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Estimating aboveground teak plantation forest biomass using remotely sensed data in Cianjur, Indonesia

○ Arief Darmawan, Satoshi Tsuyuki (Agric. and Life Sci., the Univ. of Tokyo), and Lilik Budi Prasetyo (Bogor Agric. Univ.)

1. Introduction

In the tropical region, natural forest degradation not only has made the capacity of natural forest as carbon storage highly decreased, but also has contributed to massive greenhouse gas emission into the atmosphere. Reforestation is needed as a mitigation option to reduce the increase of atmospheric CO_2 and predicted climate change. Teak (*Tectona grandis*) is the main forest product of Java Island. Despite its high economic value, teak forests play an important role in carbon sequestration and should be considered as important species for reforestation in Indonesia. This study aims to estimate aboveground biomass in stand-level information of teak plantation using multispectral remotely sensed data coupled with forest register and field observation.

2. Materials and methods

Landsat TM on May 27th 1992 and September 14th 1997, Landsat ETM$^+$ on May 12th 2001, forest register of 2001 inventory, and sub-compartment map were acquired. Ground truths and field sampling were conducted to construct the local biomass allometry. Biomass density estimation was limited to older plantations than 5 years. Multiple regression analysis was performed between the satellite variables (i.e. vegetation indices, tasseled cap, satellite reflectance) and sub-compartment variables (i.e. average girth and stand density) derived from forest register. Then, constructed models were applied to the satellite data for generating the spatial explicit biomass density map of teak plantation in Cianjur Forest Management Unit (FMU).

3. Results and discussion

Bulk correction using dark object subtraction was performed as radiometric correction. During topographic correction, the Modified Minnaert Correction was proved better in correcting topographic effects than the previous Minnaert Correction. Teak plantation was identified using maximum likelihood classification and found to be 86.15% accuracy for teak cover and 83.43% overall accuracy. Satisfactory result by NDVI differencing method was obtained during misclassification removal of teak coverage derived from maximum likelihood classification. This analysis was carried out based on defoliation event of teak tree during dry season.

Local biomass allometric equation used in this study was biomass (kg) = $0.0056 \times \text{girth}^{2.5526}$. This equation was resulted from the power regression of 44 trees by multiplying local volume equation (height × basal area × 0.7) to wood density factor (0.55). Better result was obtained by comparing RMS error to the existing biomass allometry of teak in India and Panama. Biomass density of each forest sub-compartment was calculated using forest register information (i.e. average girth, stand density) employed to the equation.

Individual relation between sub-compartment stand biomass density and average satellite variables within sub-compartment showed low correlation. Thus, two multiple regressions was performed to stand average girth and stand density. Initially, satellite variables in multicollinearity were removed. As a result, B1/B3 ratio, NDVI, SVI, and B5 were selected as predictor variables in multiple regression analysis. Validation was made by applying the model to 63 different sub-compartments that were not used in the model construction. Better results were attained for stand average girth model and stand density model with r^2=0.49 and r^2=0.62 by validation respectively. To improve the accuracy, plantation age class and average height were included into the analysis with the assumption that age classes and height can be detected using multitemporal optical and active remote sensing data respectively. Validation accuracy (r^2) increased to 0.83, 0.79, 0.75 and 0.83 for average girth equation incorporating 3 years, 5 years, 10 years age class and average height respectively. Whereas, validation accuracy also increased to 0.79, 0.78, 0.77 and 0.78 for stand density equation incorporating 3 years, 5 years, 10 years age class and average height respectively. Biomass density map based on average girth and stand density as well as incorporating 3 years age class, 5 years age class, 10 years age class and average height were developed. Aboveground carbon sequestration map of teak plantation was also created given that carbon storage was derived by multiplying biomass to carbon concentration which is about 49.5%.

4. Conclusion

From this study, biomass density distribution of teak plantation in Cianjur FMU could be defined. Total estimated biomass was 247,157 tons which contains 122,343 tons carbon in 2,524 ha of teak plantation older than 5 years with biomass density ranging from 11.9 t/ha to 364.6 t/ha. This result will be important as basic information to evaluate the importance of teak plantation in carbon sequestration as well as in estimating carbon budget and flux within teak plantation forest for the future usage. Moreover, since satellite data is easily available for every part in the world, there is a possibility to expand this method to all teak plantations in Java Island. Thus, improvement should be made for future analysis such as utilizing latest and more consistent optical remote sensing data, combining active remote sensing data, and accurate ground measurement.

(Correspondent: Arief Darmawan, arief@fr.a.u-tokyo.ac.jp)