FOREST ABOVEGROUND CARBON MAPPING USING MULTIPLE SOURCE REMOTE SENSING DATA IN THE GREATER MEKONG SUBREGION

Pang Yong, Li Zengyuan

Institute of Forest Resource Information Technique, Chinese Academy of Forestry, Beijing 100091, China
Email: pangy@ifrit.ac.cn

ABSTRACT

The Greater Mekong Subregion (GMS) is rich in forest resources. It is important to estimate forest carbon with high accuracy methods in this region. Remote sensing is an efficient way to estimate forest parameters in large area, especially at regional scale where field data is scarce. LIDAR provides accurate information on the vertical structure of forests. In this study, the forest carbon was estimated at ICESat GLAS footprint level after being trained with field measurements and airborne lidar estimations in GMS. According to different types of ecological zones, a set of categorical regression models was built between ICESat GLAS estimates and ENVISAT MERIS spectral variables together with MODIS VCF product. Then the forest carbon map with continuous value was generated. The estimation agreed well with FAO FRA 2010 report and other published results, and the average difference was about 13.3%.

Index Terms—*the Greater Mekong Subregion, forest aboveground carbon, LiDAR, imagery remote sensing*

1. INTRODUCTION

Forests play an irreplaceable role in maintaining regional ecological environment, global carbon balance and mitigating global climate change. Forest aboveground biomass (AGB) is an important indicator of forest carbon stocks. Estimating forest aboveground biomass accurately could significantly reduce the uncertainties in terrestrial ecosystem carbon cycle. The Greater Mekong Subregion (GMS) is rich in forest resources, the change of forest resources affect the regional even global climate change.

It is important to estimate forest AGB with high accuracy methods in this region. Remote sensing is an efficient way to estimate forest parameters in large area, especially at regional scale where field data is scarce. LIDAR provides accurate information on the vertical structure of forests. Combining airborne LiDAR and spaceborne LiDAR for regional forest biomass retrieval could provide a more reliable and accurate quantitative information in regional forest biomass estimate.

Light Detection and Ranging (LiDAR) is one of the most promising technologies for retrieval of various forest biophysical properties (Lefsky et al., 2007). Although airborne LiDAR can estimate tree height with sub-meter vertical accuracy and spatial resolution but its utility is limited in large area for its high cost (Boudreau et al. 2008). The first spaceborne large footprint LiDAR sensor (ICESat/GLAS) acquired over 250 million LiDAR observations over forest regions globally and has been used successfully for forest height and biomass estimation in various sites (Lefsky et al., 2007; Boudreau et al. 2008; Duncanson et al., 2010; Pang et al., 2011). Nelson et al. (2009) used optical data from the MODIS and waveform data from ICESat/GLAS to estimate timber volume in Central Siberia. The encouraging result showed that GLAS and MODIS data can be used to develop accurate regional estimates of timber volume.

In this paper, airborne LiDAR and ICESat/GLAS data were used to estimate forest aboveground carbon at footprint level in the Greater Mekong Subregion (GMS) and a continue forest carbon map was generated by combined optical data and LiDAR estimated carbon samples.

2. STUDY SITE AND DATA

The area of the GMS ranges from 92.2° to 113° east longitude and 5° to 29.2° north latitude. It includes Cambodia, the People's Republic of China (Yunnan province and Guangxi province), Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam.

The project area has a diverse geographic landscape including massifs, plateaus and limestone karsts, lowlands, fertile floodplains and deltas, forests (evergreen and semi-evergreen, deciduous, dipterocarp, mangroves, and swamp), and grasslands. The region's geographic variety and consequent variety of climatic zones supports significant biodiversity, with more than 1068 new species discovered during the last ten years. The geographic region encapsulates 16 of the WWF Global 200 ecoregions. The region's biodiversity is ranked as a top-five most threatened hotspot by Conservation International. High forest coverage and rich forest resource result in large amounts of wood export from this region. The WWF states that the region is particularly vulnerable to global climate change.

The ICESat (Ice, Cloud, and land Elevation Satellite) GLAS (Geoscience Laser Altimeter System) data from 2004 to 2006 were used. 500 field plots centered with GLAS footprints were measured for forest carbon calculation purpose.

MODIS Vegetation Continuous Field (VCF) (MOD44B) product of 2005 was used for extending the GLAS estimates (Hansen et al., 2003). The VCF product shows the coverage of vegetation such as "forest" or "grassland" exists in each pixel. Globcover Land Cover product of ENVISAT MERIS is 300 m resolution with a legend defined and documented using the UN Land Cover Classification System (LCCS) (Defourny et al., 2006). The product has 22 different land cover classes at the global level (Defourny et al., 2006). Class ID for 40, 50, 60, 70, 100, 110 and 120 were defined as forest covers in this study. The GlobCover Land Cover product of central Asia for the period from Dec., 2004 to Jun., 2006 and GlobCover Annual MERIS FR mosaic product which computed by averaging the surface reflectance values of these bimonthly products generated over the year 2005 were used in this study.

3. METHODOLOGY

A forest aboveground carbon (AGC) method was developed for this campaign. This framework uses field measurements to calibrate airborne Lidar data. This will provide a spatial distributed forest carbon at Lidar coverage scale. Then this discrete carbon will be fused with imagery remote sensing data.

As there are over 160 forest species in this region, we divided these forests into four types, which are evergreen needle-leaf forests, evergreen broad-leaf forests, bamboo forests, and other forests. Then the differences of carbon estimation using airborne lidar data among different forest types were compared and analyzed. The hyperspectral data were used to discriminate these four forest classes. Then forest carbon was estimated using lidar matrix from ALS data and forest types from hyperspectral data.

Then the regression tree method was used to extend the AGB estimation from ALS strips to continuous mapping using Landsat 8 OLI data. According to different types of ecological zones and forest types, a set of categorical regression models was built between ALS estimates and optical spectral variables.

4. RESULTS

4.1 Produce forest carbon storage map

According to different types of ecological zones, a set of categorical regression models was built between ICESat GLAS estimates and optical spectral variables. The cubist software was used for regression tree analysis (Pang et al., 2011). The MAXENT software was used for maximum entropy analysis (Philips, et al, 2006; Saatchi, et al, 2010). Both methods gave similar spatial pattern of forest carbon distribution. We fused these two estimations as the estimated carbon product as shown in Fig. 1.

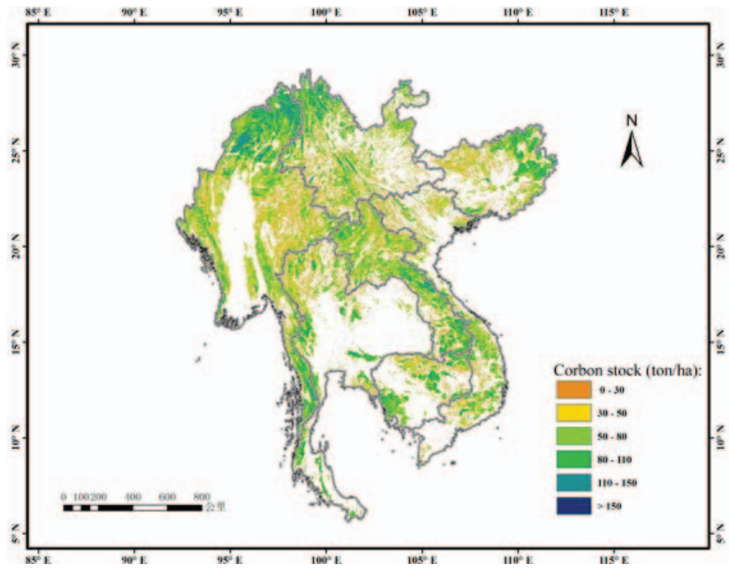

Fig. 1 Forest carbon estimation in the GMS

As shown in Fig. 1, the high carbon density forests are mainly distributed in the Northern Myanmar and the Northwest Yunnan, the Northeast of Guangxi, border regions of Myanmar-China-Loas and the southern part of Myanmar-Thailand, the center and south of Laos and border regions with Viet Nam.

4.2 Compare forest carbon storage map with other reference data

The total estimated carbon stock by remote sensing in study area was 10, 165 million tons. This estimation was comparable with FRA2010 report, whose carbon stock value was 10, 207 million tons. The Global Forest Resources Assessment (FRA) 2010 report estimations are from each country's report, which was based on traditional ground inventory method (FAO, 2010). The estimation of Yunnan and Guangxi of China was based on the data of the 7th National Forest Inventory during 2004-2008. As this data are from two different estimation methods, this comparison provided an independent data evaluation.

Then we compared these two carbon values at country/economy level as shown in Figure 2. In these seven economies, these two estimations had good linear relationship which was close to 1:1 line. For different economies, the remote sensing estimation showed different bias direction when comparing with FRA estimation. For Myanmar and Guangxi-China, remote sensing estimations indicated larger carbon stock. For Viet Nam, remote sensing estimations indicated less carbon stock. The other four economies showed remote sensing estimations were close to FRA values. The average difference was about 13.3%.

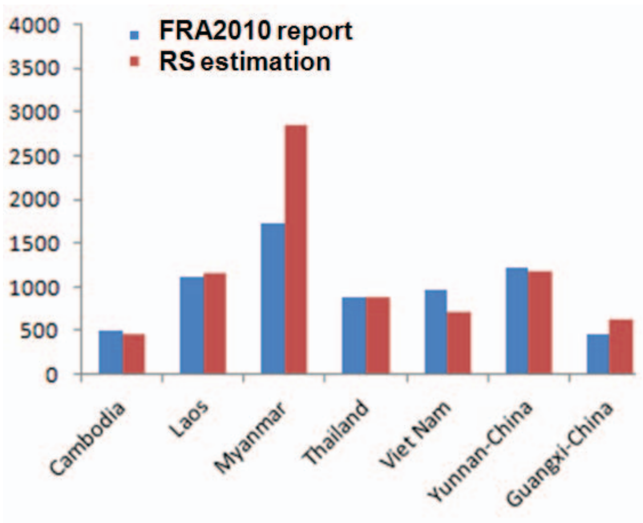

Fig. 2 Comparison of estimated forest carbon with FRA2010 (million ton) at economy level (The estimation of Yunnan & Guangxi was from the 7th National Forest inventory of China)

5. DISCUSSION & CONCLUSIONS

Regional forest carbon was estimated by combining airborne LiDAR, spaceborne LiDAR of ICESat/GLAS and optical remote sensing data. To conclude, the result of this study is encouraging that ICESat/GLAS can estimate forest aboveground carbon successfully in regional scale which described the amount and distribution of forest AGB well in the study area. With the recent available middle resolution remote sensing data such as ALOS PALSAR mosaic product and Landsat VCF product, a finer spatial resolution carbon map is becoming feasible at regional resolution.

6. ACKNOWLEDGEMENT

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