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Estimation of Tree Stem Diameters and Biomass in Japanese Cedar Forest Using Portable Imaging Lidar Data

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Abstract

Estimation of carbon sinks in forest is important to understand global climatic changes such as global warming. The amount of carbon sinks is often explained by biomass, which can be calculated by DBH (Diameter at Breast Height) of each tree. However, measuring exact DBH of standing trees by existing methods is tedious and takes longer time. Hence, studies have been carrying on developing the methodology to measure DBH and biomass.

In this study, a ground-based remote sensing technique to measure tree stem diameters and biomass in forest has been developed using portable imaging lidar data. Forty 60-year-old Japanese cedars (*Cryptomeria japonica*) in a study site of 400 m^2 were measured to estimate DBH and biomass (carbon weight).

As a result, each DBH of 31 trees (other 9 are in dead angle) was measured with RMSE (Root Mean Square Error) of 6.1 mm. The biomass of individual tree was calculated with RMSE of 11.5 kgC. Total biomass in entire study site including 9 trees in dead angle was estimated by percent method within the error of 3%. It can therefore be concluded that the methodology using a lidar can efficiently replace existing methods to measure DBH and carbon sinks with high accuracy.

Key words: Biomass, DBH, Japanese cedar, Portable imaging lidar, Remote sensing

1. Introduction

An established practice of measuring forest stand parameters of each tree is by the use of some traditional measuring instruments such as measuring tape, clinometers, and pocket compasses (Avery, 1983; Husch, 1982; Nagumo and Minowa, 1990; Nishio, 1998). However, the use of these methods often entails too much time, needs special skills and tends to cause human errors (Japan Association of Forestry Technique, 1998). Hence, measurements of each tree by airborne lidar system were studied (Omasa *et al.*, 2000). Although these studies enabled to measure wide range forests in a small amount of time, measurement accuracies needed more consideration.

In this paper, we developed a ground-based remote sensing technique using a portable imaging lidar to measure forest stand parameters such as tree stem diameters and biomass in Japanese cedar forest. DBH and carbon weight were estimated by using lidar data. The accuracies were verified by comparing to the actual DBH of individual tree and the carbon weight per unit area in the study site.

2. Materials and Methods

A Japanese cedar forest in Aomori prefecture, Japan, was selected for the study. The area was relatively flat and occupied by Japanese cedars of about 60 years old with height ranging from 20 to 30 m. In this forest, 40 Japanese cedars at a 400 m^2 site were measured using LPM-25HA, a portable imaging lidar system produced by RIEGL. Its measurable range is between 2 m and 60 m with range accuracy of about 8.0 mm, and horizontal and vertical angular accuracies are 0.009 degrees. The lidar was set at a point where it can recognize as many Japanese cedars as possible at the site. The land gradient was confirmed by measuring a point from plural directions in the area by the lidar. First, we detected the stem shape of each tree using 3-dimensional data obtained by the lidar. The stem diameter, which was lead by the stem shape at a measured height, and DBH were calculated by a method described by Omasa *et al.* (2002), Urano and Omasa (2003) and Urano (2004). In order to estimate the biomass from DBH, we used existing quadratic equation (R^2=0.843) that was derived by the relationship between actually measured DBH and the biomass of Japanese cedars based on Cannell (1982) and Takeda (1978). Carbon weight (kgC) was calculated by multiplying carbon rate, 0.45, with complete-dry weight, which was calculated by multiplying mass density, 0.35, in case of Japanese cedars (Takahashi, 1974). The accuracies were verified by comparing to the actual DBH by tape measurement. The carbon weight per unit area was verified by using

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timber volume formulas for Japanese cedars (Takeda, 1978; Tsuji, 1998).

3. Results and Discussion

Fig. 1. Lidar data image of Japanese cedar forest.

Figure 1 shows an image in gray scale of the Japanese cedar forest measured by the portable imaging lidar. This image is visualized using the lidar data as the gradation of each pixel is set in gray scale within the distance between 2.0 m and 30.0 m from the lidar sensor. The angular field in the picture is about 100 degrees in vertical and about 80 degrees in horizontal. These angular adjustments are enough to measure the whole Japanese cedar trees from the top to the bottom in the study area. At this angle, measurements took about 90 minutes. If DBH was only needed to measure, only 8 minutes would be enough with a minimum vertical angular field. Although we selected the best position to measure all trees, 31 trees out of 40 are useful for DBH measurement from one point. Other 9 trees were hidden by front trees, but their positions were roughly estimated. The DBH of measured 31 trees ranged from 251 to 535 mm.

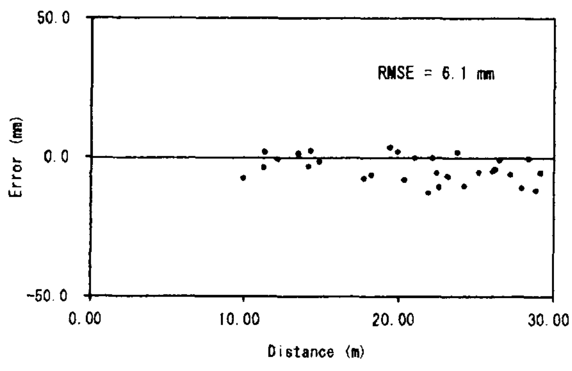

Fig. 2. Estimated DBH errors with distance.

Figure 2 shows the error of measured DBH with distance. The accuracy in RMSE (Root Mean Square Error) was 6.1 mm, which was within the range accuracy of the lidar, which is 8.0 mm. Then individual stem biomass (carbon weight) of measured 31 trees was calculated. The biomass ranged from 56.1 to 528.2 kgC and the distribution is shown in Fig. 3.

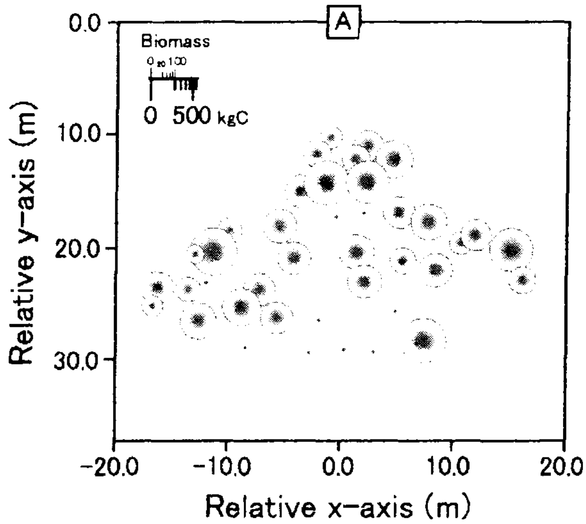

Fig.3. Biomass distribution map of the forest.

Figure 3 shows the biomass distribution map of Japanese cedar forest. X and y-axis mean relative coordinate on the ground as the lidar setting point is the origin (x, y) = (0, 0), marked [A] in the figure. The diameter of each circle indicates the biomass unless otherwise indicated only dots, which were not measured the biomass but only estimated the tree position roughly.

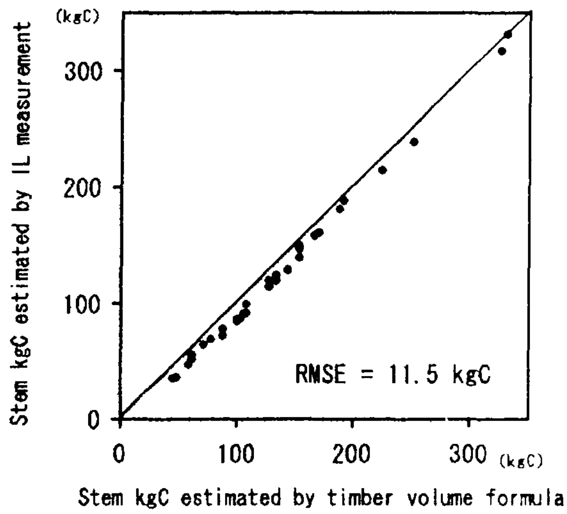

Fig.4. The difference of estimation results.

Figure 4 shows the difference of two kinds of estimation method: one: estimation of stem carbon weight measured by the lidar, two: estimation of stem carbon weight calculated by timber volume formula. According to the figure, the biomass estimated by the lidar was a little smaller than that of calculated by timber volume formula. The difference would be caused by DBH measuring accuracies. Results show that lidar measurements were more accurate than tape measurement. This would be because the efficiency of the lidar, which was 8.0 mm. Tape could not measure tightly along lumpy bark and measured only outer circumference of the bark surface; meanwhile, lidar laser could measure in faithful accordance with the surface of lumpy bark. Accordingly, tape measurement would be somewhat longer than lidar measurement. As a result, total biomass in the study area measured by the lidar was estimated 20.4 kgC/m^2, which was 3% in error comparing to the actual. The estimation on 9 trees in dead angle was carried out by percent method. By this means, the methodology to measure a forest from a point using a lidar can efficiently replace existing methods to measure DBH and carbon sinks with high accuracy even if there are some trees in dead angle.

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