Methodology for Regional Forest Biomass Estimation Using MODIS Data

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Abstract: Forest biomass is the basis of forest ecosystem. With the rapid development of remote sensing and computer technology, forest biomass estimation using remote sensing data is paid great attention and has acquired great achievements. This article focuses on discussion of methods of forest biomass estimation methods using Terra/MODIS data in Northeast China. The research include: combining the MODIS time series parameters with seasonal characteristics of forest species to identify major forest species; establishing a model to estimate forest biomass based on forest species; analyzing the effects of the existent forest biomass and increasing biomass on terrestrial carbon cycle. This research can help to make clear the mechanism of carbon cycle.
Keywords: MODIS Data, Time Series, Species Discrimination, Biomass Estimation.

1. Introduction

Forest ecosystem is a major terrestrial carbon reservoir in the global and region carbon cycle. Forest biomass is defined as the total amount of dry weight of forest trees per unit area of land at any time. The quantity of tree biomass per unit area of land constitutes the primary data needed to understand the flow of materials and water through forest ecosystem. Forest biomass is key variables in our understanding of carbon exchange between biosphere and atmosphere, both currently and under climate change conditions.

Since the plot-based forest biomass studies in the International Biological Program (IBP) in 1960-1970s, inventory-based forest was recently estimated at regional and national levels and then further calculations of carbon stock were performed. Model-based simulations of regional to global forest biomass, NPP and carbon have significantly improved in the past decade and remote sensing programs provide the opportunity to optimize the connection of remotely sensed data with key parameters in measuring and modeling forest biomass and NPP [1]. Though having made certain research achievements, there is an increasing need to improve the accuracy of the estimation of biomass as they determine the actual amount of carbon that reaches the atmosphere. The improvement of forest type classification accuracy is a guarantee of the accuracy of biomass estimation. Remote sensing technology has the potential to reduce some of the uncertainty in the estimation and mapping of aboveground carbon and biomass. This article focuses on approaches study for forest biomass estimation based on the classified forest species using Terra/MODIS data in Northeast China.

2. Methodology

1) MODIS Characteristics for vegetation classification

With the successful launching of the new generation satellites of EOS Terra and Aqua, their Moderate Resolution Imaging Spectroradiometer (MODIS) data, which designed for studying vegetation and land surfaces, has a number of advantages over AVHRR, including more spectral bands that are related to vegetation. MODIS has 2 channels of 250m spatial resolution, 5 channels of 500m spatial resolution and 29 channels of 1000km spatial resolution [2]. This can give more spatial and spectral details of the vegetation information. The Terra-AM and Aqua-FM can increase the temporal resolution. With the improvement of spatial and temporal resolution, MODIS data supply more detailed vegetation character and has more widely use in identifying forest cover types.

2) Identifying Forest Species Using Time Series Data

Timely and accurate information on forest types at the regional scale is needed for natural resource management and carbon cycle studies. The methods used to determine forest species composition vary with both the requirements for a specific application and the cost and availability of data. Satellite-based remote sensing products provide one option to meet needs. A number of earlier studies have used Landsat TM images to document forest types and changes. Because of frequent cloud cover and the long re-visit time (16 days) of Landsat, it is difficult to acquire cloud-free images for monitoring the changes in forest types at short-term intervals. NOAA/AVHRR and new generation Terra/MODIS sensors with high temporal resolution can provide time series for vegetation classification [3].

NDVI is sensitive to the presence of green vegetation and provides an indication of the "greenness" of the vegetation. The fluctuation of NDVI reflects the seasonal variation of the growing vegetation. The dynamic range of fluctuation of NDVI of a specific vegetation cover always varies within a certain range, which implies that the abnormity of the range of the NDVI fluctuation would indicate the shift between the vegetation covers. Seasonal changes in the greenness of vegetation, described in remotely sensed data as changes in NDVI throughout the year, have been the basis for forest type discrimination [4]. Based on monthly NDVI temporal profiles, Ruth DeFries and Townshend validated the deciduous and evergreen vegetation, needleleaf and broadleaf vegetation can be

distinguished [5]. Fig.1 shows NDVI temporal profile of vegetation. By analyzing the time series curve, the following characteristic parameters for distinguishing vegetation type can be derived.

Maximum NDVI: It provides an index of the greenness of the vegetation at the time of peak greenness.

Mean NDVI: The mean NDVI indicates the overall greenness of the vegetation throughout the year.

NDVI threshold: The NDVI threshold indicates the greenness of the vegetation occurring at the onset of the growing season. The beginning of the growing season is defined as the time of the greatest rate of change in NDVI between consecutive months t and t+1. NDVI threshold was taken to be the NDVI value at time t. NDVI threshold can potentially be used, for example, to discriminate mixed deciduous and evergreen forests from both broadleaf deciduous forest and coniferous evergreen forest. The NDVI threshold, coupled with maximum NDVI, was then used to derive various other seasonal parameters.

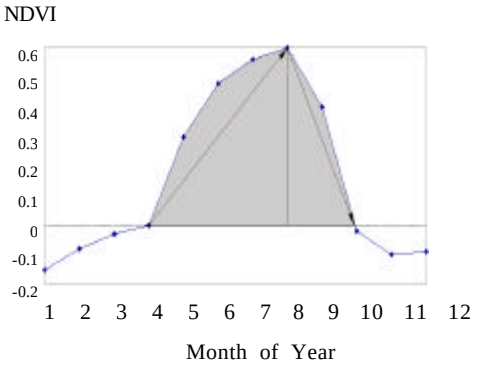

Fig.1. NDVI Temporal Profile of Vegetation

Different forest type has different NDVI characteristic parameters. So based on NDVI time series curve, the forest cover types, like conifer versus deciduous stands can be distinguished. But remote sensing data alone is not enough for forest species discrimination. The related knowledge like topographic information and forest species phenological character of study area must be fused with the time series profiles of remote sensing images. Using such time series profiles, the forest species discrimination may be based either on a parameterization of the NDVI profile and a subsequent discrimination based on the parameters computed or on the use of simple phenological criteria, These phenological criteria, like the minimum, the maximum, or the dynamic of NDVI, have the advantage of having an ecological signification and to be consequently more robust.

In this paper, MODIS NDVI time series curve was established. The phenological calendar of major forest species was investigated and positioned. Topographical data of study area was used to add auxiliary information. After integrated analysis of several layers data, the classification threshold of different forest species was confirmed. According to the threshold, forest species were identified using suitable classification method.

3) Biomass Estimation Based on Forest Species

The biomass of forest can directly reflect the variety and the way the forest is growing. Forest species have difference in contribution of carbon fluxes. In previous research, forest biomass was estimated based on coarse forest types and few were carried out according to forest species, especially in regional scale. This article focuses on studying the different increasing biomass because of species difference. Two typical forest species were selected as study cases. In this paper, a new method to estimate the biomass of conifer-dominated boreal forest would be developed. It aims to provide accurate estimation values of forest biomass. First, the principal models are computed using ground measurements and high spatial resolution satellite images, Landsat TM data. Spectral models are then applied directly to a calibrated MODIS image mosaic covering the entire area of interest. The biomass estimation was validated by Chinese National Forest Inventory data from State Forestry Administration, P. R. China.

4) Research Framework

According to above discussion, the technology processing for estimation of biomass based on forest species include four basic procedures:

(1) Analyzing the MODIS time series profiles, phenological character and distribution of major tree species. Then selecting characteristic spectrum bands of forest species information.
(2) Classification of forest species.
(3) Estimating of biomass based on classified forest species.
(4) Validation of forest type classification and forest biomass estimation.

Fig.2 shows the processing flow of research.

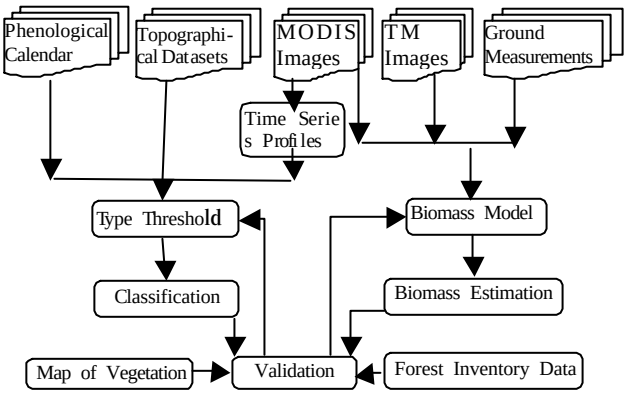

Fig.2. Processing Flow Chart of Research

3. Data and Case Study

1) Terra/MODIS data

The MODIS 16-day NDVI composites of 500m resolution from Feb 18, 2001 to Dec18, 2001 were used to characterize the spatial-temporal dynamics of the land surface. All the datasets are processed using the noise filtering, and the MVC (Maximum Value Composite)

processing. The twenty bands from the composite data were stacked into one image. Fig.3 shows the MODIS NDVI composites of Northeastern China.

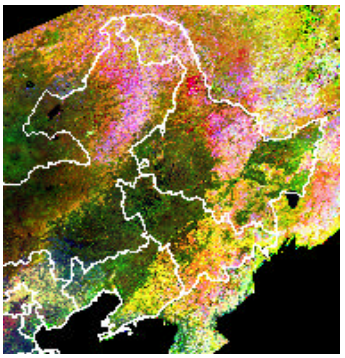

Fig.3. Twenty Bands of MOD13A1 500m 16-day Composite of Northern China (RGB-band 7, 15, 21)

2) Study Area

Northeastern China has abundant tree species and a variety of forest types, including evergreen needleleaf forest, deciduous needleleaf forest, deciduous broadleaf forest, and mixed forests. The dominant species is larch (*Larix gmelinii*), birch (*Betula platyphylla*), pine (*Pinus sylvestris var. mongolica*) and oak (*Quercus mongolica*). Because evergreen and deciduous forest species coexist in Northeastern China. It can be easily distinguished using time series data in whole year. So we choose this area as the study case to research the methodology of classification of forest species and estimation of forest biomass.

3) Preliminary Research

According to the NDVI composite data, the time series profiles of different vegetation types were established (Fig.4).

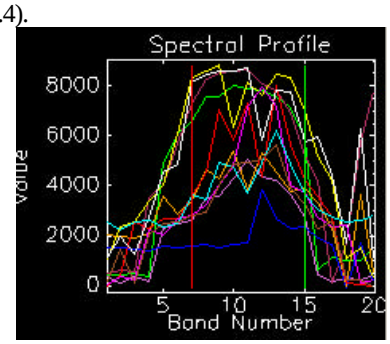

Fig.4. Time Series Profiles of multiple vegetation types

After analyzing the profile curves, considering simple criteria like the minimum, maximum, and dynamic of the NDVI, the threshold of vegetation discrimination was acquired. Based on the threshold, the forest type map of Northeastern China was acquired using unsupervised classification method (Fig.5).

The classification cannot meet needs of identifying forest species because we did not collect enough phenological calendar information of major forest species and topographic character of study area. In the future work, the detailed classes will be acquired and biomass model based on forest species will be established.

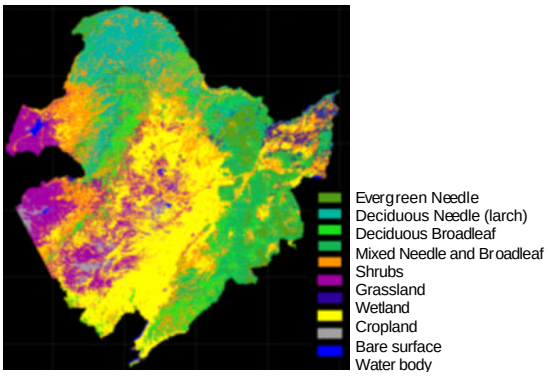

Fig.5. Classification Map of MODIS 500m 16-day NDVI Composite of Northeastern China

4. Conclusion Remarks

This paper discussed the possibility and feasibility of forest biomass based on forest species using MODIS data and phenological data. Theory and correlated experiments indicated MODIS data is used for type classification and estimation of forest biomass. But the classification and estimation require additional information of high-resolution remote sensing data and auxiliary investigation data. This study provided a new methodology of aboveground forest biomass using Terra/MODIS data and is useful for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions.

Acknowledgement

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