Integration of LiDAR and Pleiades Data in Identifying the Potential of Hazardous Trees

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Abstract
Trees beautify the landscape and provide numerous benefits for human well-being. Without proper maintenance and mitigating, the hazardous trees with structural defects can be harmful to the local community. In practice, the hazardous trees can be assessed using visual tree assessment (VTA), expertise interview and questionnaire. The advancement in remote sensing technology provides users with alternative ways to identify the hazardous trees and is very efficient especially in large areas. The intent of this study is to identify the potential of the tree hazard in UiTM Shah Alam from the integration of LiDAR and Pleiades dataset. Tree health condition and tree height were derived from LiDAR and Pleiades dataset. Height of trees were extracted from a digital canopy height model (DCHM) and the condition of tree health were assessed based on the Normalized Difference Vegetation Index (NDVI) values. Both parameters were used to classify the individual into low, moderate and high-risk ratings. The findings demonstrated that the integration of both datasets successfully identified the potential of tree hazard at the study area. Altogether 108 of individual trees were detected. 7 and 67 trees were identified as high and moderate risk respectively. This study derived significant findings that can be used to support the maintenance of tree activities in the campus area and significant to private and government sectors such park management and local authorities.

1. Introduction

A tree is taken into account as hazardous if its defects will cause a failure and hit something as it falls. Not all tree hazards are obviously visible until an extreme weather event exposes their weakness. In other words, in order for a tree to be thought of as hazardous, it should have a structural weakness (Cahoon, 2020). Cracks, weak branch unions, branch decay, root damage, and root disease are common indicators of structural weakness that should be checked or observed on a constant schedule (National Tree Safety Group, 2011). Moreover, multiple and connected defects increase the potential of failure. Trees with unbalanced or asymmetrical crowns may have their weight distributed incorrectly throughout the stem. These trees are vulnerable to failure when combined with other flaws such as decay and root disease (Smiley, 2008).

Hazard-rating assessment is the evaluation of the individual tree that has the potential to fall and can cause damage to the surrounding area, especially during extreme weather events. The main objective of tree risk assessments is to identify defective trees in high-risk areas, assess the severity of the defects, and recommend corrective actions before the trees fail. Tree-risk assessments can help communities quantify the level of risk to public safety and prioritize implementation of corrective actions. The potential of tree hazard can be classified into three levels of hazard rating which are low, moderate and high (Chuon et al., 2011).

Based on the previous studies, there are some methods used in identifying hazardous trees, especially in the urban areas. According to Sreetheran et al., (2011), a form was used to record information such as tree species, tree structure, tree health, and hazard status for tree risk assessment and the street tree inventory. The tree height was measured with a hypsometer, and the crown diameter and diameter at breast height (DBH) were measured using tape. The hazardous trees also can be identified using the Delphi method (Maruthaveeran and Yaman, 2010). This is a procedure for obtaining the most credible consensus of opinion from a group of experts.

The process of visual tree assessment is an establish method in identifying the hazardous trees however it will be challenging for a large area.

Therefore, advances in mapping technology are promising for providing tree inventories in a timely, flexible, accurate, and cost-effective manner (Ma et al., 2013). LiDAR is a remote sensing technology that can be used to extract comprehensive details of 3D structures. They can penetrate particularly dense canopies of vegetation and can be used to gain information on the 3D structure of trees and for trees that have been suppressed (Zhang et al., 2015).

Other than Pleiades image, there are past studies on SPOT-5 which have resolution of 10m with near infrared, red and green. 20m resolution of shortwave infrared band and with panchromatic 2.5m resolution. The study by (Meng et al., 2016) was mainly for mapping of forest health using remotely sensed image data. It states that this study is conducted because there is difficulty in assessing or monitoring individual tree health by using field observation. With the improvement of technology, remote sensing is the best way to conduct or to practice for this mapping activity.

2. Methodology

The overall methodology consists of 4 phases which is data acquisition, data processing and data analysis and map production as shown in Figure 1.

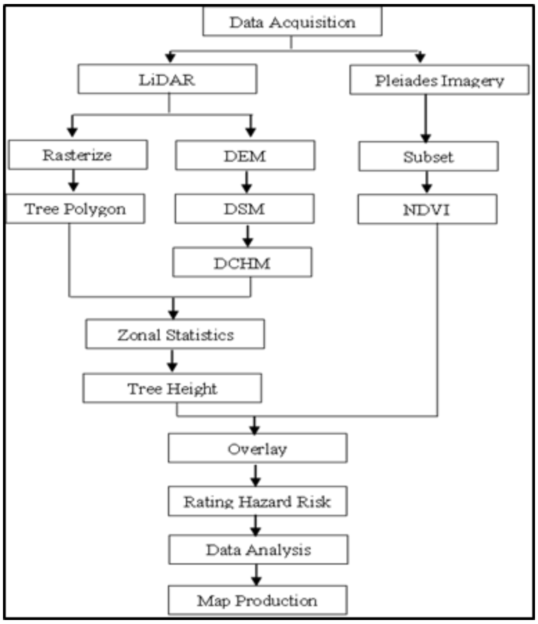

Figure 1: Flow of methodology

Data acquisition stage consists of LiDAR and Pleiades datasets. Data processing was divided into two phases, the first stage was for LiDAR data processing that involved rasterizing LiDAR data for delineating the individual tree polygons and the individual tree height were derived from digital canopy height model (DCHM). Both of the outputs are overlaid using Zonal Statistics to extract the tree height. Then, the condition of individual trees was derived from NDVI values. Derived parameters were overlaid to calculate the hazard rating of the individual trees. The map of the distribution of potential hazardous trees was produced.

2.1 Tree Height Estimation from LiDAR Data

The LiDAR data used for this study was obtained from Pejabat Pembangunan Infrastruktur & Infostruktur (PPII). The LiDAR data covered the study area of UiTM Shah Alam. Data obtained are in point cloud data and processed in ArcGIS software. The digital canopy height model (DCHM) was generated from the subtraction of Digital elevation model (DEM) from digital surface model (DSM). Individual tree heights were estimated from DCHM. Individual trees are delineated by rasterized the point cloud data and converted the raster data to polygon.

Zonal statistics is used to extract tree height. The tools extract summary statistics of the raster cells that fall within the polygon. In this study, maximum values were chosen since the highest tree tip or tree crown are the tree height. The polygon of trees is then converted into points to represent the tree locations.

2.2 Pleiades Data Processing

The Pleiades imagery used in this study was obtained from Malaysian Space Agency (MySA). This imagery consists of 4 bands which are blue, green, red and near infrared (NIR). In this study, Pleiades was used to assess the condition of the trees via NDVI values. The NDVI values are within -1 to 1 where 1 show tree with great condition. Raster calculator tool in ArcGIS was used to perform NDVI threshold. The health of the trees was classified using reclassify tools into four classes which are dead or inanimate range from -1 to 0, unhealthy trees range from 0 to 0.33, moderately healthy trees range from 0.33 to 0.66 and very healthy trees range from 0.66 to 1.

2.3 Identifying the Hazardous Tree

The hazardous trees were classified based on the hazard rating which mainly focus on the tree health and tree height as shown in Figure 2. The hazard rating was derived from the addition of tree height and tree health using add tools. According to USDA (2011), the classes of hazard rating are classified into three classes.

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Tree Height	Class
< 9.99	1
10 - 14.99	2
15 - 19.99	3
20 - 24.99	4
>25	5

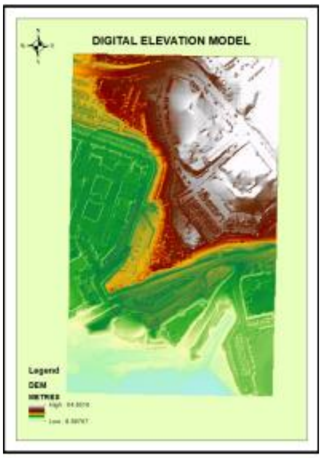
Tree Health	Class
Very Healthy	1
Moderately Healthy	2
Unhealthy / Other Features	3
Dead / Inanimate Object	4

Tree Height + Tree Health = Hazard Rating

Class	Hazard Rating	Label
1 - 3	Low	
4 - 5	Moderate	
> 6	High	

Figure 2: Tree hazard rating

Table 1: Results of DEM, DSM and CHM

DEM	DSM	CHM
		

Hazard rating 1-3 classify as low hazard potential, 4-5 classify as moderate and 6-7 classify as high hazard potential. The outputs were classified into the three classes of hazard rating with the label of green for low risk, yellow for moderate risk and red for high risk. The output of the hazardous trees is in the point of location for each tree with the colours that represent the tree risk.

3. Results and Analysis

3.1 Generation of Canopy Height Model (CHM)

Canopy height model generated from subtraction of digital surface model (DSM) and digital elevation model (DEM) is shown in Table 1. The elevation of CHM ranges from -0.751m to 98.810m. The high elevation due to the high-rise building in the study area. The results of DEM are 8.698 to 64.852 from Mean Sea Level (MSL). DSM results range between 9.32m to 141.68m.

3.2 Individual Tree Height Extraction

The tree height is based on the maximum value from the zonal statistical method. The maximum chosen from the summary of the statistics due to the highest raster value within the polygon considered as the highest point of the tree. Points are used to represent the location of the trees instead of polygons to standardize the shape. The shortest tree is tree number 70 with the height of 4.426m and the highest is tree number 63 with height of 30.102m.

3.3 Tree Health Mapping Using Pleiades

Table 2 shows the range of NDVI values between -0.9 to +0.6 which are used to classify the health condition of the trees. The dead or other features with the NDVI values of -0.993 to -0.003. Next the unhealthy health or other features with the range 0.004 to 0.32 which some of the trees are in this condition too and this range also include the other features such as buildings and road. Then, moderately healthy trees in the range of 0.339 to 0.657 which mostly the trees in the study area. And lastly the range of 0.664 to 0.684 that are the very healthy trees.

Figure 3 shows the tree health map of UiTM Shah Alam produced using ArcGIS in the raster format. The image is corrected geometrically based on the UTM47 projection and the datum is WGS84 based on the projection info in the metadata. The green area represents healthy trees, red area represents moderately healthy, orange represents unhealthy tree or other features and black represents inanimate or dead trees. Most of the trees' condition is moderately healthy and unhealthy based on the percentage of colour in the map. Tree health conditions are one of the most important criteria in tree hazard rating.

Table 2: Value of NDVI threshold based on the tree condition

Value	**Condition**
-0.9933 to -0.0029	dead/inanimate
0.0037 to 0.3272	unhealthy
0.3338 to 0.6573	moderately healthy
0.6639 to 0.6838	very healthy

Figure 3: Map of tree condition

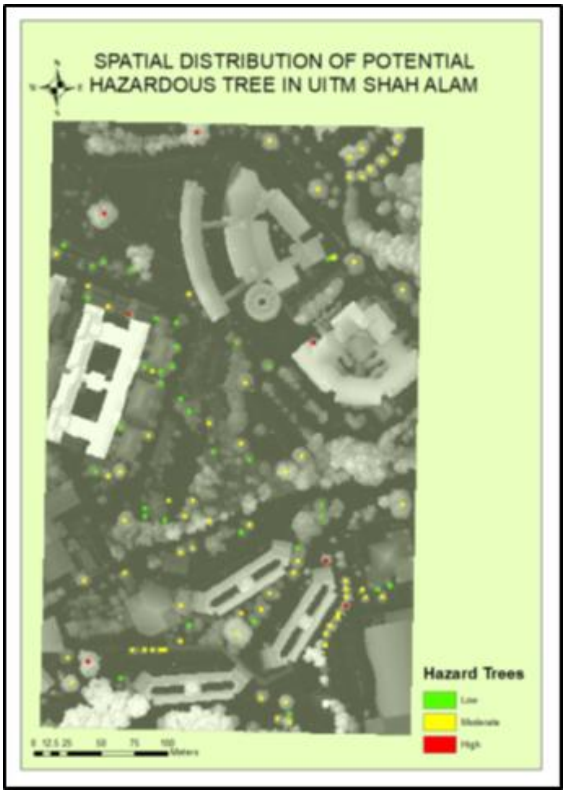


Figure 4: Spatial distribution of potential hazardous tree

3.4 Spatial Distribution of Potential Hazardous Trees

Altogether, 108 of individual trees were detected. 7 trees were classified as high-risk rating and these trees are close to the building. For moderate risk, 67 trees were identified whereas 34 trees were classified as low risk as shown in Figure 4. The trees are near to the building and some are near to the parking area which will contribute to a lot of accidents. For the high potential trees, the suggested action is to mitigate immediately, for example by promptly removing the defective tree. Then, for the moderate potential we need to monitor regularly such as document or tag the trees. Other than that, for the moderate potential we can take a prevention action by mitigating the trees to reduce the risk of an accident.

4. Conclusion

In conclusion, this research study successfully identifies the spatial distribution of potential hazardous trees in UiTM Shah Alam. The derived parameters of tree health and tree height from Pleiades and LiDAR data using NDVI and DCHM contribute significant contributions to this study. Altogether 108 of individual trees were detected in this study area using the integration of Pleiades and LiDAR data. 7 and 67 trees were identified as high and moderate risk respectively. The identification of potential of the hazardous trees will help in decision making and action taking of tree management in the campus area. Other than that, this research will help in tree management of government and private sector such as local authorities and ark management.

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