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FIELD NOTE

Correlation analysis between Enhance Vegetation Index and Wood Volume in Thua Thien Hue Province, Vietnam

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ABSTRACT REDD + in developing countries needs to estimate forest carbon stocks and above ground biomass. Remote sensing has been widely used for monitoring of vegetated area using the satellite-derived vegetation index since vegetation indices are thought to have high correlation with above ground biomass or vigor of vegetation. However, these satellite-derived vegetation indices are still doubtful whether they are available for REDD + in any types of forests such as forests with different species. We studied the relationship between wood volume data obtained by field survey and the time series of MODIS EVI data to check whether the above ground biomass in different forests with different species could be accurately estimated from satellite remotely sensed data. This paper presents the different correlation for different forests. Our analysis illustrated the correlation between annual wood volume and annual average EVI using a simple linear regression. The regression equation for Forest 1 was Y = 249.02x + 37.474; R^2 = 0.82; N = 22 and for Forest 2 was Y = 668.3x-258.61; R^2 = 0.80; N = 15, and R^2 = 0.0285; N = 15 for forest 3 which mixed more than 7 species, respectively. These different correlations are strongly correlated with composition of species in different forests. The forests with a few tree species had high correlations, while the forest mixed with many species of trees had low correlation. The composition of tree species in forests is an important characteristic for estimating above ground biomass of forests using remote sensing data.

Key words: REDD + , wood volume, MODIS EVI, CO_2, species

INTRODUCTION

Levels of wood volume and woody biomass are important indicators of the potential of forests production and carbon stock in forests. Changes in wood volume and biomass result mainly from area changes of forests or forest degradation. Amount of forest biomass per hectare could be calculated based on the volume statistics and information on wood density. However, reliable national-level data on wood volume and biomass of forests in developing countries were not available in the world (FAO 2000), because field inventories even in local forests needs high labor cost and they are very much time consuming. In the most of the developing countries, the national-level wood volume has been estimated based on the insufficient data of the national forest inventories.

In Vietnam, there have been very few studies about forest carbon stock and forest change. *Netherlands Development Organization* (SNV) made a map of forest biomass carbon stock using Moderate Resolution Imaging Spectorradiometer (MODIS) in the 2nd phase of REDD + (Reducing Emissions from Deforestation and forest Degradation and the role of conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks) readiness, in order to provide a potential map for REDD + (Holland and McNally 2009). In the Central Highlands, the biomass and carbon stocks were estimated in evergreen, semi-evergreen and deciduous forest (Hai et al. 2013, Huy et al. 2012). Trường (2012) determined carbon stocks from 6 dominant species *Dipterocarpus tuberculatus*, *Dipterocarpus obtusifolius*, *Shorea roxburghii*, *Shorea siamensis*, *Terminalia corticosa* and *Terminalia triptera* in different status of Khop natural forest in Gia Lai using field measurements. The biomass and carbon stocks of three pine plantation species (*Pinus massoniana; P merkusii; and P. keysia*), three Acacia species (*Acaciamangium; A. auriculiformis; A. hybrid (mangium x auriculiformis)*), and *Eucalyptus urophylla; and Mangletia glauca* were estimated by Hai et al. (2010) and Phuong et al. (2010). The Ministry of Natural Resources & Environment (MORNE) estimated only the CO_2 emission based on the information on land use, land cover and the data of forest field measurement (MONRE 2010).

The forest field measurement in large scale is too difficult to implement because it requires so high labor cost and it is much time consuming. Furthermore, the Ministry of Agriculture and Rural Development (MARD) and the Ministry of Natural Resources & Environment (MORNE) do not have any consistent methodologies to retain, provide and use data on forest biomass, land use and conserve land use (Angelsen et al. 2012). Even in the forest sector, the Forest Inventory and Planning Institute (FIPI), the Forest Protection Department (FPD) and the Department of Forestry (DoF) independently collect data on forest status, forest management, owners and annual forestry activities. Moreover, all of the DoF, FPD, FIPI, Forest Science Institute of Vietnam (FSIV) and Vietnam Forestry University (VFU) are separately maintaining and managing the forest database. Consequently, they lack a consistent method for estimation carbon stocks due to their different approaches and skills.

Thus, there is prompt need to develop methods which help to fast and robust evaluation of wood volume in Vietnam on a large scale to support Monitoring, Reporting and Verification (MRV) for REDD + projects. These results will help to build model equations to estimate carbon stock in specific forests to allocate money to local people based on increase of forest carbon stock. Carbon stock in forests can be estimated by the estimation of wood volume of forests. Wood volume estimation is a part of biomass estimation.

Tucker (1983) reported that the dry matter production of grass in Senegalese Sahel had high co-relationship with integrated vegetation index (NDVI) derived from satellite remote sensing data. As the dry matter in the forest is a function of wood volume, we thought that the integrated vegetation index which is MODIS EVI (Enhanced Vegetation Index) in this paper, would have a high co-relationship with wood volume in the forest of Vietnam, too. EVI was developed by Huete et al. (1997) to reduce the atmospheric effects from the satellite remote sensing data. EVI is superior to NDVI (Normalized Difference Vegetation Index.

In order to estimate wood volume in specific forest to support for REDD + project, this paper aims, 1) to assess the correlation between annual average EVI and wood volume in three different types of forests in Thua Thien Hue province, Vietnam, and 2) to infer the important characteristics of forest to apply remote sensing data to estimate wood volume.

METHODS

Study area

For the study, we selected the research areas in Thua Thien Hue province, since efficient data of field survey are available. They are located in the central Vietnam at latitude 16°19' North and longitude 107°34'East (Fig.1). As this province is located in the tropical cyclone belt in Vietnam, they have a plenty ofannual precipitation more than 3000 mm and a wide variety of forest types.

The forest investigation in Thua Thien Hue was conducted in 2011 by the Centre for Planning and Design on Agriculture and Forestry, a sub-department of DARD (Department of Agriculture and Rural Development). The method of forest investigation which was standardized by the inventory for Forest Allocation Program was used. It is named NFIMAP Methodology (FAO 2015). Under this Forest Allocation Program, totally 10,266 ha of forests as inventory area were allocated in this province as standard sample plots to represent typical forests. One sample plot is 500 m × 500m and has 40 sub-sampling plots which are arranged in L-shape lines: 20 sub-sampling plots along longitude and 20 sub-sampling plots along latitude. One sub-sampling plot was 25 m × 20m or 20 m × 25 m. Heights, the DBH (Diameter at Breast Height, 130 cm high), and the name (species) and characteristics of all trees over 6 cm of DBH were measured in all of the sub-sampling plots in a standard sample plot. Recorded data of 40 sub-sampling plots were processed and averaged to represent that standard sample plot (FAO 2015).

Three study areas were selected considering varieties of forests in this province. They are typical three types of forests in this area, forest 1, forest 2 and forest 3. They could have varieties of the average wood volumes and composition of tree species since they distribute in different ele-

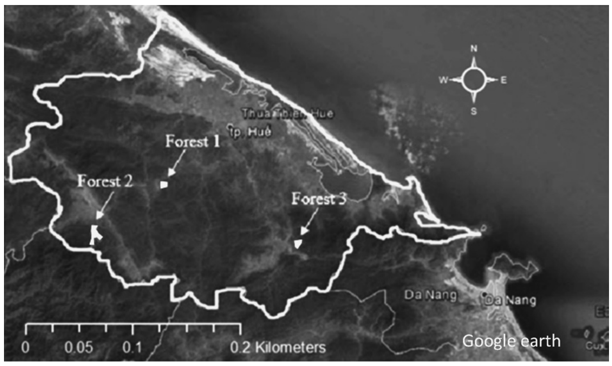

Fig. 1. Study area of three types of forest, Thua Thien Hue province.

vation zones and have different climates. The study areas shown in Fig.1 are standard sample plots in each type of forest. Fifty and two sample plots were selected to be analyzed in this research.

Forest 1 is located in mountainous area from 650 m to 1200 m in elevation. Forest 2 is in hilly area from 300 m to 500 m in elevation. Forest 3 is in low land area from 120 m to 260 m in elevation. We selected several sample plots in each type of forests; forest 1 had 22 sample area, forest 2 and forest 3 had 15 sample plots, respectively, as considering representativeness of the main different dominant species, different elevation zones and different wood volume. The outlines of each forest type: forest 1, forest 2 and forest 3 are summarized as described below.

The dominant species in forest 1 are Cơi (*Pterocarya tonkinensis*), Dẻ đá *Quercus rubertris,* Trâm sắn (*Syzygium polyanthum*), and Trám trắng (*Canarium album*). *Pterocarya tonkinensis* is a deciduous tree species with pinnate leaves from 20 cm to 45 cm long, with 11 to 25 leaflets. Its height is 10 m to 40 m tall. *Syzygium polyanthum and Canarium album* are evergreen tree species that grow up about 30 meters tall. The wood volume of forest 1 was from 105.9 m^3/ha to 184.8 m^3/ha. The forest 1 has an average amount of the forest biomass. In forest 2, the dominant species are evergreen trees including *Quercus bambusaefolia, Artocarpus hirta, Schefflera octophylla*, *Syzygium zeylanicum*. *Quercus bambusaefolia* and *Schefflera octophylla* are broad-leaved trees. While *Artocarpus hirta* is a big tree species that grows up to 25 meters tall and *Syzygium zeylanicum* is a small tree species that grows up to 12 meters tall. Regarding to the amount of biomass, forest 2 was poor. The wood volume ranges from 10.4 m^3/ha to 63 m^3/ha. The forest 3 is a mixed forest with more than 7 species such as *Pterocarya tonkinensis, Quercus kerrii, Syzygium zeylanicum, Enicosanthellum sp, Engelhardtiaroxburghiana, Hopea pierrei* and *Persica vulgaris*. The forest 3 has an average amount of the forest biomass. Its wood volume ranges from 37.5 m^3/ha to 59.7 m^3/ha.

Research data

Spatial data, non-spatial data and topographic maps were analyzed in this research. Spatial data were MODIS EVI and topographic maps. The reasons for use of MODIS EVI are as follows. A time series of MODIS EVI 16-day composite 250 m is embedded in MODIS/TERRA 13Q1, Vegetation Indices 16-day L3 Global 250 m Sin Grid V005. The EVI was developed to emphasize the vegetation signal in high biomass regions through decoupling of the canopy background signal and reducing atmosphere influences (Huete et al. 1997). The equation to compute is:

$$EVI = 2.5*(NIR-RED)/(NIR + 6*RED - 7.5*BLUE + L). \quad \text{(Eq. 1)}$$

Where, NIR: reflectance in near infrared band, RED: reflectance in visible red band, BLUE: reflectance in visible blue band, and L: a soil adjustment factor, usually 1.0 is used.

These data are expected to be very useful to describe the correlation between vegetation index and wood volume in the different type of forest. They can be used as an input data for estimating the carbon stock process to support forest monitoring.

Non-spatial data were wood volumes at three types of forests measured at the ground field surveys which were conducted in 2011 as described before. The wood volume was calculated in the following way (Eq.2) as following NFIMAP Methodology (FAO 2015). The individual tree heights measured in 40 sub-sampling plots were averaged to obtain the tree height of the standard sample plot. The average number of tree per ha in a sample plot was calculated by dividing the total number of trees in the 40 subsampling plots by the total area of the sample plots.

・Wood volume was calculated as follows

$$W = N \times G \times H \times F \ (m^3/ha) \quad \text{(Eq.2)}$$

Where:

・N: The average number of tree per ha in a sample plot
・$G = 3.14 \times d^2/4$: d means a diameter of measured tree (m).
・H : The average tree height (m)
・F = 0.45: The conversion factor to approximate wood volume from G × H.

Image processing and data analysis

This study area is covered by the MODIS tile h28v07. The MODIS tile indicates the data block location of MODIS productions such as the MODIS EVI dataset in the MODIS geolocation reference system, a kind of grid coordinate system. The tiles h28v07 indicates the location of the scene of this tile. The block of this dataset is located in the 28^{th} column and the 7^{th} row in this grid system. To assess correlation between enhance vegetation index (EVI) and wood volume in three types of forest, we conducted some of image processing to temporal MODIS EVI datasets and a simple linear regression between EVI data values and wood volume data for three types of forests shown in Fig. 2.

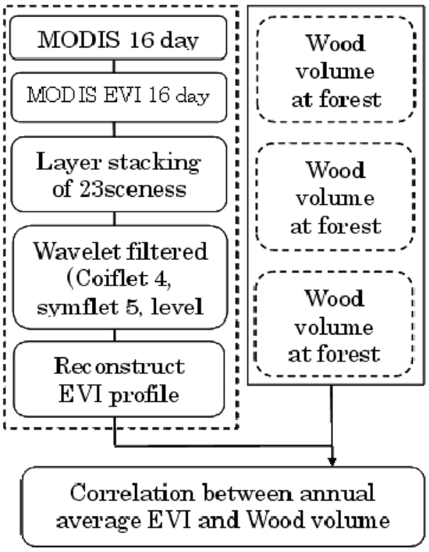

Fig. 2. Image processing and data analysis.

First, time series of MODIS images of 16-day composite 250 m datasets which were called MODIS/TERRA 13Q[1] Vegetation Indices 16-day L3 Global 250 m Sin Grid V005 for 2011, were downloaded from LPDAAC[1]. Twenty three scenes were downloaded. Second, the embedded EVI data of these dataset were extracted using the MODIS Reprojection Tool (MRT[2]), re-projected onto WGS84 using the nearest neighbour sampling algorithm and saved in the geotiff file format. The output pixel size was 0.00225 degree, which is equal to 250 m of ground resolution of a MODIS EVI pixel. Third, we converted this goetiff file format to the Erdas imagine software file format called an img-file. Fourth, the 23 img-files of the same scenes were layer stacked into one img-file. Since these sequential signals of MODIS EVI of each pixel were still contaminated by spiky noises mainly due to tiny cloud covers. Such noises should be removed and smoothed for better estimation. This finally stacked image was smoothed by de-noising process using the wavelet transform function as used in papers of Sakamoto et al. (2005) and Setiawan et al. (2011).

The noise reduction was processed using a Wavelet tool of a numerical computation software named Matlab (Mathworks Inc. 2013). For wavelet transformation to denoise signals, the Multi-signal Wavelet 1-D menu item was applied with default parameters.

At last, the annual average of EVI values was computed. According to Tucker et al. (1983), the total dry matter in grassland and the integrated NDVI (VI) were highly correlated. The average of integrated VI was almost same means as the integrated VI because the average of integrated VI was computed by dividing by twelve.

These annual average of EVI values of MODIS pixels which covered the sampling plots and the wood volume data of those sampling plots were analyzed.

RESULTS

The results show a fairly positive linear correlation between wood volumes of the 22 sample plots for forest 1 and 15 sample plots for forest 2 and the annual average integrated EVI values. It has a high coefficient of determination of $R^2 = 0.8206$, yielding the following equation,

$$y = 249.02x + 37.474. \quad \text{(Eq. 3)}$$

Fig. 3 shows the correlation between wood volume and annual average of EVI for forest 1.

Fig. 4 shows the remarkable linear correlation between wood volume of 15 sample plots and the annual average of EVI values. It also has a high coefficient of determination of $R^2 = 0.80$, yielding an equation (Eq. 4).

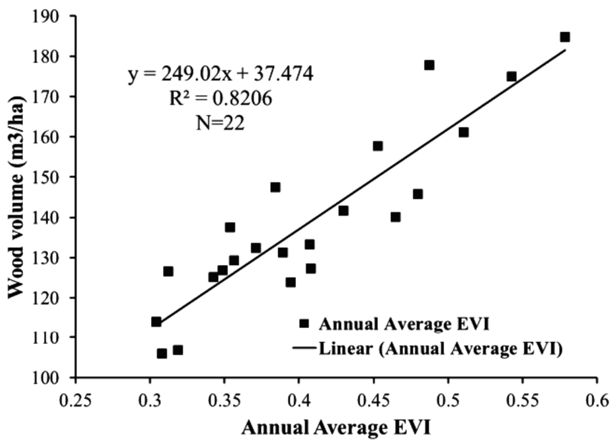

Fig. 3. Correlation between wood volume and annual average of EVI for forest 1 in 2011.

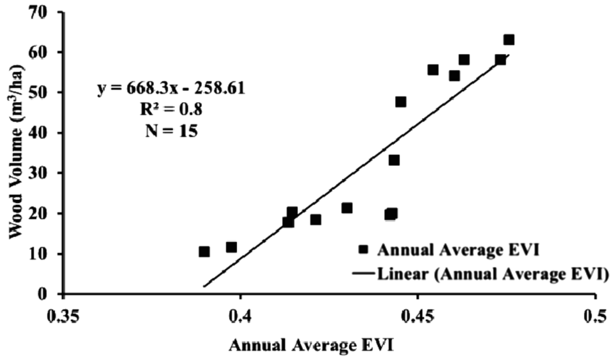

Fig. 4. Correlation between wood volume and annual average of EVI for forest 2 in 2011.

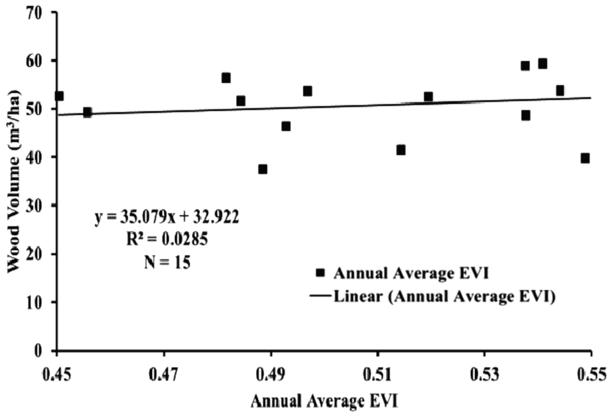

Fig. 5. Correlation between wood volume and annual average of EVI for forest 3 in 2011.

$$y = 668.3x - 258.61 \quad \text{(Eq. 4)}$$

Contrary, as seen in Fig.5, the result of forest 3 was different from former forests. Forest 3 is a mixture forest with more than 7 species. Fig. 5 showed a low correlation between wood volume and annual average EVI. The coefficient of determination R^2 was 0.0285 using with 15 sampling plots data yielding an equation (Eq. 5).

$$y = 35.079x + 32.922 \quad \text{(Eq. 5).}$$

DISCUSSION

Based on the results mentioned above, we discuss what are similar to and different from previous research and this study. Previous results showed a relationship between vegetation indices and above ground biomass and this research also resulted that enhanced vegetation indices are likely to be related to wood volume. This research showed that the annual average integrated EVI shows relatively high sensitivity to different forest types yielding high coefficients of determination R^2, for forest 1 and forest 2; they were 0.8206 and 0.80, respectively. However, the coefficient of determination R^2 for forest 3 was 0.0285. This finding reinforces the results of previous studies that showed a positive correlation between vegetation indices and above ground biomass. However, there is a difference between their results and the results of this research. The previous studies (Fu et al. 2014, Guyon et al. 2011, Muraoka et al. 2012, Das and Singh 2012, Feng et al. 2013) did not mention about different types of forests with different composition of tree species. The results of forest 3, which has many mixed species at the lowest elevation, showed low correlation. This finding clearly suggests that correlation between above ground biomass in forest and EVI depends on the composition of dominant tree species of forests. The composition of dominant tree species of forest is one of the important characteristics for estimating above ground biomass of forest with remote sensing data.

CONCLUSION

As a conclusion, the enhanced vegetation index (EVI) was associated with wood volume, but this relationship depends on the composition of the tree species in forests. The high positive correlations were observed in forest 1 and forest 2 with the number of dominant species around 4. On the contrary, for forest 3 with a mixture of many different tree species, it showed low correlation. These findings suggest that we have to take the composition of dominant species of the study forests into account, when we apply remote sensing data to estimate wood volume of forest.

Considering these findings and previous works conducted by many researchers, further studies are necessary to understand the functions of composition of species in different types of forests on remotely sensed vegetation indices for REDD + MRV.

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NOTES

[1] MODIS 13Q1 was downloaded from LPDAAC (http://e4ftl01.cr.usgs.gov/MOLT/MOD13Q1.005/)

[2] MRT was downloaded from (https://lpdaac.usgs.gov/tools/modis_reprojection_tool)

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