Multiple-scale Hyperspectral Remote Sensing of Forest Biochemical and Biophysical Properties

（課程博士・様式７）（Doctoral qualification by coursework,Form 7）

学 位 論 文 要 旨

Abstract of Doctoral Thesis

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論文題目：

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論文要旨：

Abstract：

Accurate quantitative estimation of vegetation biochemical and biophysical characteristics is necessary for a large variety of agriculture, ecological, and meteorological applications. Remote sensing, because of its global coverage, repetitiveness, and non-destructive and relatively cheap characterization of land surface, has been recognized as a reliable method and a practical means of estimating various biophysical and biochemical vegetation variables. The advent of hyperspectral remote sensing has offered possibilities for measuring specific vegetation variables that were difficult to measure using conventional multi-spectral sensors.

Utilizing hyperspectral measurements, we examined the performance of radiative transfer models inversion techniques versus spectral indices approaches for predicting biochemical and biophysical vegetation properties such as chlorophyll, leaf water, leaf mass content and leaf area index (LAI) from leaf to canopy scale in two typical vegetation types (temperate deciduous and desert forests). It was concluded that, at leaf scale, for transfer model inversion approaches, retrieval of biochemical parameters generally faces “ill-posed” problems, which dramatically decreases the estimation accuracy of an inverse model, and this problem can be much improved by designed new model inversion algorithm and make the model inversion obtaining a better estimating accuracy. The models need calibration using the local *in situ* measurements before inversely the models to retrieval biochemical parameters, especially for the desert vegetation. After careful calibration, both LIBERTY and PROSPECT are applicable for estimation leaf biochemical parameters inversely for all datasets collected from both temperate deciduous and desert forests. For spectral indices approaches, using a simulated data set generated from a mechanistic reflectance model like PROSPECT which can represent a vast range of leaf reflectance spectra to identify general spectral indices for estimating biochemical parameters is the best method in present. However, the spectral indices indentified from simulated dataset should be calibrated and validated using field measured datasets. The results from simulated dataset and field measured dataset are not always consistent, so the best efficient spectral indices should

be trade-off between simulated and measured data sets.

At canopy scale, vertical profiles of both biophysical and biochemical properties are one of the main sources of heterogeneity within a vegetation canopy, and these vertical variations are the major factors controlling canopy reflectance. Using homogeneous canopy reflectance models for calculating reflectance from a vertical heterogeneous canopy may lead to systematic errors. Hence, a computationally efficient model, the multiple-layer canopy radiative transfer model (MRTM), has been developed with the focus on the effect of canopy vertical heterogeneity on canopy reflectance. The results of validation with field measured datasets indicated that the MRTM performed better than the other homogeneous canopy models. The MRTM may help to effectively retrieve the vertical distribution of biophysical and biochemical parameters inversely. In addition, the estimation of canopy characteristics such as LAI using hyperspectral remote sensing, for vertical heterogeneous canopies has not been addressed by researchers yet. Therefore, the effectiveness of hyperspectral remote sensing in estimating LAI in a vertical heterogeneous canopy using spectral indices approach was examined in this study. The results indicated that the within-canopy vertical variations in LAI and biochemical properties significantly complicate the retrieval of LAI inversely from published spectral indices. Thus, it is critical to identify a new spectral index for estimating LAI that insensitive to the vertical heterogeneous within the canopy. The method of finding the best spectral indices for estimating LAI is using simulated datasets based on the multiple-layer radiative transfer model (MRTM) and validating with field measure dataset. The MRTM model has proven to be efficient in the finding of indices that insensitive to the vertical heterogeneous within the canopy. The best index for estimating canopy LAI under various conditions was D(920,1080). This index responded mostly to the quantity of LAI but was insensitive to within-canopy variations, allowing it to aid the retrieval LAI from remote sensing data without prior information of within-canopy vertical variations of LAI and biochemical properties.

In summary, the study contributes to the field of information extraction from hyperspectral measurements and enhances our understanding of vegetation biochemical and biophysical characteristics estimation. Several achievements have been registered in exploiting spectral information for the retrieval of vegetation parameters using physical (radiative transfer models) and statistical (spectral indices) approaches. These concern the successful implementation of radiative transfer models inversion (with extensive validation) and the derivation of new vegetation indices, which involved the development of a new model inversion algorithm, a new canopy multiple-layer model, and a new spectral indices developed method based on both simulated and field measured datasets. The future of hyperspectral remote sensing could hinge on enhancing the link between statistical and physically based approaches.