Leaf area index estimation in Fujian province based on remotely sensed imagery

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Abstract-Leaf area index (LAI) is a key parameter in carbon cycling models of forest ecosystem and acquiring LAI with a high spatial and temporal accuracy is of great importance to improve the performance of carbon cycling models. Remote sensing technology provides a promising and practical way to estimate LAI at a large area with high temporal coverage, and hence, considerable effort has been expended in developing LAI retrieval models from remotely sensed imagery. In the past two decades, much work has been done for LAI estimation in boreal forest based on remote sensing imagery. However, such studies performed in Asian subtropical monsoon climate region are relatively less. Therefore, this study has been conducted to retrieve LAI in the forested area of Yongan county, Fujian province, located in southeast of China, which has a typical subtropical monsoon climate. IPS P6 LISS 3 imagery acquired on 24 March 2008 in Yongan county was employed in this study. Firstly, a practical atmospheric correction algorithm combining MODIS imagery with conventional Dark Object Subtraction (DOS) technique was used in the atmospheric correction procedure. Then various vegetation indices (NDVI, SR, RSR, etc.) were formulated with the atmospherically corrected reflectance. Finally, LAI retrieval models for three major forest types (pinus, China fir, and broad-leaf forest) in Fujian province were determined through a comparative analysis.

Keywords: leaf area index, remote sensing, forest, Fujian, China

1. INTRODUCTION

Leaf area index (LAI) is defined as one-half the total green leaf area (all sided) per unit ground surface area (Chen and Black, 1992). Leaf area index is a key surface biophysical parameter for many ecosystem process models. It varies both spatially and temporally and is difficult and expensive to derive with ground measurement method. However, remote sensing method provides a promising and practical way to estimate LAI at a large area with high temporal coverage, and hence, considerable effort has been expended in developing remote sensing based techniques to map LAI. The empirical–statistical approach is a commonly used technique for estimating LAI, which establishes an empirical relationship between spectral vegetation indices (VI) (or spectral reflectance) and LAI by statistically fitting ground-measured LAI to the corresponding VI. The advantage of this approach is its simplicity and ease of computation. Therefore, it is employed in this study.

2. STUDY AREA AND STUDY OBJECT

The study area is situated in Yong’an county, Fujian province, located in southeast of China. Fujian has a subtropical oceanic monsoon climate, with annual temperature averaging between 15.3°C and 21.9°C and annual average precipitation between 930 mm and 1843 mm. The forest coverage rate of Fujian Province has reached 62.96%, the highest in China. Yong’an, situated in central Fujian, is one of the 48 key forestry districts and counties (cities) in the south of China, with forest coverage reached 83.2%. Pinus, China fir, and broad-leaf forest are three major forest types in Yong’an county, also in Fujian province, and this study was conducted to estimate leaf area index retrieval models of these three types with the empirical–statistical approach.

3. DATA SET

3.1 Ground-based LAI measurements

Ground LAI measurements were made using the Plant Canopy

Analyzer (PCA), LAI-2000 (Welles and Norman 1991) (LI-COR Inc., Lincoln, NE, USA). The LAI-2000 measures the gap fraction in five zenith angles, ranging from 0° to 75°. The measured gap fraction data are inverted to obtain the effective LAI under the assumption of a random spatial distribution of leaves. The ground measurements were performed in July 2008. Totally, 24 sample plots were selected for pinus, 19 for China fir, and 23 for broad-leaf forest, respectively. All plots were geo-located using global positioning system (GPS) measurements with an accuracy of <20m in both the x and y directions. In order to prevent the effects of direct sunlight on the sensor, the instrument was only operated near dusk or dawn or under overcast conditions.

3.2 Remotely sensed data preprocessing and reflectance estimation

A cloud free IRS P6 LISS 3 image, acquired on March 24th, 2008, was used in this study. The LISS 3 sensor observes with 24m pixel resolution at green (0.52-0.59μm), red (0.62-0.68μm), near infrared (0.77-0.86μm) and short wave infrared (1.55-1.70μm) bands. Digital numbers stored in the LISS 3 image were converted to land surface reflectance before any subsequent analysis was conducted. Firstly, the digital numbers of the scene were transformed into spectral radiance by using the gains and offsets obtained from the image header file. The atmospheric correction to convert the radiance values into land surface reflectance was accomplished with the practical DOS model based atmospheric correction approach proposed by Zhang *et al.* (2010).

It should be noted that there is a discrepancy between image acquisition time and LAI collection time, because the bad weather condition in southern China resulted in a cloudy optical imagery received when synchronous ground measurement of LAI was performed. However, considering the time interval between image acquisition and LAI collection is not large and LAI variation can be considered small during this period, error caused by the discrepancy should be acceptable.

4. RESULTS AND ANALYSIS

In the empirical–statistical approach, empirical relationships between LAI and reflectance in the four single spectral bands, and four VI (Normalized Difference Vegetation Index, NDVI; Simple Ratio, SR; Modified Normalized Difference Vegetation Index, MNDVI; Reduced Simple Ratio, RSR, Formulae for these VI are listed below) commonly used in forestry applications, were investigated.

$$NDVI = \frac{\rho_n - \rho_r}{\rho_n + \rho_r} \quad \text{(Rouse } et\ al.\text{, 1974)}$$

$$SR = \frac{\rho_n}{\rho_r} \quad \text{(Jordan, 1969)}$$

$$MNDVI = \frac{\rho_n - \rho_r}{\rho_n + \rho_r}(1 - \frac{\rho_s - \rho_{s\min}}{\rho_{s\max} - \rho_{s\min}}) \quad \text{(Nemani } et\ al.\text{, 1993)}$$

$$RSR = \frac{\rho_n}{\rho_r}(1 - \frac{\rho_s - \rho_{s\min}}{\rho_{s\max} - \rho_{s\min}}) \quad \text{(Brown } et\ al.\text{, 2000)}$$

ρ_r, ρ_n, and ρ_s are red, near-infrared, and short wave infrared (SWIR) reflectance, respectively. $\rho_{s\min}$ is the SWIR reflectance obtained from a completely closed canopy and $\rho_{s\max}$ is the SWIR reflectance from an open canopy.

For each forest type, relationships derived from the regression of ground based LAI measurements against these eight modeling parameters (four single spectral reflectance and four VI) were compared, and the best fitted empirical statistical model was chosen (details as shown below).

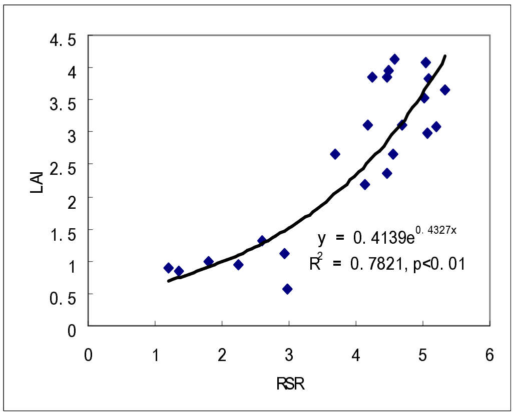

Figure 1. The best fitted empirical statistical model for broad-leaf forest

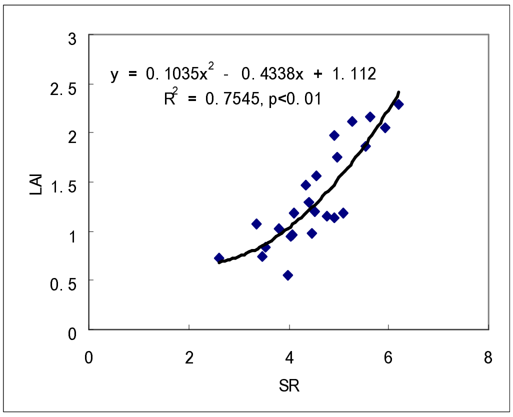

Figure 2. The best fitted empirical statistical model for pinus

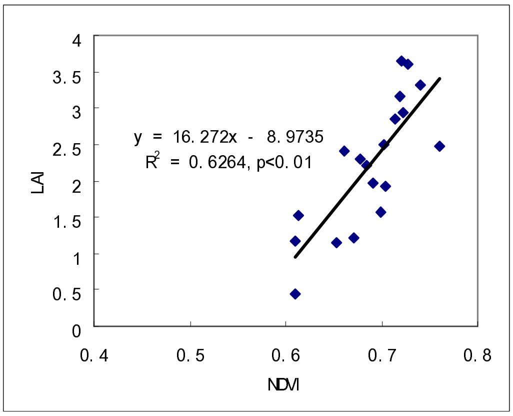

Figure 3. The best fitted empirical statistical model for China fir

As shown in the above figures, the best modeling parameters are RSR, SR and NDVI for broad-leaf forest, pinus and China fir, respectively. VI is better correlated to the measured LAI data than the single spectral reflectance, because the single spectral reflectance contains much noise. However, by constructing VI, the noise is greatly reduced.

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