

ESTIMATING LEAF AREA INDEX IN MIXED FOREST USING AN AIRBORNE LASER SCANNER

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ABSTRACT:

Leaf area index (LAI) is one of the most important parameter of forest structure. The study site was an isolated forest in Kyoto City in Japan and its vegetation type was mixed forest. We took fisheye photos at 102 points in the study area, and calculated the LAI and Canopy-open. We classified the laser data into 4 classes, that is, First pulse, Last pulse, Only pulse and Ground pulse. We counted the number of the each pulse in the 102 circles those centers were the ground truth points and each diameter was 40m. Here we introduce new indices: the ratio of the Last pulse (LFO) or Ground pulse (GFO) to (First pulse + Only pulse) and vegetation flux (VF). The ratio of the Ground pulse (GFO) and VF had very strong linear correlation to LAI ($r = -0.840$) and Canopy-open ($r = 0.885$). We made a multiple regression model for predicting LAI from LFO and GFO, and its adjusted R square was 0.704. Each analysis had a very strong correlation to the LAI estimated from fisheye photos, therefore the estimation of LAI from the laser scanner turned out to be so effective. It remains some problems. The difficulty in estimation of LAI from the laser scanner is getting the Ground pulses. We are only able to estimate the LAI which is lower than 2.360 from the regression model obtained because the constant of the equation is 2.369. Hereafter it will be the subject how to estimate the LAI over 2.360.

1. INTRODUCTION

Airborne laser scanner is a useful remote sensing tool for estimating forest structure. Among forest structure leaf area index (LAI) is one of the most important parameter. If the LAI can be estimated accurately in wide range of forest area, it is very useful for grasping forest structure and calculating biomass.

But there were few research that estimated LAI directly from the airborne laser scanner. For example leaf area can be predicted from canopy structure derived using remote sensing tools (Roberts et al., 2003). It is an indirect method using stem diameter, canopy length and so on. Three dimensional foliage distribution can be extracted from lidar, but this study did not mention LAI (Kenton et al., 2003). Ground-based laser scanner can estimate LAI almost precisely (Lovell et al., 2003). And there were several studies estimating forest structure not include LAI using airborne laser scanner (Hyypä et al., 2001; Parker et al., 2001; Drake et al., 2002). These studies indicate possibility of measuring forest parameter by laser scanner.

In this paper we will indicate LAI directly using airborne laser scanner with new indices, and estimate the utility and accuracy of the indices.

2. METHODS

2.1 Laser scanning data

The study site was Tadasu Forest in Kyoto city in Japan. It was an isolated forest and its vegetation type was that of a temperate mixed forest, mainly consisting of deciduous and evergreen broad-leaf trees.

We obtained laser scanning data in January 2003 when the leaves of deciduous trees had already fallen. The airborne laser instrument we used was a N-TOMS II mounted on a helicopter at a height of 400m.

We obtained about four laser fluxes per square meter with a laser wavelength of 1060 nm, and first and last return pulses were recorded. The diameter of the footprint was about 20 cm. We used four overlapping flight lines data.

Flight parameters and instrument settings for the data acquisition are presented in table 1.

Laser pulse frequency	20000Hz
Footprint diameter	20cm
Flying height	400m
Laser pulse density	4 pulses/m ²
Scan angle	45°, 60°
Beam wavelength	1.06μm

Table 1. Flight parameters and scanning system settings.

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2.2 Ground truth data

We took fish-eye photos at 102 points in the study area, and calculated the LAI and Canopy-open by Gap Light Analyzer (Fraser et al., 1999).

The gap fraction of a canopy is the fraction of view in some direction from beneath the canopy that is not blocked by foliage, and it corresponds approximately to the transmittance of radiation in those wavelengths of radiation where scattering by foliage is small (Stenberg et al., 1994).

We mentioned this LAI from fish-eye photo as ‘observed LAI’ in this paper.

2.3 Data analysis

We classified the laser data into four classes, that is, First pulse, Last pulse, Only pulse and Ground pulse. The Ground pulse was extracted by the classification routines in TerraScan (TerraSolid Co.,LTD).

We counted the total number of the each pulse in the 102 circles those centers were the ground truth points and each diameter was 40m.

The accuracy of the estimated forest structure indices were checked by applying the Pearson’s correlation coefficient and the Spearman’s correlation coefficient.

2.4 Indices for estimating LAI

For estimating LAI we introduced new indices: the ratio of the ground pulse or the ratio of the last pulse to (First pulse + Only pulse). The ratio of the Ground pulse is GFO, and the ratio of the Last pulse is LFO. These indices are expressed in the following formula.

$$\text{GFO} = \text{Ground pulses} / (\text{First} + \text{Only}) \text{ pulses} \quad (1)$$

$$\text{LFO} = \text{Last pulses} / (\text{First} + \text{Only}) \text{ pulses} \quad (2)$$

The vegetation flux (VF) is an index indicating the ratio of vegetation reflectance include foliage, stem and branch to all fluxes. This index is expressed in the following formula.

$$\text{VF} = (\text{First} + \text{Only} + \text{Last}) \text{ pulses} / \text{All pulses} \quad (3)$$

We made a single regression model using each index and made a multiple regression model using GFO and LFO.

3. RESULTS AND DISCUSSION

3.1 Single regression model

The Pearson’s and Spearman’s correlation coefficient between the indices and observed LAI were shown in table 2.

	Pearson	Spearman	RMSE
GFO	-0.84	-0.832	0.303
LFO	-0.787	-0.789	0.345
VF	0.843	0.826	0.3

Table 2. Pearson’s correlation coefficient and Spearman’s correlation coefficient between the indices calculated from laser scanning data and observed LAI.

We found a high level of correlation ($|r| > 0.8$) between observed and predicted LAI estimated from GFO and VF.

The index ‘VF’ had the highest correlation with LAI in the Pearson’s correlation coefficient, and the regression model was given by (Eq. (4)):

$$\text{LAI} = 25.169 \text{ VF} - 22.809 \quad (4)$$

This equation was ineffective when the observed LAI was over 2.30. It showed that we had much difficulty in getting ground pulses when there was thick foliage above the ground. Figure 1 show a cross-validation plot between the observed LAI and the LAI predicted from VF.

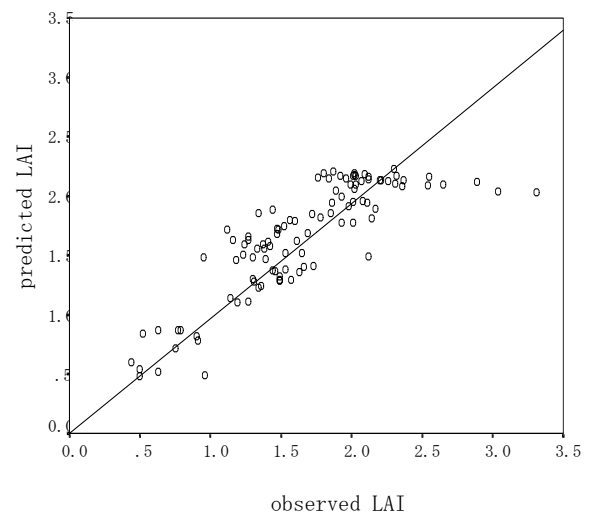


Figure 1. A cross-validation plot between the observed LAI and the LAI predicted from VF. The adjusted R square was 0.711.

GFO and VF had a highly correlation with LAI but when the observed LAI was higher than 2.50, we could not get predicted LAI plot. If the LAI is low, we can get the Ground pulse easily. But if the LAI is high, it is difficult to get the Ground pulse because the Last pulse may be returned by thick foliage above the ground.

3.2 Multiple regression model

Multiple regression model was given by (Eq. (5)):

$$\text{LAI} = -12.501 \text{ GFO} - 0.695 \text{ LFO} + 2.369 \quad (5)$$

RMSE was 0.302 and adjusted R square was 0.704. Same as single regression model this equation was ineffective when the observed LAI was over 2.40. Figure 2 show a cross-validation plot between the observed LAI and the LAI from the multiple regression analysis.

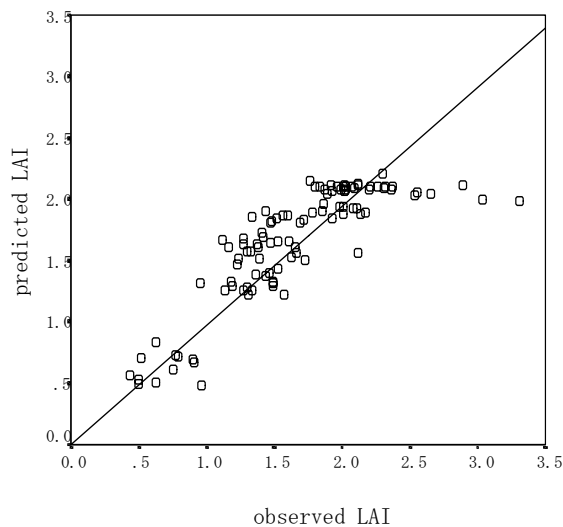


Figure 2. A cross-validation plot between the observed LAI and the LAI from the multiple regression analysis. The adjusted R square was 0.704.

The presumption equations (Eq.(4) and Eq.(5)) had ineffective parts, so we may consider other methods when the LAI is high. Because the indices GFO and LFO had some correlation ($r = 0.60$), the multiple correlation analysis may not effective. In this case single correlation analysis was more effective and easier.

4. CONCLUSION

By using high density laser scanner, we can predict LAI in highly level. Estimating LAI from the rate of each pulse may have utilities. But we are only able to estimate the LAI which is lower than about 2.30 from the regression model obtained. If the LAI is low, we can get the Ground pulse easily. But if the LAI is high, it is difficult to get the Ground pulse because the Last pulse may be returned by thick foliage above ground.

Hereafter it will be the subject how to estimate the LAI over 2.30. In this paper we obtained laser data in winter, so we could get many ground and last return pulses. It is important to test the indices estimating the LAI in sufficient level during the summer.

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