EVALUATION OF BIOMASS PRODUCTION OF PLANTATION FOREST IN TROPICAL AREAS
A case study of Acacia Plantation Forest, P.T. Musi Hutan Persada, Indonesia[1]

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Abstract

This research focused on a dynamic analysis of tree growth and biomass production of Acacia plantation in South Sumatra, Indonesia. The data used in this study came from permanent plots established in the operational plantations of *Acacia mangium* Willd. managed by PT. Musi Hutan Persada (hereinafter referred as MHP) at the Subanjeriji area, South Sumatra, Indonesia. The analyses were based on the long-term inventory data of planted stands from 2000-2005 that recorded from 2001 to 2006 (1-6 years old). The result showed that diameter, tree height and standing tree volume were not significantly affected by the block area at Unit V. However, those parameters increased significantly with plantation age. Biomass of standing trees at 5 years of age could be estimated at around 94 Mg/ha, with the estimated carbon content of forest biomass at about 72 Mg C/ha.

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Introduction

Rising concentration of atmospheric carbon dioxide (CO_2) is causing increasing concern about greenhouse gas-induced global climate change. The capacity of forests to absorb CO_2 through photosynthesis has received much attention in recent years. The world's tropical forests which cover 17.6×106 km^2 containing 428 Pg C in vegetation and soils.[1] Tropical forests are one important component in the production and consumption of CO_2 (Figure 1), therefore the ability to accurately and precisely measure the carbon stock in forests is increasingly gaining global attention. Changes in the carbon standing stock of trees reflect the balance between growth and mortality (including harvesting) and determine the status of forests as an atmospheric carbon source or sink. Forest productivity indicates the potency of the forest to absorb the CO_2, where the measurement of forest productivity is relevant with biomass measurement. Among the various methods for evaluating forest biomass, the most widely used is complete harvest of randomly selected plots. However, such methods are generally inappropriate in forest studies, so allometric methods have been developed to estimate total biomass from non destructive surrogate measurements such as diameter of the bole at breast height (dbh). One approach to quantifying carbon biomass stores consists of inferring changes from long-term forest inventory plots.[2] The available inventory data do not generally address biomass. Since the available inventory data includes information regarding volume, and the volume and biomass are strongly related, it seems appropriate to estimate biomass based on volume data.

The establishment of fast growing trees is one way of rehabilitating unproductive forest lands, which are usually covered by alang-alang grass (*Imperata cylindrica*) or weeds. Plantation forest using fast growing species has been adopted in many countries as one option for a sustainable supply of tree products and also reducing the pressure on natural forests. *Acacia mangium* is one of the major fast growing species used in plantation forest program due to its rapid growth and tolerance of a wide range of site characteristics. *A. mangium* is the native species of eastern Australia (Queensland), Papua New Guinea and the eastern part of Indonesia. *A. mangium* and is now widely planted in Indonesia for supplying the raw materials in pulp and paper and in MDF industries. In the year 2003, *A. mangium* plantation reached 800,000 hectares and is predicted to 1 million hectares in 2010. The annual growth of this species was reported as 20-50 m^3/ha and the trees could be harvested at 6-8 years old.[3]

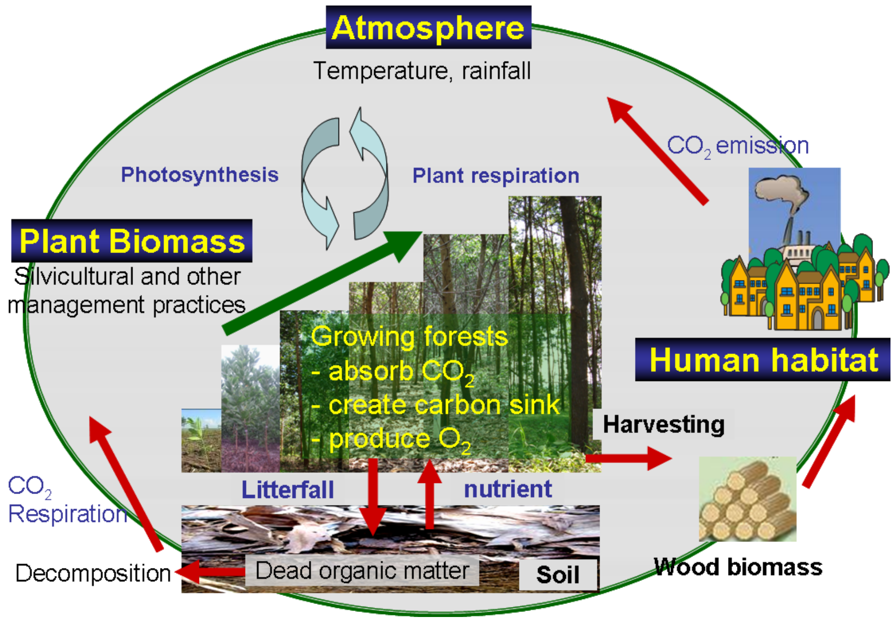

Figure 1. The forest carbon cycle

The evaluation of the forest biomass as sustainable material and environmental resources is becoming more and more important, which supports the harmonization of the local community economy, social, and the global environment. Evaluating the carbon sink function of tropical plantation forests and confirming the sustainability of wood production is the main goal of the carbon flow analysis project. Figure 2 shows the research design of the carbon flow analysis of Acacia forest. The research is performed in cooperation with a tree plantation company, PT MHP in South Sumatra, Indonesia.[4] This research as one part of the carbon flow analysis project focused on establishing the data of annual biomass production of Acacia plantation forest in tropical area and also relating the effect of the environment constraint on annual tree growth (expressed in the blue frame).

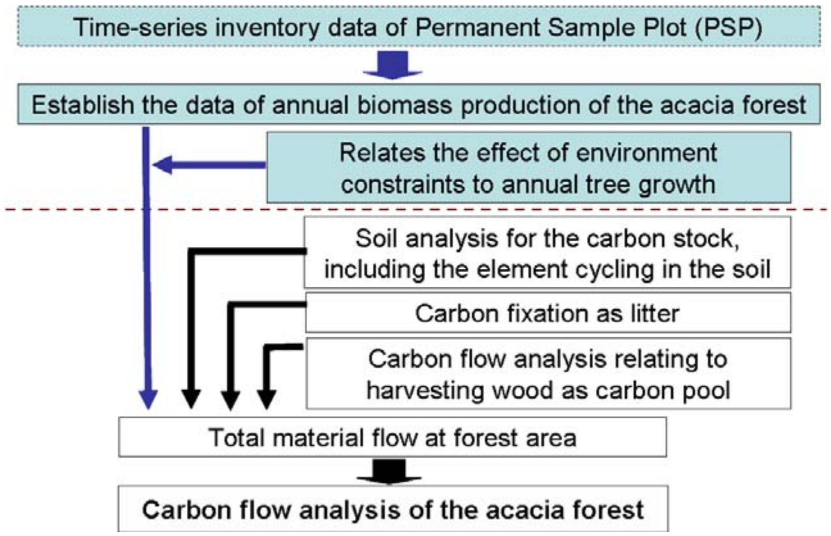

Figure 2. Research design of carbon flow analysis project

Study site

The research sites are located in southwest Palembang, South Sumatra between 03^{o}05-04^{o}28 S latitude and 103^{o}10-104^{o}25 E longitude, with the altitude ranges from 60-200 m above sea level. The annual rainfall in the plantation area is 2000-3000 mm, which falls mostly between October-May with a relatively dry period in June-September. The average daily temperature is 29ºC, with minimum temperature that is not lower than 21ºC and an average maximum temperature 32^{o}C.

PT MHP began to establish its Acacia plantations in 1990 on unproductive sites formerly dominated by alang-alang (*Imperata cylindrica*) grass, on which a total of 193,500 ha have been planted mainly with *Acacia mangium*. The total concession area consists of 300,000 ha in three different forest area, i.e. the Benakat area, the Subanjeriji area and the Martapura area (Figure 3), in which the conservation forest, i.e., secondary natural forest occupies 70,000 ha. The plantation will be harvested to feed pulp mills that need around 2.2 million m^3 of solid roundwood to produce 450,000 tons of bleached kraft pulp every year. The rotation of 6 years is recently used in MHP to supply the pulp factory.

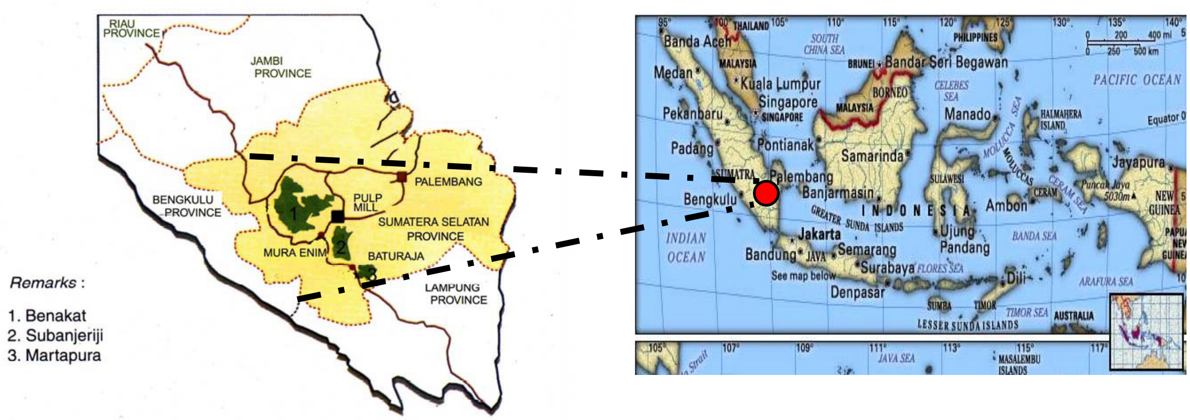

Figure 3. Location of PT Musi Hutan Persada, Palembang, Indonesia

Analysis Data

A long-term inventory data of randomly selected permanent sample plots (PSP) collected by MHP was used for the analysis. The area of PSP is 0.05 ha, and the total area of PSP is 0.05% of the plantation area. The study area is Acacia plantation at Unit V in Subanjeriji area of MHP, which consists of 4 block areas, i.e. Lengi, Niru, South Sodong, and West Sodong. The data of the 2nd rotation plantation at unit V of PT MHP was used for the analysis. The inventory data of planted stands from 2000 to 2005 was recorded from 2001 to 2006 (1-6 years old). The annual recorded data of 2nd rotation plantation consisted of stand density, tree height, stem diameter at breast height (dbh), and standing tree volume.

Result and Discussion

Figure 4 shows standing tree volume of *A. mangium* at each block area in unit V. It showed that standing tree volume was not significantly affected by the block area at Unit V, as well as dbh and tree height. However, those parameters increased significantly with plantation age. In rotation of 6 years, the height and dbh of 1-year-old forest of Acacia ranged from 2.2 to 6.7 m and from 2.5 cm to 7.4 cm, respectively (Figure 5). After 5 years of planting, the height and dbh of Acacia trees ranged from 12.8 to 21.1 m and from 13.3 cm to 19.9 cm, respectively. In humid areas of the Caribbean region of Colombia height growth of *A. mangium* was comparable with the growth in other areas of the tropical world reaching on average sites 15 m in 3 years.[5]

After 5 years of planting, the mean annual increment (MAI) for dbh of Acacia ranged from 2.49 to 3.97 cm/yr and for tree height ranged from 2.67 to 3.96 m/yr. The current annual increment for dbh generally increased rapidly in the early 2 years, at around 4.5 cm/yr, and then started to decrease at ca. 1.3 cm/yr at 6 years old.

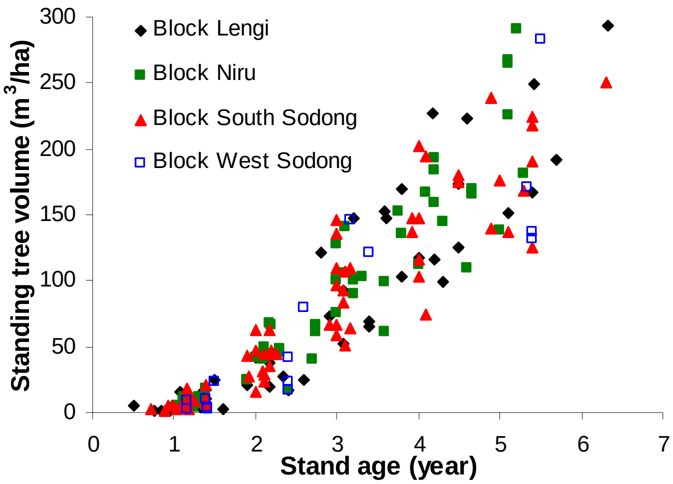

Figure 4. Standing tree volume of *A. mangium*

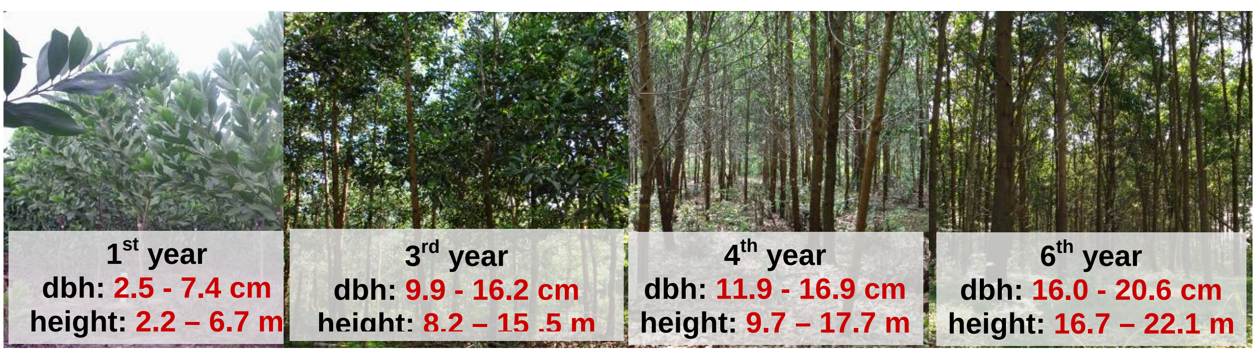

Figure 5. Distribution of dbh and tree height of *Acacia mangium* at 1st, 3rd , 4th and 6th years old

The relationship between tree height and dbh of *A. mangium* seemed to fit well in a power-law relationship, particularly for trees in the same site. However, Chave J *et al.* (2005)[2] pointed out that in reality, a power-law was not the best relationship for predicting height from diameter, particularly in large diameter trees. It is believed that stem diameter is a reliable predictor for stem wood mass. A good correlation was observed between the stand volume and dbh where a high coefficient of determination (R^2 = 0.98) could be obtained.

Figure 6 shows the average of standing tree volume and the annual increment of *A. mangium*. Growth of *A. mangium* was very rapid during the first 3-4 years. The MAI of Acacia recorded in 5-year-old stand reached 36.8 m^3/ha/yr, with the CAI was 48.6 m^3/ha/yr. When the average of MAI and CAI of each stand age were plotted in the curve, it was found that the point at which the curves intersect was at around 6 years old, which it conventionally meant that it was the time to harvest. Subarudi *et al.* showed that *A. mangium* would be harvested in year 6 from Sumatra site and in year 8 from Kalimantan site.[6] Another researcher reported that the annual growth of Acacia was 20-50 m^3/ha and the trees could be harvested at 6-8 years old.[3] The growth of trees is usually determined by a complex of interacting factors and conditions, including seasonal conditions and silvicultural treatments (Figure 1).

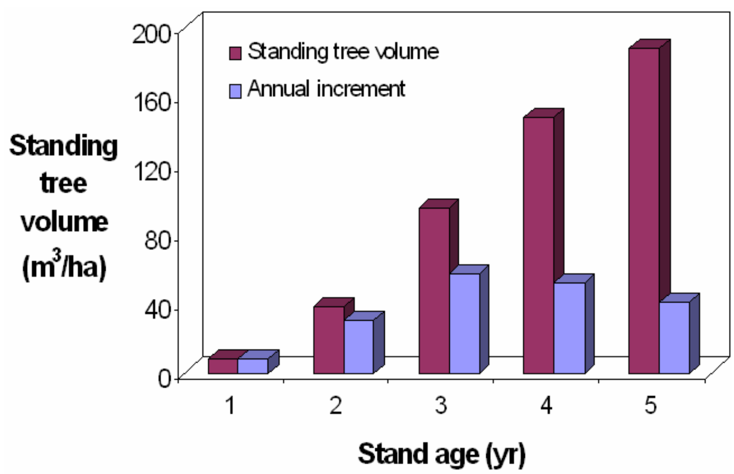

Figure 6. Standing tree volume and annual increment of *A. mangium*

Figure 7 shows the monthly and annual rainfall data in the Subanjeriji area, South Sumatra, Indonesia in 2000-2006. The area received 3500 mm of rainfall in 2005, and only 1800 mm of rainfall in 2002 and 2006. Based on the patterns of the annual increment of each plantation year, the planted stand in 2002 showed a slightly lower annual increment than the planted stand in 2000 and 2001. As mentioned before that *A. mangium* grows rapidly during the early stages after planting. It predicted that there was some correlation between annual rainfall and annual tree growth, especially in the early stages. However, the result showed that there were no consistent and statistically significant annual increment patterns. Current annual increment varies from year to year being affected by seasonal conditions as well as silvicultural treatments and management practices. Therefore there is a need to continuously identify the dynamics in forest ecosystems in term of contributing to sustainable forest management.

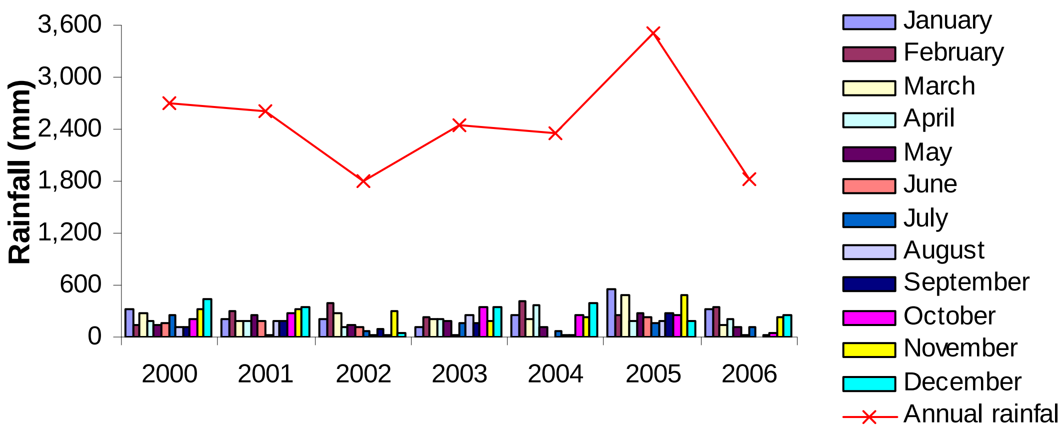

Figure 7. Rainfall data in the Subanjeriji area, South Sumatra, Indonesia (2000-2006)

The average stand volume of Acacia recorded at 5-years-old stand was 188 m^3/ha. With the density of Acacia is about 0.5 Mg/m^3, the biomass could be estimated at around 94 Mg/ha. About one half of the biomass is composed of carbon (C). Tree biomass consists of leaves, stem, branches, fruit, twigs, and root. With the assumptions that the stems (including barks) represent about 65% of total forest biomass (including the roots), the estimated carbon content of forest biomass at 5 years of age was about 72 Mg C/ha or equivalent with 264 Mg CO_2 /ha.

Summary and Conclusions

This paper has discussed the dynamic analysis of tree growth and biomass production of Acacia plantation in South Sumatra, Indonesia. The data used in this study came from permanent plots established in the operational plantations of *A. mangium* managed by PT. MHP at Unit V in Subanjeriji area, South Sumatra, Indonesia. The analyses were based on the long-term inventory data of planted stands from 2000-2005 that recorded from 2001 to 2006 (1-6 years old). The effects of block area, stand age, and the correlation among tree growth parameters were evaluated. Annual increment was calculated and its relation with annual rainfall was discussed.

The standing tree volume was not significantly affected by the block area at Unit V, as well as dbh and tree height. However, those parameters increased significantly with plantation age. The average stand volume of Acacia recorded in 5-year-old stand was 188 m^3/ha. The biomass of standing trees at 5 years of age could be estimated at around 94 Mg/ha, with the estimated carbon content of forest biomass at about 72 Mg C/ha. It seemed that there was some correlation between annual rainfall and annual tree growth, especially in the early stages. However, there were no statistically significant annual increment patterns in this research. Therefore, the assessment of C dynamics associated with an expansion of the time scale and location should be continuously conducted.

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