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Comparison of Leaf Area Density Measured by Laser Range Finder and Stratified Clipping Method

By

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Summary

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Leaf area density (LAD) have an important role in biomass productivity models, radiative transfer studies, remotely sensed data and so on. In this study, the vertical profile of leaf area density (LAD) was measured by the laser range finder, which is the instrument to measure three dimensional coordinate. LAD was calculated by the method of NORMAN & CAMPBELL 1989 from gap fraction which is the probability of light passing through the canopy. In order to measure the vertical profile of LAD, gap fraction in horizontal layer divided into the canopy can be measured by the laser range finder. The vertical profile of LAD was compared with LAD measured by the stratified clipping method in two different-aged Japaneses larch forests, one is 5-year-old and another is 47-year-old.

In 5-year-old forest, high correlation was seen in LAD between both methods (R^2=0.94) and slope of regression equation is about 1.00. In the vertical profile of LAD, both method was shown that the maximum LAD in the layer from 1.0 m to 2.0 m and LAD decreased toward the upper and lower layer. In 47-year-old forest, LAD measured by laser range finder was underestimated by LAD measured by the stratified clipping method. In the profile of LAD, both methods were shown that the maximum LAD in the layer from 11.3 m to 13.3 m, but high LAD in the lower layer than 5m height was seen in the method of laser range finder. The cause of this difference is considered that only larch was measured by the stratified clipping method, on the other hand, low trees or shrubs were measured by the laser range finder.

Consequenty, by using the laser range finder, it was possible to measure the vertical profile of LAD at the understory of forest.

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Introduction

The spatial distribution of leaves is closely related to the process of absorbing and scattering of sun beam in the forest. Then we clarify the process which is important for the estimation of photosynthetic rate (RUNNING & COUGHLAN 1988) and the implementation of remotely sensed data (KUUSK 1995). In general, the spatial distribution of leaves is represented by leaf area density (LAD) and average leaf inclination angle (ALIA).

The point quadrat technique developed by WILSON 1960 is important, because this technique developed and progressed to the gap fraction method. This method is able to measure LAD without laborious work and destruction of canopy. Gap fraction was measured from the probability of sun beam passing through the canopy. Therefore, this method can not measure the vertical profile of LAD, because it is difficult to measure the height when the sun beam was intercepted by the canopy.

On the other hand, the laser range finder has been focused on becoming the instrument for measuring forest structure in recent years. By using the laser range finder, gap fraction in horizontal layer can be measured by the ratio of the number of laser beam passing through the layer to coming into the layer.

In this study, in order to develop and verify the method to measure the profile of LAD by using the laser range finder, and compared with the stratified clipping method in two different aged canopies.

Material and Methods

Theory

The profile of LAD was derived by MACARTHUR & HORN 1969 as follows. Let $L(h)$ denote LAD at height h above the ground. Leaf area index (LAI) in horizontal layer between height h_1 and h_2 ($h_1 < h_2$) is calculated by

$$L(h_1, h_2) = \int_{h_1}^{h_2} L(h)\mathrm{d}h = \ln\left\{\frac{P(h_1)}{P(h_2)}\right\} \tag{1}$$

where $L(h_1, h_2)$ is LAI between height h_1 and h_2, $P(h_1)$ and $P(h_2)$ is the gap fraction of height h_1 and h_2, respectively. Because of the common normalizing denominator in $P(h_1)$ and $P(h_2)$, they arrived at the following equation (RADTKE & BOLSTAD 2001)

$$L(h_1, h_2) = \ln\left\{\frac{N(h_1)}{N(h_2)}\right\} \tag{2}$$

where $N(h_1)$ and $N(h_2)$ can be considered as the number of laser beam passing through the height of h_1 and h_2, respectively. LAD between height h_1 and h_2 is calculated by dividing LAI by the thickness of the layer, $h_2 - h_1$.

Because it is impossible to distinguish leaf area and wood area by this method, $L(h_1, h_2)$ calculated from equation (2) denote plant area index (PAI). For this reason, in order to estimate LAD, measuring wood area density (WAD) during the defoliate season and calculating the difference between plant area density (PAD) measured at the leafing stage and WAD.

Laser range finder

Because the laser range finder can only measure distance, the laser range finder is mounted on two rotation stages (ARS-936-HP & ARS-136-HP, Chuo-Seiki), which are attached to perpendicular each other, to measure three-dimensional coordinate from azimuth and zenith angle of laser beam. Wavelength of laser is 970 nm and divergence angle of laser is 3 mrad.

Study site

Two different aged Japanese larch (*Larix kaempferi* Sarg.) forests were chosen for data collection. One is five-year-old Japanese larch planted at the experimental field of National Institute for Environmental Studies located in Tsukuba, Ibaraki, Japan (36°02'N、140°04'E) and another is forty-seven-year-old Japanese larch planted at the Tomakomai flux research site located in Tomakomai, Hokkaido, Japan (42°44'N、141°31'E).

The experimental field

Japanese larches with the height of about 5 m are planted at flat field of 18 m × 18 m area with 2 m spacing between trees. Measurement was carried out for 10 × 5 trees in five rows from the easternmost end. Measurement by laser range finder was conducted at 36 (9×4) points in the forest. Each measurement point was arranged at the center of four adjoining trees. In each measurement point, laser range finder was set up to start laser beam at height of 40 cm. The canopy was divided into horizontal layers of 0.5 m thickness, and gap fraction was measured in each layer except the two layers from soil surface to 1.0 m height. These layers have little leaf, so measuring gap fraction as one layer. Direction of laser beam ranges from 10° to 70° with interval of 5° in zenith angle, and from 0° to 360° with interval of 0.4° in azimuth angle, so the number of laser beams is 11700. NORMAN & CAMPBELL 1989 method was used to calculate LAD from gap fraction. In their method, it is necessary to classify the gap fraction according to zenith angle of laser beam. In this study, we defined three zenith angle classes from 10° to 25°, 30° to 50°, 55° to 70°.

Measurement of LAD by stratified clipping method was conducted on October 12, 2003. Measurement was carried out for three trees with uniform growth in seven and eight rows from the easternmost end of forest. Manner of dividing the canopy was the same as the method with laser range finder. After stratified clipping, leaf and wood were separated and only leaf was dried at 80 °C for 24 hours and weighted. In order to decide specific leaf area (SLA), the relation between area and dry weight of leaf, sample of leaves in each layer was collected from trees clipped stratified, and leaf area was measured then leaves were dried at 80 °C for 24 hours and weighted.

Tomakomai flux research site

In Tomakomai flux research site, height of forest is about 18 m and population is 681.4 plants/ha. In the forest, 40 m × 40 m plot was established, and the measurement of laser range finder was conducted at 36 (6×6) points with interval of 8 m in this plot. The canopy was divided into horizontal layers from 0.0 m to 0.3 m, 0.3 m to 1.3 m, and 2.0 m interval up to 1.3 m, and gap fraction was measured in each layer. The method of shooting the laser beam and calculation of LAD was the same as the method at the experimental field. PAD was measured at September 21 and 22, 2004, and WAD was measured from November 30 to December 3, 2004, and LAD was calculated from the difference between PAD and WAD.

The measurement by the stratified clipping method was conducted at August 30, 2001. Ten larches were divided into horizontal layer with same interval as the measurement by laser range finder, dry weight of leaves was measured in each layer. SLA was measured at the top of the canopy in September 9, 2003.

Results and Discussion

In the experimental field, the largest SLA is 153.2 cm^2/g in the layer from 1.0 m to 1.5 m and smallest SLA is 91.8 cm^2/g in the layer from 4.0 m to 4.5 m. This result shows that SLA in higher layer is smaller than lower layer. In other words, the leaves at lower layer are thin and thick at higher layer.

Fig. 1 shows the relation of PAD and LAD measured by the method of laser range finder (hereafter referred to this method) and stratified clipping method. High correlation was seen in LAD between both methods (R^2=0.94) and slope of regression equation was about 1.00. On the other hand, PAD with this method overestimated LAD about two times (slope of regression equation was 1.89).

The vertical profile of LAD measured by this method and the stratified clipping method was shown in Fig. 2. Both methods showed the maximum LAD at the layer from 1.0 m to 2.0 m and LAD decreased toward the higher and lower layer.

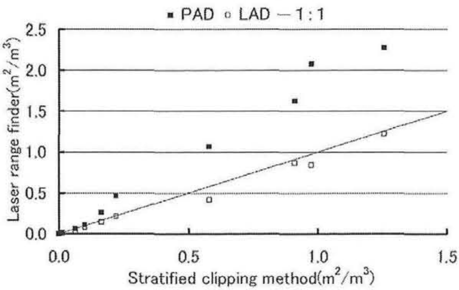

Fig. 1. The relation between PAD and LAD measured by laser range finder and LAD measured by stratified clipping method at the experimental field.

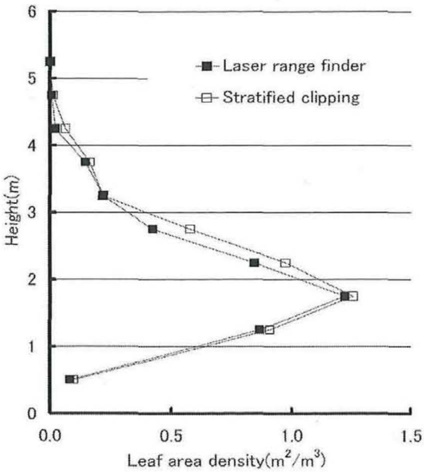

Fig. 2. The vertical profile of LAD measured by laser range finder and stratified clipping method at the experimental field.

In Tomakomai flux research site, SLA was obtained about 99.0 cm^2/g. So, this value was used to estimate LAD from dry weight of leaves in each layer measured by the stratified clipping method.

Fig. 3 shows the relation of PAD and LAD measured by the both methods. In fig. 3, LAD measured by this method underestimated LAD. On the other hand, PAD measured by this method overestimated LAD.

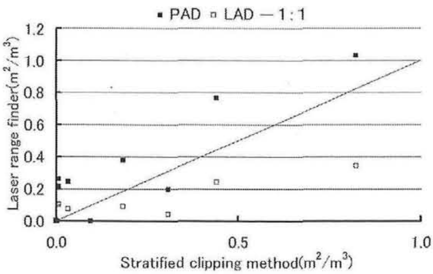

Fig. 3. The relation between PAD and LAD measured by laser range finder and LAD measured by stratified clipping method at Tomakomai flux research site.

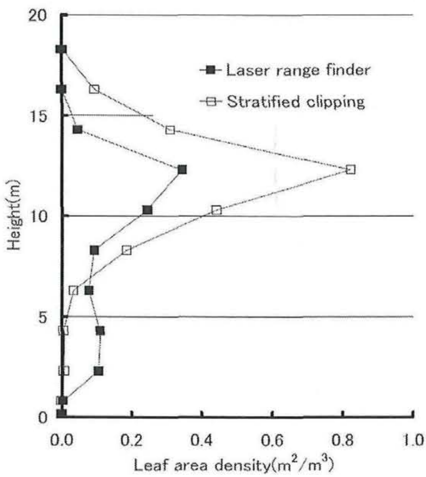

Fig. 4. The vertical profile of LAD measured by laser range finder and stratified clipping method at Tomakomai flux research site.

Fig. 4 shows the profile of LAD measured by this method and the stratified clipping method. Both methods showed the maximum LAD at the layer from 11.3 m to 13.3 m, but high LAD below 5 m and no leaves above 15.3 m was seen in this method. The reason of this difference is considered that only larch is measured by the stratified clipping method, on the other hand, low trees or shrubs are measured by this method.

In general, PAD calculated by gap fraction tends to underestimate LAD measured by direct method such as the stratified clipping method and litter trap method (GOWER & NORMAN 1991). The method with the laser range finder also besed on gap fraction theory, so it was expected to underestimate LAD measured by the stratified clipping method. However, PAD measured by this method result in overestimation of LAD. DEBLONDE & al. 1994 showed that PAD calculated by gap fraction overestimated true LAD when the ratio of wood area is large. In this study, PAD measured at the full-covered period include the area of stem and branch significantly, so PAD measured by this method is overestimated compared with LAD by the stratified clipping method. Another reason is considered that gap fraction is underestimated by the large footprint of laser beam. The footprint of laser beam used in this study is large compared with the leaf size, therefore the gap between needles can not be detected.

In conclusion, by using the laser range finder, it was possible to measure the vertical profile of LAD at the understory of forest. However, it was found that LAD measured by this method included the uncertainty of the nonuniformity of leaf distribution, the ratio of wood area and leaf area and the footprint of laser beam. In the future, in order to estimate LAD with accuracy, these uncertaities have to be evaluated quantitatively.

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