CASE APPLICATIONS FOR FOREST RESOURCE ASSESSMENT USING AIRBORNE LASER SCANNER

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Commission VIII, WG VIII/7

KEY WORDS: Forestry, LiDAR, Application, Disaster prevention, Canopy Height Model, Hazard mapping

ABSTRACT:

Three case applications for forest resource assessment using airborne laser scanner (LiDAR) will be introduced. The first case is "assessment of high density forest area". The area where forest maintenance is necessary is extracted using colour composite of three layers developed from laser point group; (1) attained distance from DSM into forest (2) tree height (3) reflection intensity. The second case is "applied counting method for the number of trees". The method is based on local maximum filtering but improved to be able to calculate the distribution of multi-storied forest by analyzing laser point group. This method is also able to count the number of lower storied trees by considering the area. The third case is "extracting hazard area facing fallen trees". The risk of fallen trees into conservation area (houses and roads) is evaluated by calculating the location and height of trees using local maximum filter and buffering the tree height from the tree location.

1. INTRODUCTION

In mountainous regions, forest management plays an important role not only in resource management but also in disaster prevention. Trees growing on slopes are an anchored by their rhizomes, which stabilize the slopes by holding the soil together, however, the trees may get uprooted when mass movement of sediment occurs. The uprooted trees may damage roads and buildings. The sediment may sometimes form a dam that obstructs the flow of a river - in a worst-case scenario, this could result in debris flow when the dam bursts.
In Japan, forestry for the harvest of timber has witnessed a decline for several decades. This long-term slump has led to the abandonment of man-made forests. As a result, the forests have fallen into a state of decrepitude, and hence, the slopes on which they were cultivated have become unstable. The exact locations of such regions are generally unknown because they are no longer overseen by any authority. Therefore, extracting data for such regions is essential from the perspective of hazard prevention. In addition, assuming the volume and location of the trees is important because it affects the scale and impact of mass movement of sediment.
In this study, we presents three case applications for disaster prevention based on forest resource management; for this purpose, we analyze airborne *L*ight *D*etection *A*nd *R*anging (LiDAR) data, which have been obtained for large areas by the government to develop a highly accurate national land terrain model for Japan.

2. APPLICATION 1: ASSESSMENT OF HIGH DENSITY FOREST AREA

2.1 Purpose

In general, abandoned man-made forests have a high density of trees; hence, the canopies of these forests virtually shut out sunlight. Similar to solar radiation, the laser pulse radiation from airborne LiDAR cannot penetrate the forest canopies; most of the radiation gets reflected off the surface of the forest canopies and fails to reach the ground. Such regions are susceptible to sheet erosion and slope failure resulting from inadequate exposure to sunlight.
The objective of this case application is to extract the characteristics of high-density forest area.

2.2 Algorithm

The light environment existing below the forest canopy is represented by the random variation in the reflected pulse elevation. In a healthy forest, there is considerable variation in the pulse elevation because the area below the canopy receives sufficient light. In contrast, abandoned forests having extremely dense canopies do not receive sufficient light; most of the laser pulse radiation gets reflected off the canopies, resulting in little variation in the pulse elevation. Therefore, the standard deviation in the pulse elevation indicates the health of a forest in terms of exposure to light.

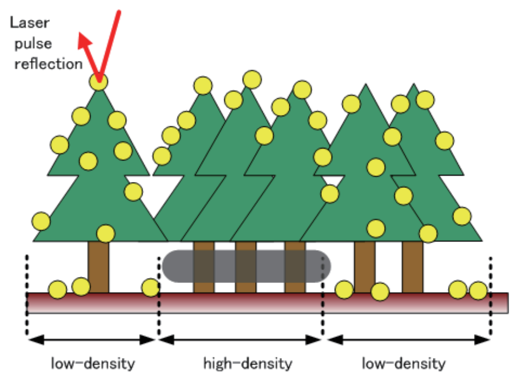

Figure 1. Forest light condition and laser pulse reflection

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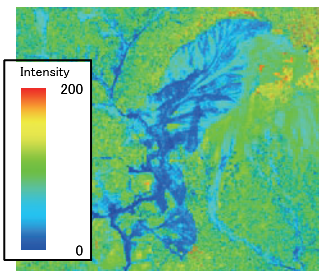
Buildings, roads, glass, etc. possess characteristics similar to those of high-density forests. Extraction errors occur particularly in fields and grasslands because the reflection patterns of the laser pulse radiation in these regions are similar to those in high-density forests. To avoid extraction errors, two indices from LiDAR data are employed: (i) intensity of laser pulse reflection and (ii) canopy height model (CHM).

The intensity of the laser pulse reflection can be used to distinguish between vegetation and other landforms or structures. In general, LiDAR systems employ a near-infrared wavelength laser. Therefore a number of vegetations reflect strongly the wavelength light, the intensity is acquired as large value on in the regions, e.g. Figure 2.



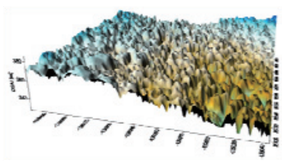
(a) intensity

(b) Orthophotograph

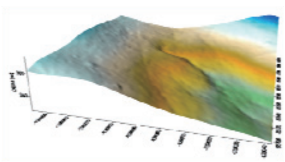
Figure 2. Intensity image

By analysing the intensity of the reflected radiation, it is possible to avoid mistaking other kinds of physical features for high-density forests.

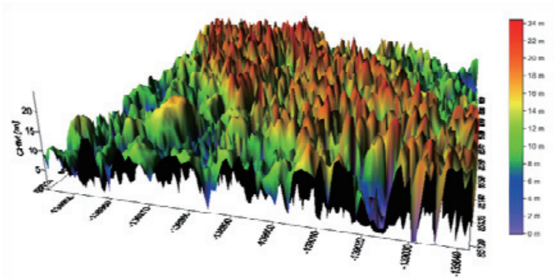
The CHM index, which indicates the height of the canopy from the forest floor, is calculated as the difference between the digital surface model (DSM) index and the digital elevation model (DEM) index; therefore, it serves as a measure of the height of vegetation above the ground.



(a) DSM



(b) DEM



(c) CHM

Figure 3. CHM index image

High-density forests cannot be distinguished from grasslands by using intensity analysis because both the forests and the grasslands exhibit similar intensity pattern. However, the CHM index can be used to distinguish high-density forests from other types of vegetation; the CHM index of high-density forests is considerably higher than that of grasslands.

By applying these three indices (Intensity, Standard deviation, CHM) to an RGB layer, a colour map that represents high-density forests in mountainous regions is obtained.

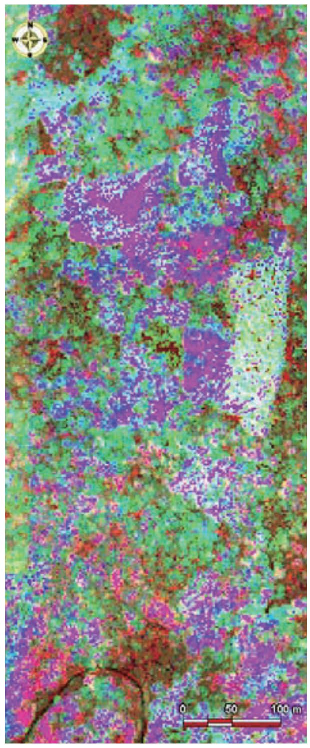
In this study, the three indices are assigned, as shown bellow.

Colour	[Red] Intensity	[Green] SD	[Blue] CHM	Physical features
Purple	High	Low	High	High-density forest
White	High	High	High	Healthy forest
Green	Low	High	Mid	Healthy forest (deciduous tree)
Red	High	Low	Low	Grassland
Black	Low	Low	Low	Road

Table 1. RGB colour composite reference

2.3 Results

The comparison between orthophotograph and the light condition map as following:



(a) Forest light condition map

(b) Orthophotograph

Figure 4. Forest light condition map

The purple region indicates high-density vegetation that corresponds Japanese cedar trees. The vegetation in this region comprises deciduous trees. Japanese cedar is not native to this region; thus, it is concluded that the Japanese cedar trees constitute a man-made forest. The light-green region of Japanese cedar represents controlled thin forest.

The objective of this method is to accurately extract data for target objects in large regions. Mountainous regions in Japan are particularly characterized by large variety in terms of physical features because of the complicated land utilization.

3. APPLICATION 2: METHOD FOR DETERMINING THE NUMBER OF TREES IN MULTISTORIED FOREST

3.1 Purpose

In recent years, estimating the forest volume in mountainous regions has emerged as an important factor in disaster prevention planning because the forest volume directly affects the sediment volume when mass movement of sediment occurs. The forest volume is calculated on the basis of the number and elevation of trees. Although methods for determining the number of trees using LiDAR have been reported in some studies, these methods have been applied to man-made forests and not to multi-storied forest. Determining the number of trees in a multi-storied forest, by using the CHM results in underestimation because the trees below the forest canopy are not accounted for.
The objective of this case application is to estimate the number of trees in a multistoried forest by using LiDAR data.

3.2 Algorithm

The algorithm for determining the number of trees in a multi-storied forest is shown below:

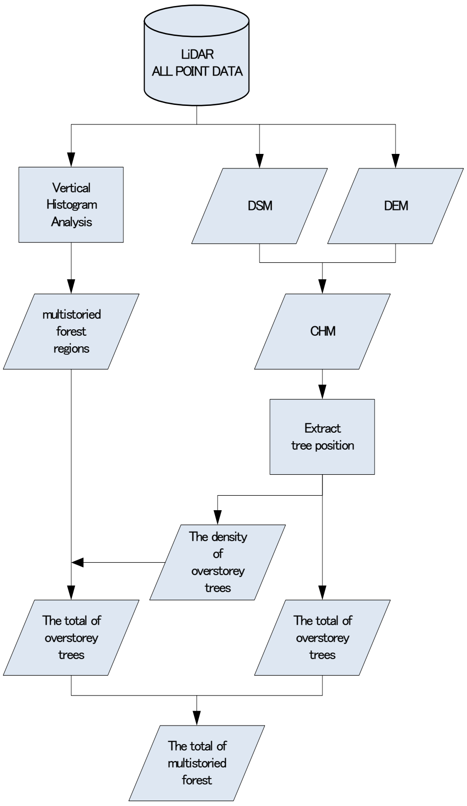
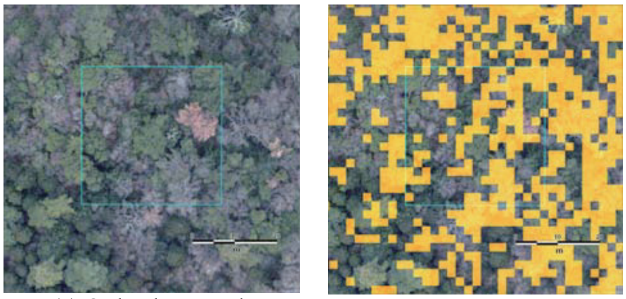


Figure 5. Determining the number of trees for multistoried forest

(i) Extracting data for multistoried forest
Using all the point data, create a vertical histogram in a unit region (4 m^2 square in this case). The number of histogram waves corresponds to the number of tree crowns. The region having two or more waves represents a multistoried forest.



(a) Orthophotograph (b) multistoried forest region
Figure 6. Extracting multistoried forest region

(ii) Determining the density of overstorey trees
The density of overstorey trees can be determined by using CHM analysis.
(iii) Determining the number of understorey and whole trees
Applying the overstorey tree density to the area of multistoried forest. The calculated value shows the number of trees under forest canopy.
The sum of overstorey and understorey trees gives the total number of trees in a multistoried forest.

3.3 Results

We did a side-by-side test with a field investigation for the verification of this algorithm in Rokko mountainous regions, Hyogo Prefecture, Japan. This investigation was executed by setting up plots (900m^2 square / plot) in four places.
The table below shows the number of trees determined by using this algorithm and the number of trees determined by field investigation.

Forest physiognomies	Estimated			Field investigation
	Overstorey	Understorey	Total	
Fagaceae 1	116	46	162	160
Fagaceae 2	98	44	142	150
Red Pine / Ericaceae 1	105	30	135	153
Red Pine / Ericaceae 2	69	21	90	74

Table 2. Number of trees in four forest physiognomies

The number of trees estimated by using this method is close to that determined by field investigation.

Considering tree density and forest structure, this method should be applied to each forest physiognomy. Further, the optimum parameters for this analysis differ by region because the vegetation structure depends on local characteristics such as climate, elevation, geological features, etc. In particular, the grid size of the CHM and the focal window are affected. These parameters should be determined on the basis of the field investigation results.

4. APPLICATION 3: EXTRACTING DATA FOR AREAS IN WHICH UPROOTED TREES ARE A HAZARD

4.1 Purpose

Sometimes, in the mountainous regions of Japan, houses are haphazardly constructed in the vicinity of forests. Measures such as improvement cutting, among others, are required to ensure the safety of such houses.

The purpose of this case application is to plot a hazard map for such regions.

4.2 Algorithm

(i) Extract tree positions
Tree positions can be extracted by CHM analysis. If the centre of the focal window exhibits maximum height in a forest region, it indicates a tree position.
(ii) Create damage zone
A damage zone is created by buffer analysis. The width of the buffer zones is determined on the basis of tree height, which is equal to the CHM index of the location. The created buffer zone represents the area that may be affected by uprooted trees.
(iii) Identify buildings susceptible to damage
Buildings in the buffer zone are highly susceptible to damage by uprooted trees. These buildings are extracted automatically by searching intersection between the buffer zone and the buildings.

4.3 Results

The results are depicted in the following image:

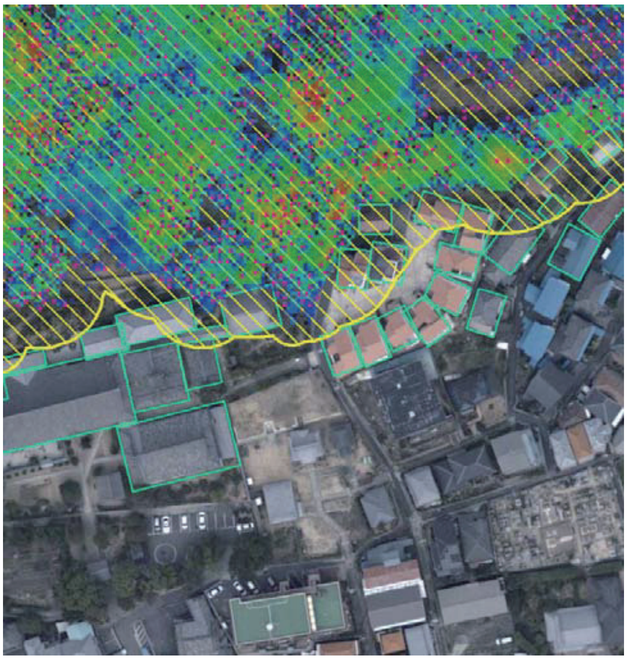


Figure 7. Calculated hazard area of uprooted trees

The yellow polygon represents the buffer zone. The mean tree height is about 20 m in the study area; thus, the buffer zone around perimeter of the forest is 20 m wide. Many houses and buildings lie within the buffer zone and hence susceptible to damage by uprooted trees.

5. CONCLUSION

In this study, we introduce three applications of LiDAR analysis for forest resource assessment; these applications can play a vital role in disaster prevention. Moreover, these applications can contribute towards preventing the abandonment of forests and mitigate the damage caused by earthquakes or heavy rainfall. The occurrence of disasters related to forests is likely to increase in developing countries; thus, it is crucial to focus on and invest in disaster prevention analysis like this study.

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