Identifying Tall Trees in Man-Made Tropical Rain Forest using Airborne LiDAR Point-Cloud

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Abstract. *Shorea glauca* or locally known as Balau Laut has been listed in Malaysia Book of Records in 2016 as the tallest tree ever planted with height of 72.4 meter. The tree was found in FRIM Selangor Forest Park (FRIM-SFP) tropical rain forest. In addition, there are other tall trees found within FRIM-SFP. However, tall trees are always exposed to lightning strikes that eventually damage and may lead to mortality of the trees. Therefore, it is important to identify these tall trees for conservation purposes. Conventional approach which is ground survey requires a lot of man power and time consuming due to wide forest area. The topographic condition also could hinder the survey. This study used canopy height model (CHM) and incorporate it with 3-dimensional structure of LiDAR point-cloud to improve individual tree detection. The location of tall trees were mapped. The finding showed that most of the tall trees are clustered in eight spots and a few found isolated from other tall trees. The CHM were then overlaid with soil map and Digital Terrain Model (DTM). The result showed that the first two tall trees and 36 trees of 60-65m height class are grown in Tai Tak soil series in hilly area with slope 16-25°.

1. Introduction
Forest Research Institute of Malaysia’s Selangor Forest Park (FRIM-SFP) is a testament to the success of large-scale tree planting. This area previously is ex-mining in low land, vegetable farming in hilly area and some area also covered by shrubs and bushes. With the extra ordinary effort of the head of Malayan Forest Department, G.E.S. Cubitt and Dr F.W. Foxworthy, a tropical forest scientist have initiated the experimental planting since year 1920s.

Various local and exotic tree species have been planted and after almost 100 years, there are more than 2,724 plant species of which 1,349 are tree species consisting of 131 dipterocarps, 180 non-dipterocarps and others. The trees that planted in the early of establishment of FRIM-SFP also have been regenerated and this re-created forest resemble like others complex structure of natural tropical rain forests.

In this forest, a tree of *Shorea glauca* species or locally known as Balau laut that were planted on year 1927 has been listed in Malaysia Book of Records (MBR) in 2016 as the tallest forest tree ever planted with height of 72.4 meter, while common height for this tree around 40-50 meters. However, trees in FRIM-SFP often encounter direct lightning strikes that could cause severe damage and even death to the tree if the strike totally passed through the tree trunk. Lightning tends to hit tree that often become the tallest object in surrounding [1], especially tall tree are the most vulnerable to lightning strikes. Therefore, identifying the distributions of tall trees in FRIM is crucial to ensure the tree can be
conserve and reduce the risk of lightning strikes. Preventing the trees from the strike also require less cost compare to treat the affected trees.

To identify the individual stand of tall trees in FRIM, we used Light Detection and Ranging (LiDAR) point-cloud data intensively in two sequential approaches. The first approach is the canopy height model (CHM) derived from input LiDAR data are used to segregate the LiDAR point-cloud of area with stands height of 55 m and above. Secondly, the treetops of tall trees were identified individually using Marker Tool in FUSION/LDV software [2].

Previous studies usually used local maxima to detect the treetop [3] and watershed algorithm to segment the crown of individual tree [4]. However, due to complex structure of FRIM-SFP forest this approach may lead to over segmentation. In addition the small area of CHM more than 55 m height indicated that there is only small number of tall trees, therefore Marker Tool is appropriate for this study. FUSION/LDV software also allows users to view the vertical structure of the point-cloud and can construct the tree model, which can improve the individual tree detection.

2. Methodology

2.1. Study area

The study area is located in Forest Research Institute of Malaysia’s Selangor Forest Park (FRIM-SFP), Kepong, Selangor, Malaysia with area about 589 ha and elevation varies from 50 to 296 meter from mean sea level (MSL).

FRIM-SFP was divided into 55 fields which are then further subdivided into sub-fields containing some study plots. The largest field is Field 38 with area of 29.66 ha and the smallest field is Field 3 with area of 2.18 ha. Each tree species in study plots were planted in different spacing gap and topography condition in order to study the suitable planting approach, the tree growth and species adaptation.

The forested area covered 75% from the total FRIM-SFP area, meanwhile the remaining campus area consists of research buildings office, botany gardens, schools, staff residential, forestry training center, mosque, recreation area and other infrastructures.

The soil found in FRIM-SFP consists of ten types [5], where major soil type are Tai Tak and Tai Tak red variant that covers 46.7% from total FRIM-SFP. The other soil series are Rengam (18.2%), disturbed soil (13.9%), Beserah (12.1%), Colluvium (4.1%), rock outcrop (2.8%), Baling (1.1%), Batang Merbau (0.6%) and Telemong (0.5%).

2.2. LiDAR data pre-processing

LiDAR data were acquired using Optec Gemini Airborne Laser Terrain Mapper (ALTM) sensor on April 2013. The average point density was 1.23 points/m², meanwhile the vertical and horizontal accuracy is 5-35 cm and 70 cm respectively. The LiDAR sensor able to record up to 4 ranges of measurements for each pulse, namely first return, intermediate returns (second and third return) and last return. The LiDAR data were processed using FUSION/LiDAR Data Viewer Analysis and Visualization System (FUSION/LDV) software to produce digital terrain model (DTM), digital surface model (DSM) and canopy height model (CHM).

The LiDAR dataset was classified for the ground return and aboveground return before. From this dataset, the DTM was generated directly from the ground return data using GridSurfaceCreate model function. The aboveground returns were checked cautiously to detect artificial points that are knowns as outliers which might be the returns from flying objects such as birds over the tree canopy during LiDAR data acquisition and also due some technical errors of the sensor system. We then eliminated these outliers from aboveground returns using FilterData model function. After that, the aboveground returns were normalized using clipdata model function to obtain the height of the aboveground returns or called DSM. The resulted DSM were then further processed using canopymodel function to produce CHM.
2.3. Individual tall tree detection

This study will exploiting the 3D structure of LiDAR point-cloud to improve individual tree detection. The treetop and 3D structure of individual tall trees were identified using Measurement Marker tool in FUSION/LDV software. FUSION/LDV allows user to view the LiDAR point spatial arrangement in any angle and provide function to construct the tree model which enhance individual tree detection in this complex forest as shown in Figure 1 [6]. Besides, the shape of measurement marker in FUSION/LDV can be change; elliptical or circular according to tree crown shape. The point-cloud within the measurement marker area that have been measured can be excluded from surrounding point-cloud to speed up next individual tree detection and to prevent duplicate measurement of the same tree. The distance of the trees also can be measured directly in FUSION/LDV (Figure 2).

![Figure 1](image-url)  
*Figure 1. Point-cloud and tree model constructed in FUSION/LDV for tallest and second tallest tree.*
Figure 2. The distance of tallest and second tallest tree with height 68.08 m (Point A) and 65.61m (Point B) respectively is automatically calculate and display in LDV window below the point-clouds.

3. Results and discussion

The resulting CHM map is used to classify the FRIM-SFP forest according to seven class heights, comprise of < 10 m, 10-30 m, 30-55 m, 55-60 m, 60-65 m and > 65 m. From Table 1, we found out that the area of first four height class have significant percentage, which indicate the normal height for most of tree stands in FRIM-SFP. On the other hand, the height class of 55-60 m, 60-65 m and 65-70 m that only covers 0.92 ha (0.21%) from the total area indicate that only small number of trees reach this height. Therefore, we considered height class of 55 m height and above as tall trees.

From the height classification, we inspected all areas of 55 m height class above and found out that most of the tall trees are living in cluster and a few trees are isolated from other tall trees. There are eight cluster of tall trees that we name it according to alphabetical order from Cluster A to Cluster H, with Cluster A are the largest cluster and Cluster H the smallest cluster. The location of tall tree clusters are shown in Figure 3.
Table 1. The percentage area according to class height derived from CHM-LiDAR.

| Height Class (m) | Tree Height Area (%) |
|-----------------|----------------------|
| < 10            | 17.43                |
| 10-30           | 47.94                |
| 30-50           | 33.20                |
| 50-55           | 1.22                 |
| 55-60           | 0.18                 |
| 60-65           | 0.03                 |
| > 65            | 0.001                |

Figure 3. The location of eight clusters of tall tree found in FRIM-SFP.

Trees above than 55 m also individually detected in FUSION/LDV Viewer using Marker Tool as explained in methodology. Based on individual tree identification, a total of 213 trees were found with height at 55 m and above. One hundred eighty five (185) trees living in clusters, while 28 trees are isolated with other tall trees. Cluster A have two trees in class height of more than 65 m with exact tree height are 68.08 m and 65.61 m. The height of tallest tree that acquired from LiDAR data on 2013 has increased from 68.08 m to 72.4 m within 3 years. Cluster A also have the highest number of tree in 60-65m and 55-60 m class height, with 29 and 60 trees respectively. The details of trees number according to height class are shown in Table 2.
Table 2. Trees number according to height class of each location type.

| Type of location | Number of trees of 65-70 m height | Number of trees of 60-65 m height | Number of trees of 55-60 m height | Total of trees above 55 m height |
|------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------------|
| Cluster A        | 2                                | 29                               | 60                               | 91                              |
| Cluster B        | -                                | 11                               | 20                               | 31                              |
| Cluster C        | -                                | 1                                | 22                               | 23                              |
| Cluster D        | -                                | 1                                | 14                               | 15                              |
| Cluster E        | -                                | 1                                | 5                                | 6                               |
| Cluster F        | -                                | -                                | 11                               | 11                              |
| Cluster G        | -                                | -                                | 5                                | 5                               |
| Cluster H        | -                                | -                                | 3                                | 3                               |
| Non-clustered    | -                                | -                                | 28                               | 28                              |
| **Total of Trees** | **2**                            | **43**                           | **168**                          | **213**                         |

The tall trees were also overlaid with soil map and slope map. The result showed that the first two tall trees, 36 trees of 60-65 m height class and 67 trees of 55-60 m height class are grown in Tai Tak soil series in hilly area with slope of 16-25°. Fifty trees also grown in hilly slope of 16-25°, but in Rengam soil series. Meanwhile, 24 trees were found grown in very hilly area of 25-30° slope of Beserah soil series. The other distribution of tall tree stands can be seen in Table 3 below.

Table 3. Proportion of tall trees according to soil series and slope.

| Soil Series | Slope          | Number of trees of 65-70m height | Number of trees of 60-65m height | Number of trees of 55-60m height |
|-------------|----------------|----------------------------------|----------------------------------|----------------------------------|
| Baling      | 30-35°         | -                                | -                                | 1                                |
| Beserah     | 25-30°         | -                                | 1                                | 24                               |
|             | >35°           | -                                | -                                | 2                                |
| Colluvium   | 2-8°           | -                                | 1                                | 3                                |
| Disturbed land | Various slope | -                                | -                                | 1                                |
| Rengam      | 16-25°         | -                                | 2                                | 50                               |
|             | 8-16°          | -                                | -                                | 2                                |
| Rock Outcrop| 30-35°         | -                                | -                                | 7                                |
|             | 2-8°           | -                                | -                                | 2                                |
|             | 16-25°         | 2                                | 36                               | 67                               |
| Tai Tak     | 8-16°          | -                                | -                                | 4                                |
|             | 25-30°         | -                                | 3                                | 2                                |
|             | 30-35°         | -                                | -                                | 2                                |

4. Conclusion and recommendations

From the results obtained, we found that there are 213 tall trees in FRIM-SFP with 2 trees exceeded 65 meter height, 43 tree with height 60-65 m and 168 trees with height 55-60 m. Most of the tall trees were grown in cluster that may be caused by environment factor. We then overlay the location of the tall trees with soil map and DTM. The finding showed the soil type and the topographic conditions influence the height growth of the trees. Most of the tall trees were found in Tai Tak soil series and hilly area with slope 16-25°.

Proper conservation plan for identified tall trees especially trees exceed 60 m height should be taken to avoid lightning strike that always hit the trees in FRIM-SFP. Preventing the valuable tall trees from lightning strike also require less cost compare to treat the affected trees. One of prevention approach can be taken is to install lightning system to tall tree that can dilute and release electrical charge potential slowly to the ground.
References

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