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LEAF AREA INDEX RETRIEVAL USING RED EDGE PARAMETERS BASED ON HYPERION HYPER-SPECTRAL IMAGERY

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ABSTRACT

Leaf area index (LAI) is an important surface biophysical parameter as an input to many process-oriented ecosystem models. Remote sensing technology provides a practical way to estimate LAI at a large spatial scale, and hence, considerable effort has been expended in developing LAI estimation models from remotely sensed imagery. LAI estimation models were usually formulated using multi-spectral satellite imagery, and hyper-spectral satellite data was scarcely used because it is very difficult to acquire the needed hyper-spectral satellite imagery. Compared to multi-spectral imagery, hyper-spectral imagery has its advantage in LAI retrieving because hyper-spectral data can be used to extract red edge optical parameters, which provides a new way to estimate LAI. In this paper, EO-1 hyperion hyper-spectral imagery was used to estimate LAI in the forested area of Yongan county, Fujian province, located in southeast of China. Two primary red edge optical parameters, red edge position (REP) and red well position (RWP), were extracted from hyperion data; and LAI estimation models for broad-leaf forest in Fujian province were formulated.

Keywords: *Leaf Area Index, Hyper-spectral Remote Sensing, Red Edge*

1. INTRODUCTION

Leaf area index (LAI) is defined as one-half the total green leaf area (all sided) per unit ground surface area [1]. LAI is an important surface biophysical parameter as an input to many process-oriented ecosystem models, which varies both spatially and temporally and is difficult and expensive to derive with ground measurement method. However, with the development of remote sensing technology, it is possible to acquire LAI at a large area with high temporal coverage, and in the past two decades, considerable effort has been expended in developing remote sensing based techniques to map LAI. The empirical–statistical approach is the commonly used technique to estimate LAI. In this method, spectral vegetation indices (VI) are firstly computed from multi-spectral satellite data. Then an empirical relationship between VI and LAI are established by statistically fitting ground-measured LAI to the corresponding VI. Numerous vegetation indices have been proposed in the literature, among which the normalized difference vegetation index (NDVI) [2] and the simple ratio (SR) [3] are the most frequently used VIs to retrieve LAI.

Besides the empirical–statistical approach, there are other methods to estimate LAI from multi-spectral satellite data, such as the radiative transfer models [4-6], reduced major axis (RMA) regression analysis [7] and the linear spectral mixture model [8-9].

With the emergence of hyper-spectral remote sensing, it is possible to extract the red edge optical parameters from hyper-spectral data, and a new LAI estimation method, the red edge method, were proposed [10-11]. There are two primary red edge optical parameters: red edge position (REP) and red well position (RWP). REP, located between 680 and 750 nm, is defined as the wavelength of the inflection point of the reflectance slope at the red edge. RWP is the wavelength position corresponding to a plant's minimum reflectance in the red spectral region [10]. In this paper, firstly, the two red edge optical parameters were extracted with the hyperion hyper-spectral data; then LAI estimation models were formulated based on the red edge optical parameters.

2. STUDY AREA AND DATASETS

The study area is situated in Yong'an county, Fujian province, located in southeast of China. 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

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forest coverage reached 83.2%. Broad-leaf forest is a major forest type in Yong'an county and Fujian province, and this study was conducted to construct the LAI estimation model of the broad-leaf forest.

EO-1 Hyperion data were acquired on May 22, 2012. The Hyperion sensor observes with 30m spatial resolution and has 220 bands, covering 0.4–2.5μm at approximately a 10-nm spectral resolution (Table 1). Ground LAI measurements were carried out at the end of July, 2012, and a total of 24 LAI measurements were obtained with the LAI-2000 Plant Canopy Analyzer (PCA).

Table 1 Features Of EO-1/ Hyperion

Features	EO-1/ Hyperion
Spectral Range	0.4-2.5 microns
Visible Bands	35
Near Infrared Bands	35
Spectral Coverage	Continuous
Short Wave Infrared	172
Spatial Resolution	30m
Swath Width	7.5km

3. METHODOLOGY

3.1 Radiometric Correction

In this study, radiometric calibration was firstly performed to convert the digital numbers stored in the EO-1 hyperion image to spectral radiance by using the gains and offsets obtained from the image header file.

The digital values of the Level 1 product are 16-bit radiances and stored as a 16-bit signed integer. The Short Wave Infrared (SWIR) bands have a gain value of 80 and offset of 0; and the Visible Near Infrared (VNIR) bands have a gain value of 40 and offset of 0. Therefore, radiances (*L*) for the SWIR and VNIR bands could be obtained from Digital Number (DN) with equations (1-2)

$$L = \frac{DN}{40} \quad \text{for VNIR bands} \quad (1)$$

$$L = \frac{DN}{80} \quad \text{for SWIR bands} \quad (2)$$

Then, radiance image was atmospherically corrected with the FLAASH (fast line-of-sight atmospheric analysis of spectral hypercubes) module in ENVI software.

3.2 Red Edge Optical Parameters Extraction

Various methods have been proposed to extract the two red edge optical parameters (red edge position (REP) and red well position (RWP)), such as the Four-Point Interpolation method, Polynomial Fitting method, Lagrangian Technique, and Inverted-Gaussian Modeling [10]. Different approach has its advantages and limitation. The four point interpolation method was selected to extract REP and RWP in this study, which is very practical, easy to implement, and has a high accuracy for forest LAI estimation. More details about the four point interpolation method can be found in the work of Pu et al. (2003) [10].

With the Four-Point Interpolation method, REP can be obtained with equations (3-4). In equation (3), the reflectance at the inflection point (ρ_i) is firstly calculated; Then, the wavelength (λ_i) corresponding to the reflectance at the inflection point is obtained with equation (4).

$$\rho_i = (\rho_1 + \rho_4)/2 \quad (3)$$

$$\lambda_i = \lambda_2 + (\lambda_3 - \lambda_2)\frac{\rho_i - \rho_2}{\rho_3 - \rho_2} \quad (4)$$

Where λ_1, λ_2, λ_3, and λ_4 refer to wavelengths of 670, 700, 740, and 780nm, respectively, and ρ_1, ρ_2, ρ_3, and ρ_4 correspond to reflectances at corresponding wavelengths, respectively. In a similar way, the other red edge optical parameter, the red well position (RWP), can be obtained with equation (5).

$$\lambda_p = \lambda_1 + (\lambda_2 - \lambda_1)\frac{\rho_i - \rho_2}{\rho_3 - \rho_2} \quad (5)$$

For hyperion data, four spectral bands centered at 671.62nm, 702.12nm, 742.80nm, and 783.48nm respectively were employed in the computation of REP and RWP.

4. RESULTS AND ANALYSIS

The two red edge optical parameters (REP and RWP) were regressed against ground based LAI measurements and different forms of empirical relationships were compared, finally the best fitted empirical statistical model with the highest R^2 (coefficient of determination) was chosen (details as shown in figure 1 and figure 2).

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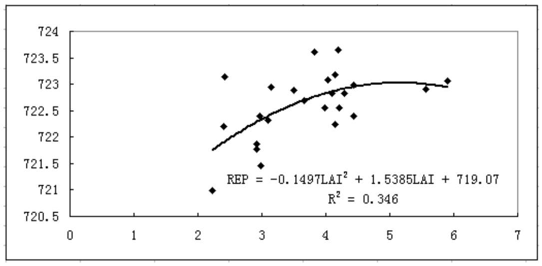

Figure 1: LAI Versus REP

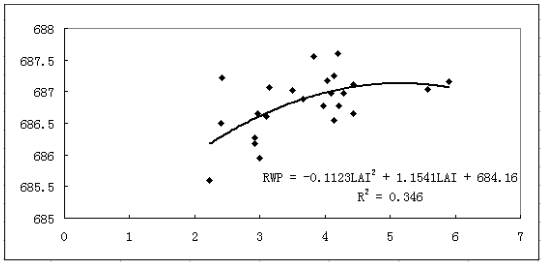

Figure 2: LAI Versus RWP

As can be seen from figure 1 and figure 2, both red edge optical parameters (REP and RWP) correlate well with the ground measured LAI data (the best fitted empirical statistical models are listed in equations 6-7). For REP, the function form and the highest R^2 of the best fitted empirical statistical model is the same as the RWP, possibly due to the fact of RWP is a function of REP [12]. As figure 1 and figure 2 show, the highest R^2 for REP and RWP is 0.346, not very high, which may be explained by the discrepancy between image acquisition time and LAI collection time.

$$REP = -0.1497LAI^2+1.5385LAI+719.07 \quad (6)$$

$$RWP = -0.1123LAI^2+1.1541LAI+684.16 \quad (7)$$

5. CONCLUSION

In this study, two red edge optical parameters (REP and RWP) extracted from EO-1 Hyperion hyper-spectral data were employed to estimate forest LAI. The result shows both parameters perform well in LAI estimation. In the future, acquisition of hyper-spectral satellite imagery will become easier, and LAI estimation method based on the red edge parameters will be widely used in the remote sensing community.

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