

# EVALUATION OF BIOME-BGC MODEL FOR ESTIMATING NPP AND LAI OF TEAK PLANTATION OF THAILAND USING SPOT-DATA AS REFERENCE

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**ABSTRACT** In this study, BIOME-BGC was used to estimate the NPP and LAI of Teak plantation during 2004-2007 at Mae Moh site, Thailand. The model general ecophysiological parameterization defined by White et al (2000) was used, except the dates for vegetation onset and offset which was particularly specified for this site. Several climate parameters were generated by MT-CLIM based on meteorological data observed at the field. The outputs of BIOME-BGC are validated by SPOT s10 data. The LAI from SPOT and LAI observed from field has a good correlation ( $R^2 = 0.80$ ) and small RMSE of 0.86. Then LAI from SPOT is used to validate the simulated LAI from the model. Similarly, LAI observed from SPOT and LAI simulated from the model presented an acceptable correlation of ( $R^2=0.67$ ). The RMSE result of the observed LAI from SPOT and simulated LAI from model showed a small enough at 1.05. This is because of the facts that the pixel that SPOT detected contains not only teak but also many varieties of species at below canopy and the ecophysiological constants of BIOME-BGC is not specified for teak. The estimated NPP from BIOME-BGC in these four years of evaluation was 776.1, 740.4, 605.6 and 687.4 gC/m<sup>2</sup>/y respectively. The results from sensitive analysis of simulated NPP to meteorological input parameters demonstrated that NPP at the site is sensitive to precipitation and VPD. The method is feasible to estimate NPP of teak by applying BIOME-BGC in tropical area.

## 1. INTRODUCTION

Basic theoretical understandings of ecosystem function which cannot be tested with field methods have been developed by applying the ecosystem models (Churkina and Running 1998). The use of remote sensing data and ecosystem simulation models is mostly promising. Particularly, the former has been demonstrated to be efficient in providing direct estimation of vegetation conditions (e.g. LAI, FAPAR, etc.) related to global forest productivity (Waring and Running, 1998). Ecosystem simulation models are instead efficient means to combine data from different sources such as meteorological and soil measurement and structural and ecophysiological information. As the result, more complete characterizations of vegetation processes for example, transpiration, photosynthesis, respirations and allocations are presented.

The BioGeochemical Cycles (BIOME-BGC) model simulates net primary productivity (NPP) and leaf area index (LAI) in a defined type of terrestrial ecosystem (Running et al, 1993; Thornton 2000). In addition, the model operates with a daily time step which indicates that each flux is approximate for a one-day period and weather is the most important control on vegetation processes. Leaf area index (LAI, m<sup>2</sup> leaf area per m<sup>2</sup> ground area) controls canopy radiation

absorption, water interception, photosynthesis, and litter inputs to detrital pools. NPP is divided into the leaves, roots and stems according to a function of dynamical allocation patterns. However, considering a function of dynamical allocation patterns has eventual limitation due to availability of and competition for nitrogen.

Net primary productivity (NPP) is based on gross primary production indicated as the difference between the Farquhar photosynthesis routine (Farquhar et al. 1980) and the maintenance respiration. The maintenance respiration is calculated as a function of tissue nitrogen concentration (Ryan 1991) and growth respiration (a constant fraction of gross primary production). The inner processes and logic of Biome-BGC have not been described further, because they were discussed in detail by Running and Coughlin 1988, Running and Gower 1991, Kimball et al. 1997.

Although the recent advances in the application of remote sensing data and BIOME-BGC are wide-spread, there are still few applications of this model in the deciduous forest of Thailand. The deciduous forest is a type of tropical seasonal forests and has remarkable role in the global carbon budget (Yoshifuji 2006). One of the important species in this type of forest is *Tectona Gandis* or teak which covers large areas in the northern parts of Thailand. In the deciduous forest, transpiration and primary productivity are significantly influenced by large seasonal change in leaf area (Yoshifuji 2006). Moreover, the potential impact in the deciduous forest has been paid much less attention than that in temperate and boreal deciduous forest (White et al. 1999; Wilson and Baldocchi, 2000; Barr et al, 2004).

In this research, we attempt to (1) estimate the net primary productivity (NPP) and leaf area index (LAI) in teak plantation during 2004-2007 at Mae Moh site, Thailand by using BIOME-BGC model, (2) to validate the simulated NPP and LAI from BIOME-BGC with remote sensing data and (3) to perform a sensitivity analysis of the NPP model outputs compared with the meteorological input data in Thailand.

## **2. MATERIALS AND METHODOLOGY**

### ***Simulation***

The BIOME-BGC model version 4.1.1 was used. It required daily maximum and minimum air temperatures, humidity, incident solar radiation and precipitation to determine daily carbon and water fluxes. Average daily incident shortwave radiation ( $Q_i$ ) was simulated using MT-CLIM logic according to Running et al. (1988) based on meteorological data observed at the field. Average daily net solar radiation ( $Q_n$ ) was estimated using a prescribed constant albedo for vegetation.  $Q_n$  was attenuated through the vegetation canopy by using Beer's formulation and a prescribed extinction coefficient. The prescribed extinction coefficient was modulated by LAI to derive the amount of solar radiation transmitted through the canopy ( $Q_t$ ). The amount of solar radiation absorbed by the canopy ( $Q_a$ ) was calculated as the difference between  $Q_i$  and  $Q_t$ . Photosynthetic photon flux density (PPFD) was evaluated based on the assumption that photosynthetically active radiation represents approximately 50% of  $Q_a$  (Running and Coughlan 1988).

In addition, aspect, elevation, nitrogen deposition and fixation, and physical soil properties are necessary for evaluating a varieties of parameters including daily canopy interception, evaporation and transpiration; soil evaporation; outflow; water potential and water content; LAI; stomatal conductance and assimilation of sunlit and shaded canopy fractions; growth and

maintenance respiration; GPP and NPP; allocation; litter-fall and decomposition; and mineralization and leaching.

Furthermore, the model requires a static description of the ecophysiological characteristics of the vegetation which is Teak in the study area. Also, deciduous broadleaf group (DBF) was selected for this simulation. The general ecophysiological parameterization defined by White et al. (2000) was used, except the dates of leaf onset and offset which was particularly specified for this case.

### ***Derived LAI from SPOT-data***

The SPOT-VGT data used in the study were 10-day-composite data (S10) at the resolution of 0.008928° (about 1 km) in plate-carree geographic projection available from <http://free.vgt.vito.be/> for years 2004 to 2007. Seasonal variation of NDVI was derived by imagery which were one pixel cut-offs with center at flux tower site. The calculation of NDVI was carried out by the following equation.

$$NDVI = (0.004 * DN) - 0.1 \tag{1}$$

The evaluation of NDVI images by the equation (1) exhibited the positive correlation between LAI and NDVI and the regression is 0.59 on the teak plantation site. LAI were then calculated by the following equation.

$$LAI = 2.1343(NDVI)^2 + 6.087(NDVI) - 0.5217 \tag{2}$$

Local Maximum Fitting (LMF) was executed for the correction of 10-day composite data in order to consolidate cloud-free data, while spatial resolution was retained. The LMF processing not only combined time series filtering with a functional fitting technique but also removed the effect of clouds, haze and other atmospheric effects from the LAI time series data of each pixel and extracted the seasonal change pattern of the ground. The figure 1 below illustrated the LAI data from SPOT before and after LMF processing.

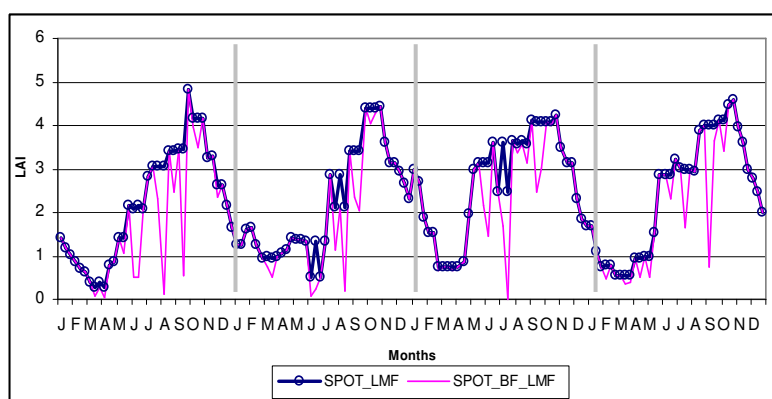


Figure 1. LAI data (year 2004-2007) before and after LMF processing at 10 day composite.

### ***Sensitivity Analysis***

The sensitivity analysis was focused on the effect of input parameters used in MTCLIM and/or BIOME-BGC on the biome state variables under steady state. The effects of the individual site and eco-physiological parameters were assessed on the set of the key output variables.

### 3. RESULT AND DISCUSSION

#### *Simulation Result Validation of Biome-BGC*

The study site was located on a flat area where the stand structure was almost homogenous. The mean tree height and diameter at breast height (DBH) were 18 meters and 19.5 cm respectively. There was understory vegetation around the site as well. BIOME-BGC simulated daily NPP and the trend were displayed in the figure 2. The estimated NPPs from BIOME-BGC in these four years of evaluation were 776.1, 740.4, 605.6 and 687.4 gC/m<sup>2</sup>/y respectively. This model was applied to evaluate the negative daily NPP in dry season. A negative NPP indicated that plant respiration was greater than the uptake of carbon by plants during a month when vegetation was stressed by drought conditions or low precipitations. The model revealed that the peak of NPP occurred during the rainy season since September to October in the site. Similarly, the season trend of LAI exhibited the highest LAI in the rainy season. The LAI peak was presented between November and December. The figure 2 illustrated the seasonal trend of NPP and LAI.

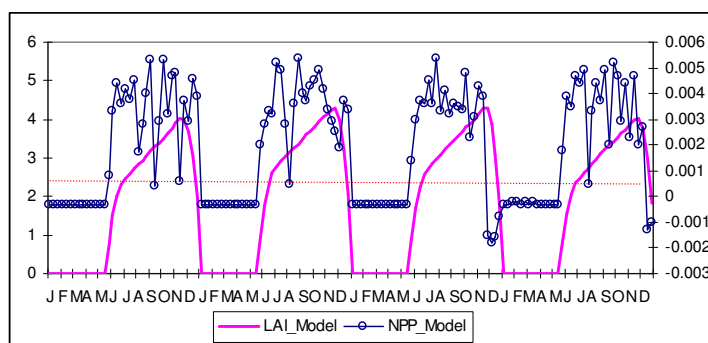


Figure 2 four-year time series of NPP and LAI estimated from BIOME-BGC

BIOME-BGC was validated by using SPOTs10 data after LMF processing. The LAI from SPOT and LAI observed from the field (Figure 4-a) displayed a good correlation ( $R^2 = 0.80$ ) and small RMSE of 0.86. LAI from SPOT was also used to validate the simulated LAI from the model. Like LAI observed from SPOT, LAI simulated from the model (Figure 4-b) presented an acceptable correlation of ( $R^2=0.67$ ). Moreover, the RMSE result of the observed LAI from SPOT and simulated LAI from model showed a small adequate value at 1.05. The RMSE result had the small value since the pixel detected by SPOT contained the teak and a variety of species at below canopy and besides, the ecophysiological constants of BIOME-BGC was not specified for teak.

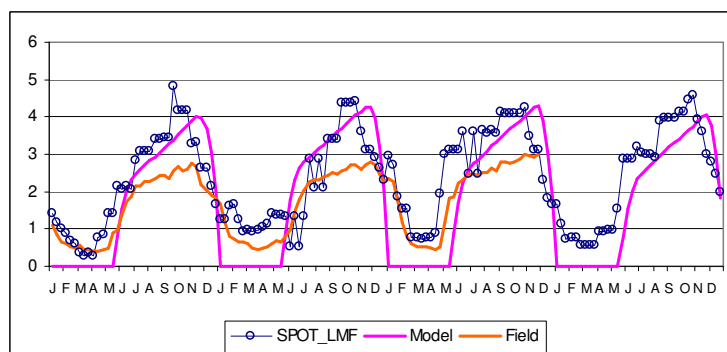


Figure 3 Seasonal trend of LAI from SPOT, BIOME-BGC and field survey

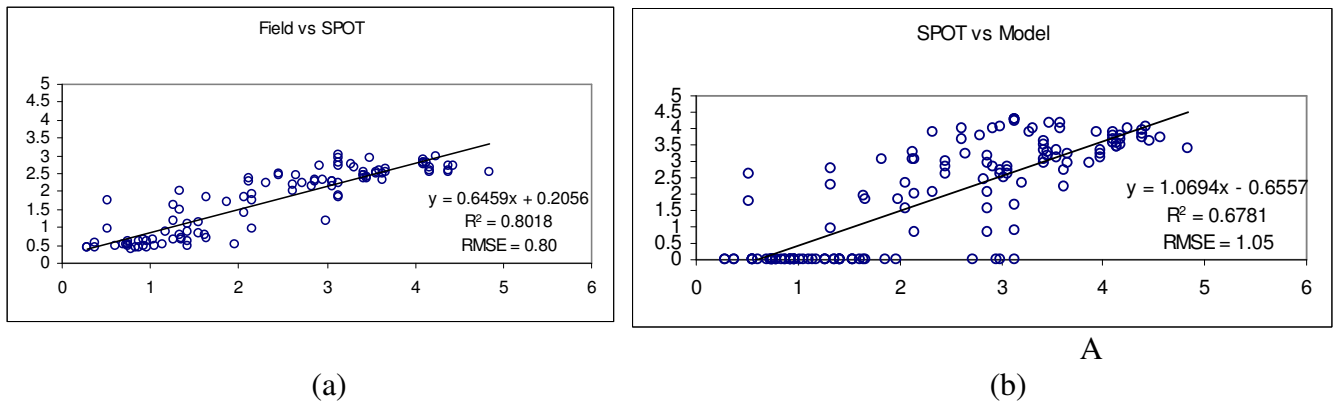


Figure 4 comparison of LAI from SPOT, BIOME-BGC and field survey

### Climate Control on NPP

The results from sensitive analysis of simulated NPP to meteorological input parameters demonstrated that NPP at the site was sensitive to precipitation and VPD in teak plantation of Thailand. Rainfall affected to NPP in this site. This increase in rainfall was correlated with a significant increase of annual NPP among the year 2004 2005 and 2007. However, in 2006, there was high rainfall but NPP dropped because of the forest fire in November. VPD showed negative relationship with NPP (Figure 5).

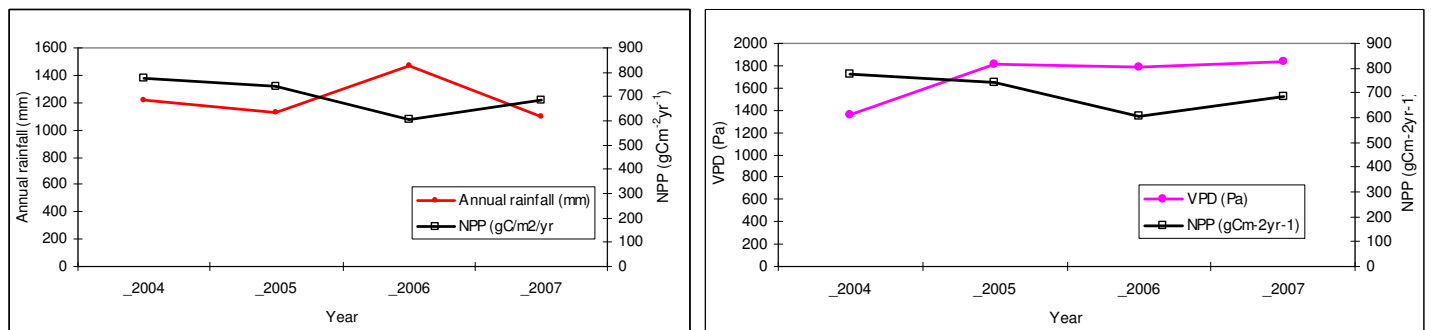


Figure 5 climate controls on NPP

## 4. FURTHER STUDY

In this paper, the preliminary result of this study was presented. Other mentioned steps will be conducted in order to calibrate BIOME-BGC model by using data assimilation technique. The data assimilation technique is applied for combining the source code of Biome-BGC version 4.1.1 and Genetic Algorithm (GA) obtained from Visual C. The process will be performed by using GA to identify the Biome-BGC model parameters over teak plantation in tropical area.

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