserve covered by WorldView-3 imagery.

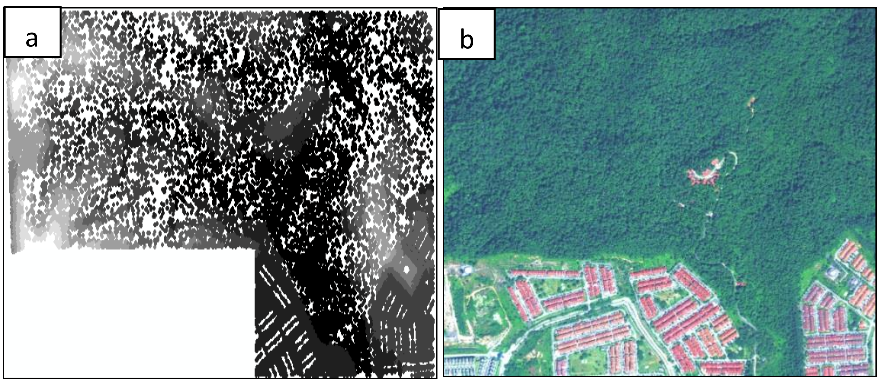

Figure 2a) LiDAR point cloud, 2b)WorldView-3 image of study area

3. METHODOLOGY

3.1 Derivation of canopy height model

Canopy heights were derived from LiDAR data; however an estimate of ground elevation is needed. A digital terrain model (DTM) was constructed from LiDAR last return point clouds of bare soils and road surfaces. A canopy height model (CHM) was calculated the difference between values in the LiDAR digital surface model (DSM) and ground elevation (DTM) at corresponding location.

3.2 Gap Light Analyzer (GLA)

Gap light Analyzer is software used to analyse digital hemispherical canopy images. The DHP will go through image threshold, brightness, contras, and colour fill processing. The extraction of canopy structure such as gap fraction, canopy openness, effective LAI and gap light transmission indices is produce. Other than that, The Gap Light Analyzer (GLA) is a Windows-based software application designed to import, display, and analyse DHP by providing extraterrestrial radiation, frequency distribution, and sun fleck duration, solar position and intensity and sky-region brightness.

3.3 Vegetation Indices

NDVI calculation using red and near-infrared band, $NDVI = (rNIR - rRed) / (rNIR + rRed)$. The result of NDVI calculation is always between -1 to +1. But there is no green vegetation give value close to zero because zero means no vegetation. And value close to +1 (0.8-0.9) show the highest possible density of green leaves.

Enchanted vegetation index (EVI) is used as variable in calculate LAI. Besides that, EVI also develop to overcome some limitation of NDVI. EVI is more sensitive to changes of area that have high biomass. EVI also change vegetation index value by reducing the influence of atmospheric condition and make correct for canopy background signal. EVI is more sensitive to plan canopy difference such as leaf area index (LAI), plan phenology and stress, and canopy structure compare to NDVI that more respond to the amount of chlorophyll in green vegetation.

3.4 Multi-resolution segmentation and identification of local maxima

Multi-resolution segmentation is a method used to extract images object in this study. It used wise region merging technique which is bottom up algorithm. The setting parameter used to detect images object are 30 for scale parameter, 0.1 shapes and 0.5 compactness. Suitable scale parameter need to be choose if the scale is below or above 30 will cause small object be under segmentation and large object will be over segmentation. The brightness value of individual pixel for tree compartment is based on the convex grey level curvature. It mean that the tree top need to be giving highest reflectance (local maxima) while the crown edge giving lowest reflectance (local minima). It is because, the detection of local maxima will provides the location for individual tree and the identification of the local minima drew the crown boundary which give result of separates between the tree crown from gaps and shadows.

4. RESULTS AND DISCUSSION

4.1. Analysis of canopy properties

Based on Table 3 shows direct comparison was made between field measurement and LiDAR CHM. The sample plot number for this study is 32 with 889 total number of trees. A dataset of univariate statistics is presented in the table above. The CHM is slightly underestimated compared with respect to field measurement with the minimum deviation tree height of field data are 2m while CHM are 3.14m. The mean deviation was 16.98m for field data and 17.20 for CHM. Median and maximum deviation of field data and CHM can be conclude has the same value and only differ in decimal place. Besides that, the RMSE between field data (observed height) and CHM (predict height) was calculated and has result of 0.67m which means the error of tree height between field data and CHM are 0.67m. Many research paper shows that the LiDAR application use for tree height estimation has a significant relationship with true tree height.

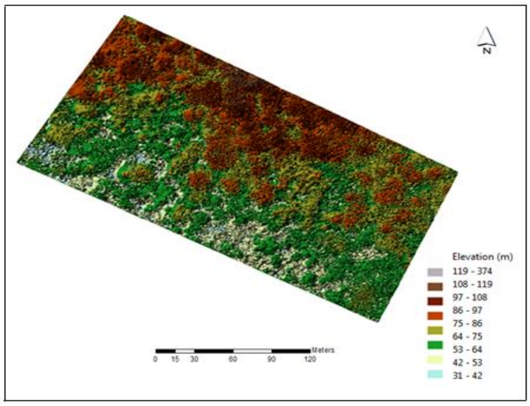

Figure 3: Map of Digital Surface Model (DSM)

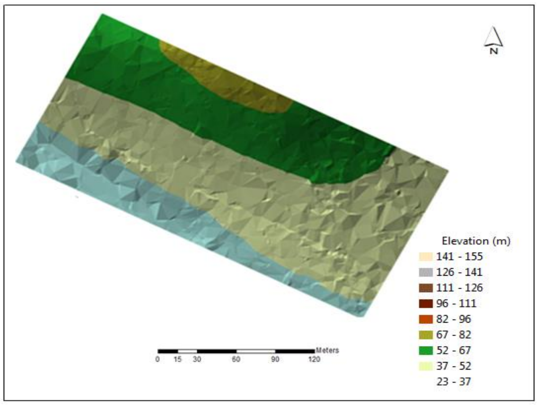

Figure 4: Map of Digital Elevation Model (DEM)

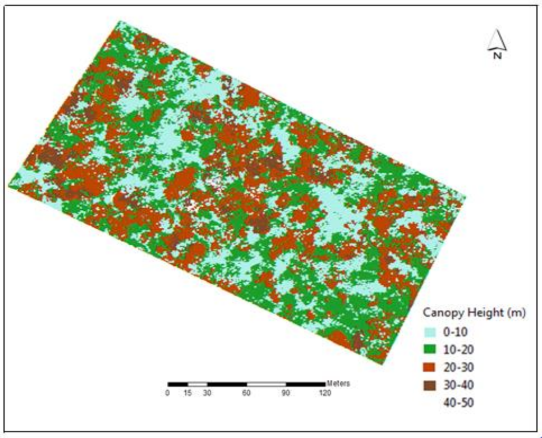

Figure 5: Map of Canopy Height Model (CHM)

Table 3: Height estimation (m) of field measurement vs. LiDAR CHM

	No of trees (n)	Min	Max	RMSE
Field measurement	889	2	35	0.67
CHM (LiDAR)	889	3.14	34.9	

Figure 10 shows the graph of individual tree height between field measurement and LiDAR prediction. Based on the graph above, most of the data are falling in linear line and close to the regression line. There are some trees heights that are falling far from the line are classified as error in estimation the tree height. The graph shows that most of the value of tree height is between located 5m-20m reading. While the tree height reading between 20m-35m can be refer as the tree are located at different topographic surface and has live longer compared to other tree. The maximum of tree height based on the graph is 35 meters and the minimum tree height is 2 meter. The regression line is used to identify the relationship between field measurement and LiDAR prediction in determining tree height in Ayer Hitam Forest Reserve. The graph shown that the R^2= 0.99 which mean the LiDAR prediction and Field measurement has excellent correlation between each other and it can be said that the LiDAR technology can be used to predict tree height for forestry inventory management

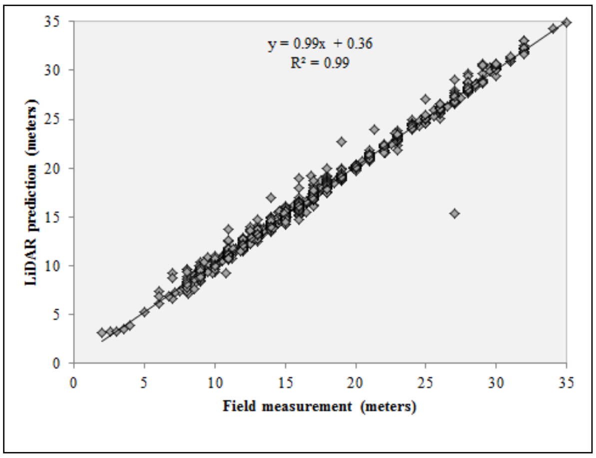

Figure 6: Graph of tree height LiDAR prediction vs. Field measurement

4.2. Analysis of Leaf Area Index (LAI)

The number of sub-plots measured is 32. The average of LAI is calculated based on each subplot. The table above show that DHP and WorldView-3 has slightly difference for minimum deviation where DHP reading is 1.39 and WorldView-3 reading 1.38. The difference of minimum deviation was on 0.01. While the median, mean and maximum deviation between DHP and WorldView-3 show a little bit higher difference compare to the mean value. The median, mean and maximum value for DHP is 3.77, 3.62 and 6.48 while for WorldView-3 is 4.52, 4.75 and 6.97. The difference value of median, mean and maximum is 0.75, 1.13 and 0.49. Besides that, the calculation of RMSE shows the result value of 1.36 between DHP and WorldView-3. It shows that the error of reading are 1.36 which are higher compare to RMSE error for tree height ±0.67.

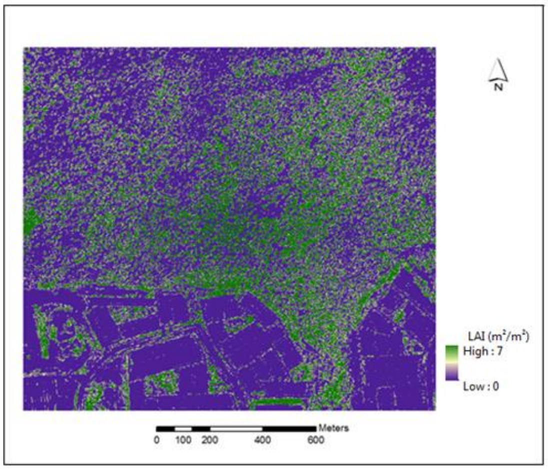

Figure 7: Map of Leaf Area Index (LAI)

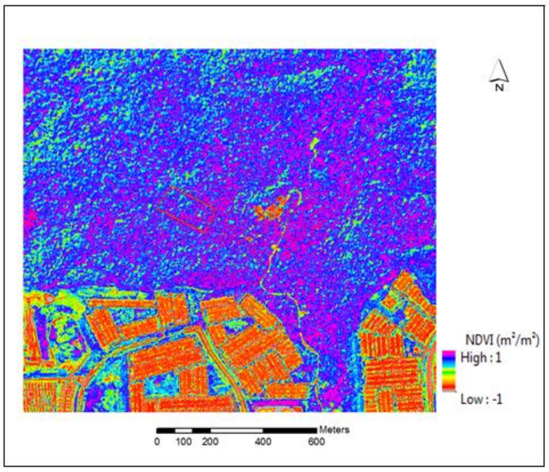

Figure 8: Map of Normalised Difference vegetation Index (NDVI)

Figure 9 shows the graph of DHP vs. WorldView-3 for Leaf Area Index prediction. The DHP LAI reading are processes using Gap Light Analysis and both average of reading are calculated based on sub-plot to produce the graph above. The minimum value on the graph shows the value 1.38 and maximum value at 6.97. Most of the point are distributed close to the regression line and prove that it has a significant relationship between one and another while some point that fall far from the line are being classified as an error that happen either in processing the data or collected the data. Furthermore, the graph above shows the distribution of DHP and worldview-3 value in determining LAI based on sub=plot value has excellent relationships with value of R^2= 0.77.

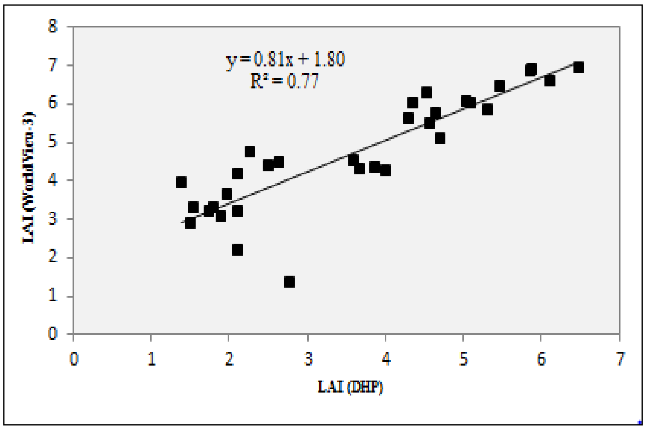

Figure 9: Graph of LAI (DHP) vs. WorldView-3 pixel values

4.3. Analysis of Tree Crown

The total sample trees for tree crown diameter are 825. The RMSE between field measurement and WorldView-3 prediction are 1.16m which are higher compare to the RMSE of tree height and LAI.

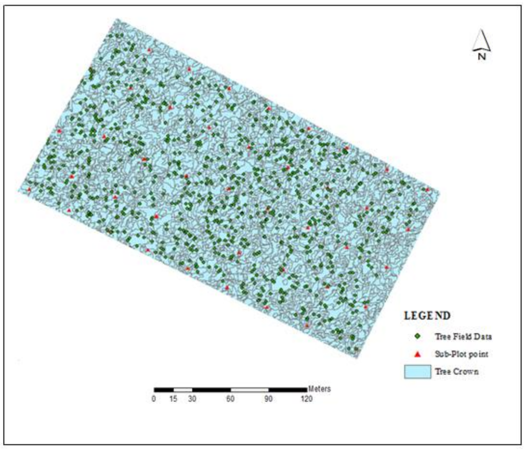

Figure 10: Map of Tree Crown

Figure 11 shows the graph of the relationship between field crown diameter and worldview-3 prediction. Based on the data graph above, most of the point is focused on crown diameter between 0.1-3.0 m and there some point is falling far from the regression line. It shows that the method used in this study not accurately extract tree crown, but it can be used for monitoring forest growth and management. Besides that, there is a gap between trees which much easier to differentiate the tree crown. The results show in the graph above show that the regression calculation between field crown diameter and WorldView-3 prediction are $R^2= 0.36$ which show moderate relationship.

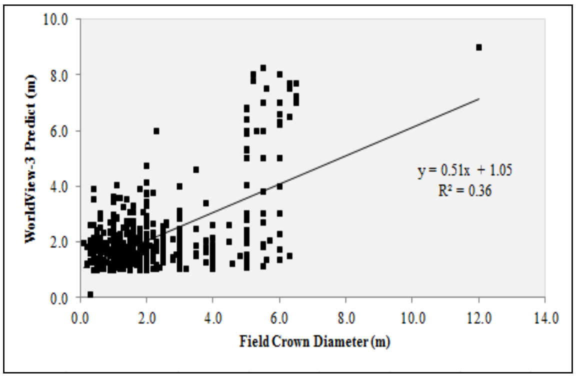

Figure 11: Graph of Field Crown diameters vs. WorldView-3 prediction

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5. CONCLUSION

Overall, LiDAR data can be effectively used for tree height identification with X, Y, Z information in LiDAR point returns. The results of this study showed that CHM has excellent correlation between LiDAR and field measurement with $R^2= 0.98$ and this method has been used in monitoring forest growth and management. It can be concluded that the LiDAR technology is suitable to be used in monitoring tree height for forest inventory management and system. Besides that, in forest management, the condition of the tree is important to monitor forest health for further action. In this study, Leaf area Index (LAI) is used to recognize the signs of ill forest health and teasing apart the causes. DHP has a good relationship with LAI calculated using WorldView-3 imagery. Tree crown is also a part of forest biometric that is used to monitor the health and the greenness of tree or forest. In conclusion the extraction of forest biometrics of CHM, LAI, and tree crown using remote sensing technology and LiDAR has been achieved.

6. ACKNOWLEDGEMENT

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