ESTIMATION OF TIMBER VOLUME USING AIRBORNE LASER SCANNER FOR VARIOUS FOREST TYPES IN JAPAN

Tomoko FURUTA and Naoka OGAYA

Japan Forest Technology Association,

Rokubancho, Chiyoda, Tokyo, Japan;
Tel; +81(3)-3261-5496
E-mail:t_furuta@jafta.or.jp

KEY WORDS: Airborne laser scanner, standing stock, Japanese forest

Abstract: Estimation of the amount of forest resources in a country level is needed in recent year, more accurately. However it is difficult to estimate forest resources such as timber stock and biomass, for various forest types and climatic zone in Japan covered from the sub-arctic to the sub-tropical zone, using only the satellite imagery of the optical sensor in which broader-based estimation is possible, with sufficient accuracy. Airborne laser scanner offers an opportunity to gather information on topographic features such as elevation, slope and aspect, simultaneously with vegetation variables such as height from ground. In this study, development of the regression model using point cloud data with the three-dimensional position information acquired from the airborne laser scanner which can measure forest stand height for the purpose of creation of a simpler timber stock estimation was conducted. Study site is about 94sample plots across the country from middle to south part of Japan. For regression model of timber volume estimation, tree census was conducted as ground truth and volume was calculated. As a result, relationship between standing stock from ground truth and digital crown height model obtained from laser measurement data showed a different tendency in the coniferous and the broadleaved forest.

INTRODUCTION

The understanding of the amount of forest resources at the national level is required with more accurate estimates and extensive area, recently. Typical indicator in forest and forestry is standing stock, *i.e.*, total timber volume of forest stand, and we can estimate the amount of biomass and potential of timber production. Remote sensing is necessary technique to get the information in extensive area of the national level. However it is difficult to get height parameter for accurate measure using satellite borne optical sensor. Therefore, we aim to develop a model for estimation of forest standing stock of national level using active sensor, airborne laser scanner, which can measure the distance between aircraft and ground surface object, with more close distance to the ground surface than satellite.

Airborne laser measurement was originally developed for topographic survey, but has been also applied to acquire forest information in recent years. The purpose of measurement in forest area has been to estimate the tree height and standing stock (Nilsson 1996) because of the characteristics of the laser measurement of height. Height of forest stand is obtained by taking the difference between the reflection from the ground and the canopy. It is considered that simple method with less parameter is effective to development of a model estimated standing stock of the national level. According to the research of the past, the correlative relationship has been shown between digital crown height model (DCHM) means integrated value of height acquired laser measurements points and standing stock (Tsuzuki *et al.* 1998).

Estimation of standing stock using airborne laser scanner has not been implemented yet on national level in Japan. In this study, we examined whether there is a difference among forest type, and also among region for relationship between standing stock and DCHM, applied to various regions of Japan integral method using DCHM.

MATERIALS AND METHODS

The study sites were located in several regions across the middle to southern part of Japan (Fig.1), and covered form near sea level to 2,500 m at above sea level. Forest types in study area include typical forest in Japan, such as coniferous plantation, deciduous broadleaved forest, evergreen broadleaved forest and mountainous coniferous forest.

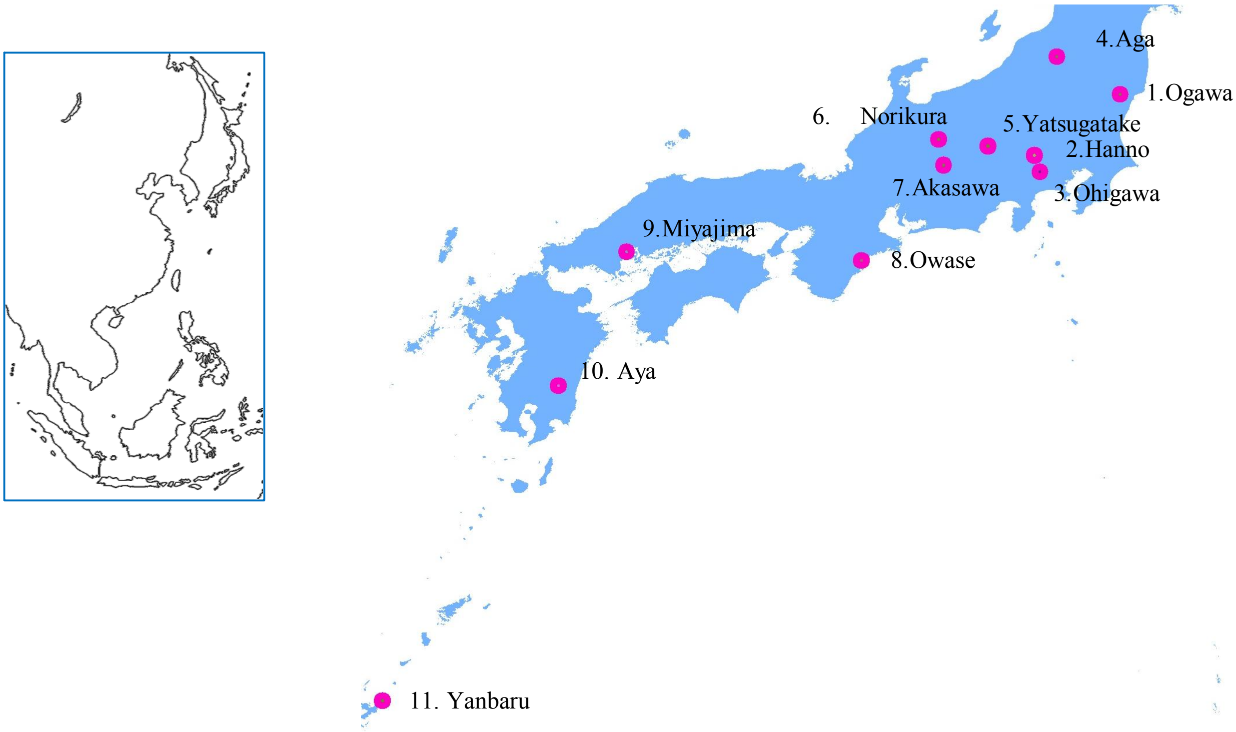

Figure 1. Study area

Table 1. Forest types of each study site

Site name	Vegetation zone	Forest type	Dominant species
1. Ogawa, Ibaraki	Cool-temperate	Coniferous plantation, deciduous broadleaved	*Chamaecyparis obtusa*, *Cryptomeria japonica*, *Pinus densiflora, Fangus crenata, Quercus* sp.
2. Hanno, Saitama	Temperate	Coniferous plantation, deciduous broadleaved	*Chamaecyparis obtusa*, *Cryptomeria japonica*
3. Ohigawa, Shizuoka	Temperate	Coniferous plantation	*Chamaecyparis obtuse*, *Cryptomeria japonica*,
4. Aga, Niigata	Cool-temperate	Deciduous broadleaved	*Chamaecyparis obtusa*, *Cryptomeria japonica*,
5. Yatsugatake, Nagano	Sub-alpine	Natural coniferous	*Picea* sp., *Abies* sp, *Tsuga* sp.
6. Norikura, Gifu	Sub-alpine	Deciduous broadleaved, natural coniferous	*Betula* sp., *Acer* sp., *Quercus* sp.
7. Akasawa, Nagano	Temperate	Coniferous plantation	*Chamaecyparis obtusa*
8. Owase, Mie	Temperate	Coniferous plantation	*Chamaecyparis obtusa*, *Cryptomeria japonica*
9. Miyajima, Hiroshima	Temperate	Coniferous plantation and evergreen broadleaved	*Cryptomeria japonica*, *Pinus densiflora, Quercus* sp.
10. Aya, Miyazaki	Temperate	Evergreen broadleaved	*Machilus thumbergii*, *Castanopsis siboldii*
11. Yanbaru, Okinawa	Sub-tropical	Evergreen broadleaved	*Machilus thumbergii*, *Castanopsis siboldii*

Field survey was conducted by standard forest survey and by a simplified method for 94 plots. In study areas for standard forest survey, the data of the hierarchical structure in forest stand, location of crown or tree, survey items related to biodiversity survey were recorded. And in simplified method survey, we recorded basic survey item such as stand structure, classification forest types. Each survey items are shown in Table 2

Table 2. Ground survey items

Type		Standard forest survey	Simplified forest survey
Sample plot area		1000 sq.m	From 40 sq.m to 240 sq.m
Method of plot setting		Circular plot and 0.1ha horizontal projected area. Set triple circle and measured diameter at breast height (dbh) for more than 1cm diameter in small circle of the 1st from center, 5cm or more in middle circle of the 2nd, and more than 18cm in large circle of 3rd.	Set rectangular-shaped plot covered the upper layer tree of more than 10 trees in the plot. And five trees to be measured.
Survey item	Site condition	Altitude, slope aspect, land form	Altitude, slope aspect
	Tree mensuration	Species identification and diameter measurement for more than 1cm dbh (object trees for measurement are dbh of greater than 1, 5 or 18 cm in each circle), and also height measurement and vertical length of crown for 20 trees The health, and the presence or absence of damage caused by disease, insect or wildlife.	Count, dbh measurement, height and vertical length of crown for upper layer tree
	Conditions of forest stand	Dominant species, stage, vegetation coverage, forest management history, damage, sign of wildlife, and so on	Dominant species, stage, vegetation coverage, forest management history, damage, sign of wildlife, and so on
	GPS location	Center of sample plot	Center of sample plot

Airborne laser scanner was conducted by three of Japanese aerial survey companies, Pasco Co., Asia Air Survey Co., Ltd and Kokusai Kogyo Co., Ltd. Measurement instrument was Leica Geosystems, pulse rate 83,000 ~ 200,000 Hz, height accuracy 13 ~ 30 cm, and scan angle in degrees 0 to plus or minus 37.5. Point density was measured so as to be at least 1point / sq.m.

Laser data is LAS format, specifically for laser data of the binary file format. Each data points hold the information such as coordinate value, reflection intensity, return value, and scan angle.

DCHM was calculated to subtract from laser data to all return point data as digital surface model (DSM) to ground surface data of 1m mesh as digital terrain model (DTM). And then mean DCHM of each sample plots was calculated to obtain by averaging the DCHM point data within plot.

It is considered that standing stock is proportional to tree density and tree size, in general. Namely, many points of laser measurement are gotten from surface of forest canopy in which case forest stand density is high. Conversely, the reflection from a low point near the ground will increase in forest of lower tree density. In addition, the higher DCHM was obtained if there are tall trees in height is shown, and the lower DCHM in tree height is low, as shown in figure 2. Therefore, it is estimated that there is a proportional relationship between standing stock and DCHM that reflects the tree density and tree height of forest stand.

The independent variables for developing a regression model was used average DCHM in the sample plot as shown in the following equation. A is shown area of sample plots, h_i is each point height of DCHM and h_{m_dchm} means DCMH.

$$h_{m\_dchm} = \frac{\sum h_i}{A}$$

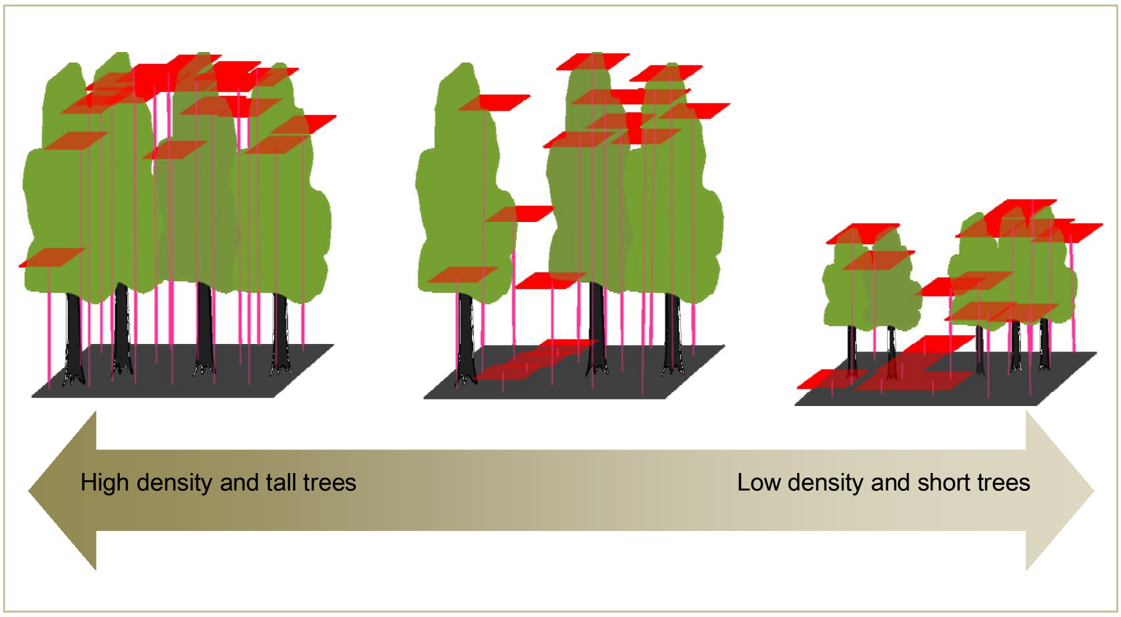

Figure 2. Basic concept of relationship between DCHM and standing stock

Regression coefficient of natural coniferous forest, coniferous plantation, deciduous broadleaved forest, and evergreen broadleaved forest were developed and compared each forest types. And also it was compared the regression model different forest types, the relationship between the standing stock survey and local DCHM average obtained. And also, for coniferous plantation, it is compared that regression coefficient of the standing stock and DCHM of Ogawa located on the Pacific Ocean side and about 650m above sea level in the cool-temperate zone in Ibaraki prefecture, Aga located in about 400m above sea level in the cool-temperate zone in Niigata prefecture, and Akasawa located in the temperate about 1200m above sea level in Nagano prefecture.

RESULTS AND DISCUSSION

Relationship between mean DCHM obtained from laser measurement and standing stock by ground survey was shown for four forest types in figure 3. Dark gray diamond shows coniferous plantation. And it is shown for natural coniferous forest by black diamond, evergreen broad-leaved forest by white circle, and deciduous broadleaved forest by light gray circle.

The slopes of the regression line for each forest types were 37.1 of coniferous plantation ($r = 0.74$), 39.5 of natural coniferous forest t ($r = 0.65$), 24.0 of deciduous broadleaved forests ($r = 0.71$), and 24.2 of evergreen broadleaved forest ($r = 0.89$), respectively. The slope of coniferous forest put together plantation and natural was 24.0 and broadleaved of deciduous and evergreen was 37.4.

The result of analysis of covariance to test of parallelism and significance to compare slopes of the regression line for coniferous and broadleaves forest showed significant difference (p=0.0035). There were no significant result between coniferous plantation and natural coniferous forest (p=0.9830), and also between deciduous and evergreen broadleaved forest (p =0.8337).

The difference between the slope of coniferous and broadleaved forest, is considered as one of the reasons for the difference in tree form. Although the distribution of foliage and branch of coniferous forest is often conical shape similar to crown and stem form, in the case of broadleaved tree, crown is distributed to shape of broom. It is considered that a lot of laser data are reflected from surface of crown, i.e., laser data return in broadleaved forest might be in a higher position than coniferous forest. And then it is estimated that DCHM is higher for broadleaved forest than coniferous if standing stock is same.

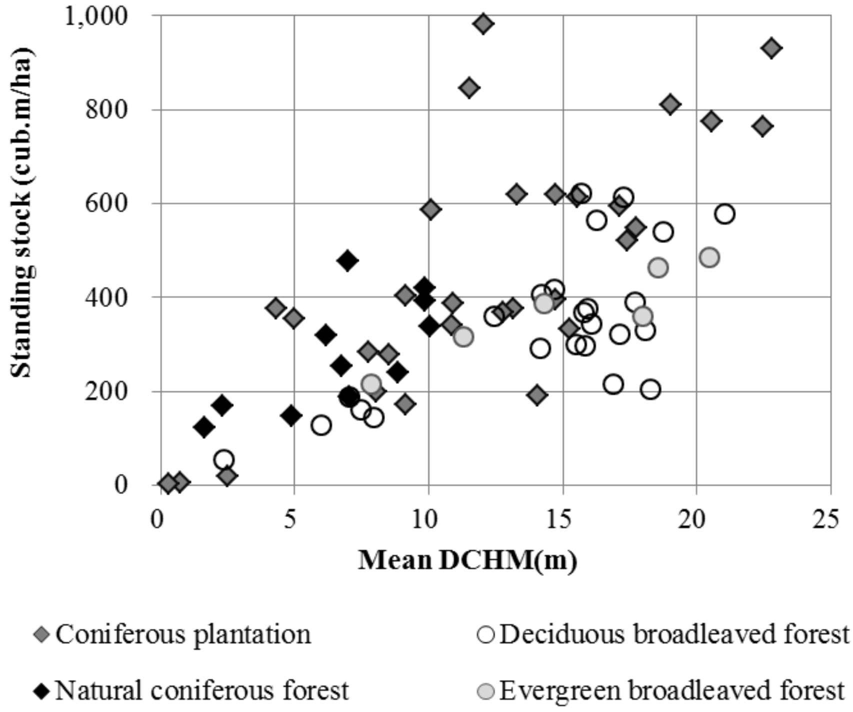

Figure 3. Relationships between DCHM and standing stock in different forest type.

Next result of relationship between mean DCHM and standing stock in coniferous plantation of different three regions of Ogawa, Aga and Akasawa was shown in figure 4. Legend is the following, Ogawa as white square, Akasawa as black triangle, and Aga as dark gray diamond. The slopes of the linear regression of each region showed 30.3 in Ogawa, 43.3 in Akasawa and 51.3 in Aga.

As a result of analysis of covariance, there was significant difference (p= 0.001) at the 5% significance level between Akasawa where slope was largest and Ogawa where smallest and no significant difference between Ogawa and Aga (p=0.064), and Aga and Akasawa (p=0.299). These results showed clear difference in regional.
In addition, it was not shown the significance of the regression coefficients for difference in species, main species are Japanese cedar and cypress in coniferous forest, in Japan.

In Ogawa, the one of reason of smaller slope compare to other two regions shown in Ogawa is considered that stand density was high. As for where the field survey was conducted, higher of average tree density of trees for upper layer is 2769 in Ogawa, but Akasawa is 1128 and 1431 in Aga, Ogawa. In addition, it is also shown that tree density was higher but standing stock was same level, in relatively.

In case of tree density is high even at the same level as standing stock, it is considered that crown has been closed and then laser beam reflected by the surface of the crown is more frequently and less penetration from ground.
From the above, it is estimated to be able to more accurately estimate of standing stock, by developing a regression model that also considered tree density.

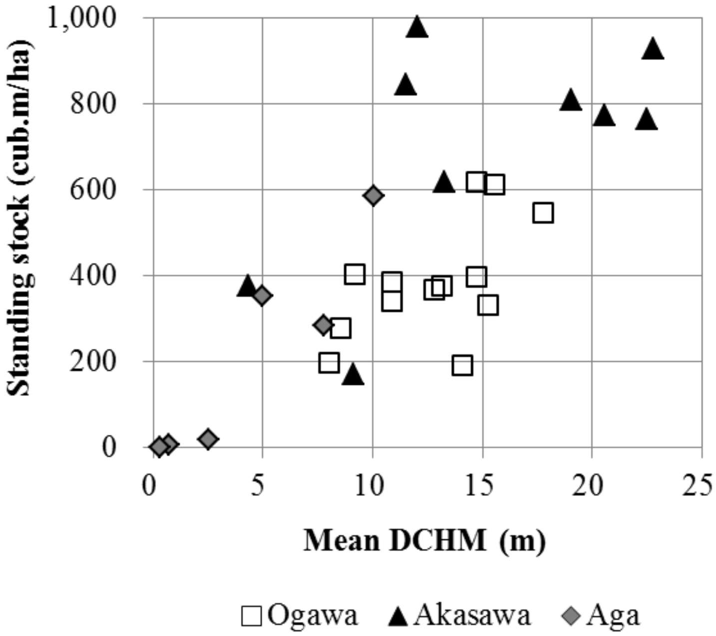

Figure 4. Relationships between DCHM and standing stock in coniferous plantation.

REFERENCES:

Nilsson, M. 1996. Estimation of tree heights and stand volume using an airborne lidar system. Remote Sensing of Environment, 56(1), pp. 1-7.

Tsuzuki, H., Abraham, E. R. G., Kusakabe, T., Yamamoto, T. and Sweda, T. 1998. Timber Cruising over Extensive Forest Area with Airborne Laser Altimeter. In Proceedings of IUFRO International Symposium on Global Concerns for Forest Resource Utilization (FORESEA), pp. 746-754.

ACKNOWLEDGEMENT

This study was supported in part of the digital forest information development, the project of the Forest Agency of Japan.