Relationship between vegetation indices and gross primary production in dry dipterocarp forest, western Thailand

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Abstract:
This study aims to investigate the relationship between the tower-based gross primary production (GPP) measurements and the satellite-based vegetation indices in dry dipterocarp forest). The study was carried out from September 2008 to March 2011. The results show that vegetation indices are strongly correlated to LAI and GPP. These indices also captured well the temporal variations of GPP during the measurement period. The coefficients of relationship between GPP and these indices were 0.88, 0.88, 0.85 and 0.88, for EVI, NDVI, MSAVI and SAVI, respectively. EVI has the strongest relation with GPP ($y = 14.63x + 0.13$, $R^2 = 0.80$) and therefore recommended as reliable proxy to derive the GPP for this forest.

Keywords: *Gross Primary Production; Flux Tower; MODIS; Remote Sensing; Vegetation indices*

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1. Introduction

One of the major uncertainties in global carbon cycle study is the current and future pool size of the forest carbon sink. The pool size is directly linked to the amount of carbon as CO_2 in the atmosphere. In recent years, continuous CO_2 measurements of flux between forests and the atmosphere at flux tower sites have allowed for a more detailed examination of Gross Primary Production (GPP) of forest ecosystems with the possibility to scale up the GPP from site to a larger spatial scale. (Aaron et al., 2011). With this regard, remote sensing is one of the upscaling techniques widely used. However, before being applied, validation with respects to forest type and variations in time and space need to be established. In this study, the use of various vegetation indices from Moderate Resolution Imaging Spectroradiometer (MODIS) were investigated for their relationships with GPP measured by eddy covariance towered and with the leaf area index (LAI) measured at the dry dipterocarp forest tower site. The objectives of this study are to determine whether there exists the relationship between remotely sensed data, gross primary production (GPP) and leaf area index (LAI) and to demonstrate the potential or limitation of using each vegetation index or leaf area index (LAI) in the CO_2 flux estimation in dry dipterocarp forest.

2. Material and methods

The study area is located in the King Mongkut's University of Technology Thonburi, Ratchaburi Campus, approximately 110 km southwest of Bangkok. The center coordinates for the site are 13° 35'13.3" N and 99° 30' 3.9"E. The forest at the study site comprises mostly regenerated dry dipterocarp forest resulting from local villagers who have cleared the land and used the forest for gathered timber and non-timber forest products. In 2008, most trees were 3-4 years old and the average height and girth was 4.6 m and 16 cm, respectively. The main tree species in this forest are *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtuse* and *S. siamensis* (Dipterocarpaceae) (Phiancharoen et al., 2008). Measurements of CO_2 flux above forest canopy have been continued since 2008. In this study, two sampling plots (300 x 300m) located nearby flux tower were made and these were used to for vegetation indices study based on MODIS data. Leaf area index (LAI) was measured by using LAI-2200 Plant Canopy Analyzer (LI-COR, USA.) in 12 sampling plots by systematic grid sampling. The LAI data were collected every 16 days from

December 2010 to March 2011. CO_2 fluxes over forest canopy were measured by eddy covariance technique as described by Sangwangsri et al. (2011). The MODIS VI products (MOD13Q1) has provided the spatial resolution at 250 m (band 1-2), 500 m (band 3-7) and 1 km (band 8-36) and derived each 16 day and each calendar month. Satellite imageries were downloaded from http://edcsns17.cr.usgs.gov/NewEarthExplorer. MOD13 already provided EVI, NDVI therefore MSAVI and SAVI were calculated by using ERDAS IMAGINE 9.2 program.

3. Results and discussion

Leaf area index (LAI) from Plots 1 and 2 shows the same pattern. In the dry months, the lower LAI than during the wet months was observed, corresponding to the litter fall. It was found that LAI is correlated with all MODIS vegetation indices, but with different degrees. The coefficients (r) between LAI and EVI, NDVI, MSAVI, and SAVI (n=8) were 0.93, 0.91, 0.74, and 0.74, respectively. Thus, EVI has the strongest relationship with LAI, possibly due to the fact that EVI include the correction for the effect of background reflectance and atmospheric errors (Huete et al., 2002). These results suggest that LAI has the potential to be an estimator in the GPP estimation model for this dry dipterocarp forest.

Gross primary production (GPP) of the dry dipterocarp forest averaged over 16 days was estimated by eddy covariance during September 2008 to March 2011 are shown in Fig. 1. There is a general trend in temporal variations of GPP that it usually increases following the onset of wet season (May-June). The highest GPP value was found in wet period in September (9.48 $gC/m^2/d$), and the lowest GPP in dry period in February (3.51 $gC/m^2/d$). As demonstrated by previous studies, the pattern of GPP followed the changes in forest phenology, that plant activity (photosynthesis and respiration) becomes actively mainly during the wet season when rainfall amount and soil moisture increases to optimal (Huete et al., 2008).

The variations of four vegetation indices; NDVI, MSAVI, SAVI, and EVI data also followed forest activity and the onset of wet season. All vegetation indices were relatively low during dry season compared to that of the wet season. The ranges of EVI, NDVI, MSAVI, and SAVI were 0.23-0.65, 0.39-0.82, 0.55-0.91 and 0.57-1.26, respectively (Fig. 1).

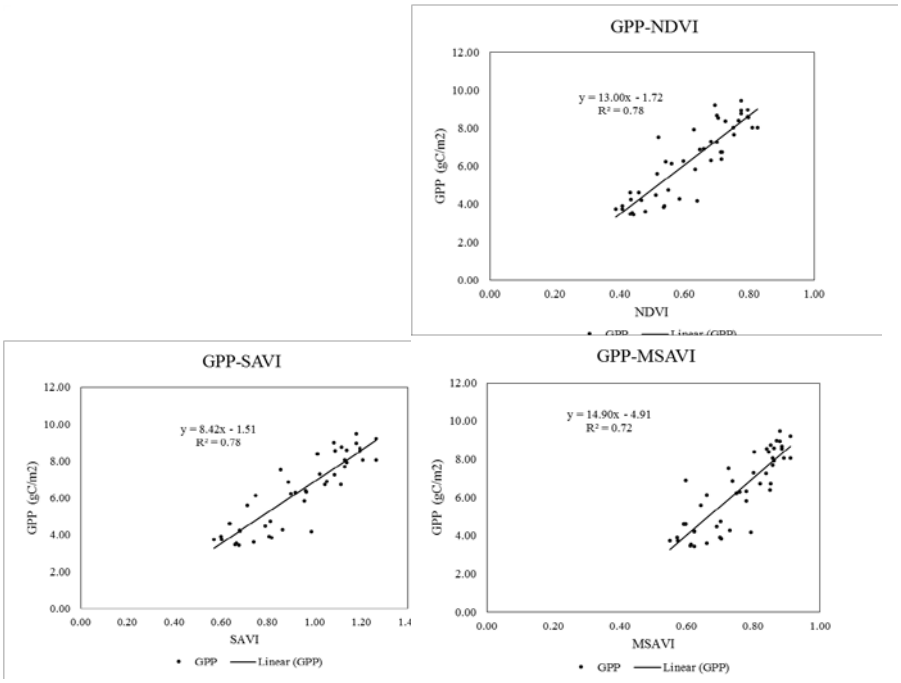

Fig. 1 Relationship between GPP and MODIS vegetation indices in dry dipterocarp forest.

Investigating the relationship between GPP derived from eddy tower and MODIS vegetation indices reveals that there are strong correlations between these two variables (GPP vs. Indices). The coefficients of correlation for EVI, NDVI, SAVI and MSAVI (n = 47) were 0.90, 0.88, 0.89 and 0.85, respectively. EVI has shown the strongest relationship with GPP, and can be expressed as GPP= 14.63x + 0.13, R^2 = 0.80. Similar results of high relationship between GPP and EVI were also reported at Maeklong drought deciduous tropical dry forest (Huete et al., 2008). The utilization of the blue band to correct for aerosol influence in red band for EVI may be the reason why such strong relationship can be seen between these two variables. We then used this relationship to estimate the GPP for the whole eddy flux measurement period (2008-2011). Results in Fig. 2 show that EVI actually can be used as proxy of GPP in this forest. Since eddy covariance measurements are usually associated with data missing due to atmospheric stability and other turbulent conditions, the relationship established in this study could be used as one of the methods for gap-filling.

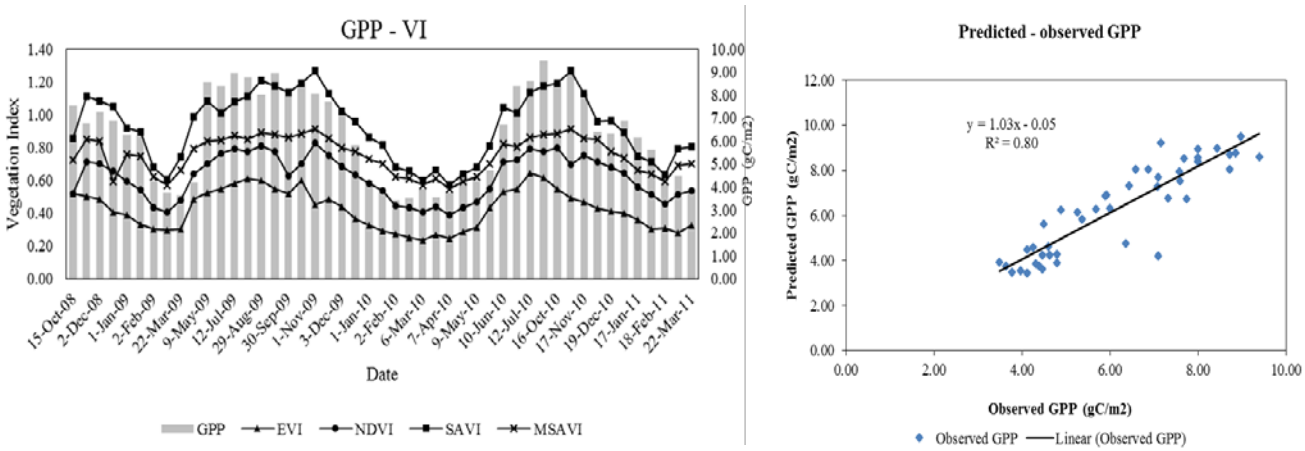

Fig. 2 Temporal variations of vegetation indices and GPP (left) and relationship between observed and estimated values (right) based on the relationship between EVI and GPP in dry dipterocarp forest.

4. Conclusion

In This study, MODIS vegetation indices were analyzed and validated against the observed data from eddy flux tower in dry dipterocarp forest during December 2010 to March 2011. LAI during the same period was also measured to be used as independent parameters for these vegetation indices cross-check. The empirical relationship between vegetation indices and GPP were then established. Based on the relationship derived, GPP during October 2008-March 2011 were then simulated. The results show that vegetation indices are strongly related to LAI and GPP. Also, vegetation indices were found to relate to GPP with EVI gave the best performance. Relationship between EVI and GPP was then used to simulate GPP throughout the measurement period of eddy flux. We concluded that EVI can be used a proxy to estimate GPP in this forest ecosystem.

5. Acknowledgement

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