Carbon Stocks In *Acacia mangium* Willd. Stands of Different Ages

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ABSTRACT

Terrestrial ecosystem plays an important role in global carbon cycle as CO_2 source or sink. The terrestrial ecosystem role as carbon sink can be enhanced by planting more trees for aforestation or reforestation (A/R). *Acacia mangium* is a fast growing tree species having ability to tolerate wide-range soil conditions, which make this species attractive for tree planting in critical lands. Given the opportunity to sell the carbon sequestered during A/R for climate change mitigation, information on the carbon stocks of *Acacia mangium* plantation forest in various environmental conditions is needed. This study aimed to investigate the amount of carbon or carbon stocks in *Acacia mangium* stands of different age (1, 3, 5, 7 years old) at Parung Panjang, West Java Province, Indonesia. In this research the total carbon stock of a stand consist of the carbon stored in aboveground tree biomass, understorey biomass, litter, and soil organic matter. The result shows that the amount of carbon stocks was 44.87 Mg/ha, 73.53 Mg/ha, 77.81 Mg/ha, and 72.88 Mg/ha for 1, 3, 5, and 7 years old stands respectively. This study also found that the major contributor to total carbon stocks in *Acacia mangium* stand up to 7 years old was soil carbon and then followed by aboveground tree biomass.

Key Words

Acacia mangium, carbon stock, reforestation, Parung Panjang

INTRODUCTION

Terrestrial ecosystem plays an important role in global carbon cycle as CO_2 source or sink. CO_2 exchange in terrestrial ecosystem is mainly controlled by photosynthesis process and vegetation respiration. The terrestrial ecosystem role as carbon sink can be enhanced by planting more trees for aforestation or reforestation (A/R).

Acacia mangium Willd. is a tropical species capable of colonizing difficult sites. Its important attributes include rapid early growth, good wood quality (for pulp, sawn timber, and fuel wood), and tolerance of a range of soil types and pH (National Research Council, 1983 *cited in* Pinyopusarerk *et al.*, 1993; several sources *cited in* Forrs *et al*., 1996; Djumakking, 2003). These characteristics make this species often used as the main component in aforestation or reforestation of critical lands.

Acacia mangium is a native plant from Australia, Papua New Guinea, and Indonesia (Pinyopusarerk *et al.*, 1993; Forrs *et al*., 1996; Widyorini *et al*., 2009). Since its introduction to Sabah, Malaysia, as an exotic in 1966, *Acacia mangium* has become one of the tree or four most common plantation tree spesies in Asia. 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 forest (Widyorini *et al*., 2009). In Indonesia, *Acacia mangium* has been selected for reforestration since the late 1970s (Heriansyah *et al*., 2007).

Plantations of *Acacia mangium* have been developed at several provinces in Indonesia such as Jambi, Riau, South Sumatra, West Java, West Borneo, Central Borneo, and East Borneo (Anggraeni and Wibowo, 2005).

Besides producing woods for industries, *Acacia mangium* plantation forest also has role in providing environmental service such as carbon sequestration given the high growth rate of this species. Given the opportunity to sell the carbon sequestered during A/R for climate change mitigation, information on the capacity of *Acacia mangium* plantation forest in sequestered carbon in various environmental conditions is needed.

MATERIALS AND METHODS

Study Area

The study was conducted in *Acacia mangium* plantation forest by Perum Perhutani Unit III, a state-owned company. The plantation was located in Resort Pemangku Hutan (RPH) Maribaya, Badan Kesatuan Pemangku Hutan (BKPH) Parung Panjang, Bogor, West Java, Indonesia (Figure 1). The coordinates was between $106^o27'$ – $106^o29'$ E and $06^o22'$ – $06^o25'$ S. The study area was situated on a hillside approximately 60-100 m above sea level. The annual rainfall is 3000 mm and daily temperature is approximately 18 – 30^oC, and the terrain is gently undulating (several sources, *cited in* Heriansyah *et al*., 2007; Djumakking, 2003).

Figure 1. Location of West Java relative to Indonesia and south east Asia

(Souce : http://www.anjjabar.go.id/gambar/peta_indonesia1.jpg)

Field Sampling and Data Analysis

Field sampling were conducted in four sites with stand ages of 1, 3, 5, and 7 years. The total carbon stock of a stand measured in this research consisted of the carbon stored in aboveground tree biomass, understorey biomass, necromass, litter, and soil organic matter (Hairiah and Rahayu, 2007). In principle, the aboveground tree, understorey, necromass, and litter components were estimated from the biomass value. Subsequently, all biomass values were converted into carbon using 0.5 conversion factor (Brown, 1997). While soil carbon stocks were estimated from the concentration of soil carbon and soil bulk density.

Measurement for tree and necromass was conducted in 20 x 30 m^2 plot, 3 plots were used for each stand age. Whereas sampling for understorey, litter, and soil were conducted in six 0.5 x 0.5 m^2 sub-plots located randomly within 20 x 30 m^2 plot. The size and arrangements of sampling plots are depicted in Figure 2.

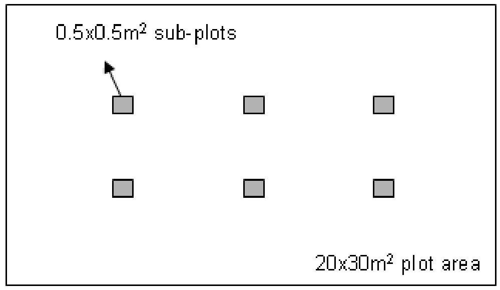

Figure 2. Plot design for sampling

In each plot, the biomass of tree was estimated using the allometry method. In this method, the stem diameter of all trees was measured and these values were later converted into biomass using an allometric equation. The equation used in this study was specifically developed for *Acacia mangium*, i.e. $W = 0.0477D^{2.6998}$ (Heriansyah, 2005). W refers to aboveground biomass (kg) and D refers to tree diameter (cm). The diameter measurement for 3, 5, and 7 years stand were conducted at breast high (or DBH) while that of 1 year stand were measured at basal. In addition to stem diameter measurement, the number of stems was also counted to measure the stand density.

In contrast, the biomass of litter and understorey was estimated trough destructive sampling. Understorey taken as sample was all live tree specimens with the diameter of less than 5 cm, shrubs, and herbs. In destructive sampling, the vegetation in a given area was cut and weighed (fresh weight), and the subsamples of them was dried at $80^{o}C$, and weighed again after oven-drying.

Soil carbon content per unit area can be calculated by taking of disturbed soil and undisturbed soil samples (Hairiah and Rahayu, 2007). Disturbed soil samples were taken as deep as ± 20 cm (MacDicken, 1997) from each sub-plots and then they were mixed and homogenized before being sent to the BALITSA laboratory for chemical analysis. Undisturbed soil samples for bulk density measurement were taken using core sampler. Soil carbon stock was calculated using the equation developed by MacDicken (1997):

$$\text{Bulk Density [BD] (g/cm}^3\text{)} = \frac{\text{Dry Weight (g)}}{\text{Volume (cm}^3\text{)}}$$

Soil Carbon Content (Mg/ha for the 0-20 cm soil depth)

$$= \text{BD x 200 kg/m}^2 \text{ x Carbon concentration (\%) x 10}$$

Total carbon stock consists of the sum of carbon stocks from all components, *i.e.* aboveground trees, understorey, necromass, litter, and soil organic matter. All values were represented in Megagram (or Tons) carbon per hectar (Mg/ha or Tons/ha).

RESULTS AND DISCUSSION

The result showed that the amounts of (total) carbon stocks were 44.87 Mg/ha, 73.53 Mg/ha, 77.81 Mg/ha, and 72.88 Mg/ha for 1, 3, 5, and 7 years old stands respectively (Figure 3). The variation of carbon stocks among the stands of different age is statistically significant according to One-Way ANOVA test with confidence interval of 95%. Further statistical test using Tukey-test indicates that the carbon stocks of 1 year old stand was significantly different with the other three stands, whereas there were no differences on the carbon stocks among the 3, 5 and 7 years old stands.

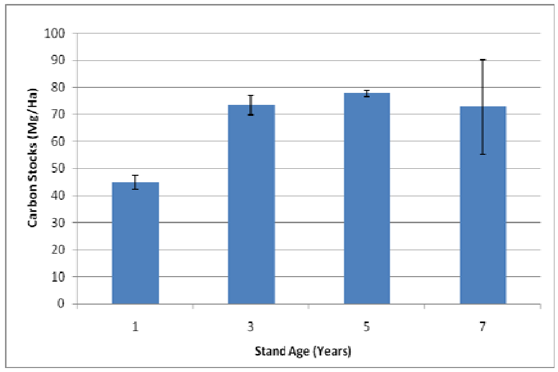

Figure 3. Total carbon stocks in *Acacia mangium* plantation forest

Figure 4 (a & b) presents the distribution of carbon stocks among components, i.e. aboveground tree biomass, understorey biomass, litter, necromass and soil. They indicates that, at all age groups, the level of carbon stocks in the aboveground (tree, understorey, necromass and litter) was lower than the carbon stock in the soil. The proportions of soil carbon to the total carbon stocks across all age groups range from 52 to 97 %. By comparing the trends in Figure 4(a) and (b), it is clear that the soil carbon proportion decreases as the stand age increases and this is due to the increase of carbon stocks in tree biomass. Meanwhile, the proportions of carbon stocks in litter, understorey and necromass proportion were low at age groups.

According to Figure 4(a), the carbon stocks values at aboveground tree component were 0.22 Mg/ha, 12.45 Mg/ha, 28.59 Mg/ha, and 31.48 Mg/ha for 1, 3, 5, and 7 years old stands respectively. The increase in tree biomass and consequently carbon stocks as the stand age increases is frequently reported in tree plantations, e.g. *Pinus merkusii* (Heriansyah, 2005), *Pinus strobus* (Matthias, 2006), and *Dipterocarpus alatus* (Wachrinrat, 2009).

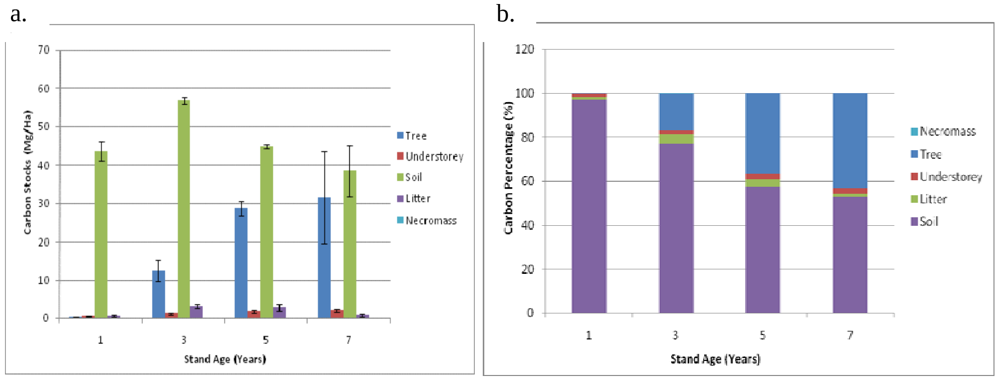

Figure 4. Distribution of carbon stocks by component presented in

(a) absolut amount (Mg/ha) and (b) percentage.

Meanwhile, the values of soil carbon stocks were 43.55 Mg/ha, 56.71 Mg/ha, 44.71 Mg/ha, and 38.51 Mg/ha for 1, 3, 5, and 7 years old stands respectively (Figure 4-a). The value of soil carbon stocks in 3 years old stand was higher than in other stands. The reason for this could be related to the level of litter. The carbon stocks from litter at 3 years old stand was 3.19 Mg/ha, and this was higher than in other stands. Litter input to the soil may increase soil organic matter content (Hairiah *et al.*, 2004 *cited in* Hairiah *et al.*, 2009).

Before presenting the level of carbon stocks in litter and understorey, we will discuss the management of the stands, particularly the thinning. Thinning is a practical method of intermediate cutting by releasing some trees from the stand to increase the growth rate of trees after thinning (Suwannapinant, 1983 *cited in* Wachrinrat *et al.*, 2009). Furthermore, it can control pest and disease and earn incomes before the final harvesting (Wachrinrat *et al.*, 2009). In this study area, the thinning has been done once, two times, and three times in 3, 5, 7 years old stands respectively. The results of the thinning were decreasing number of trees (stand density) as the stand age increases (Figure 5). The stand density were 1050 trees/ha, 889 tree/ha, 839 tree/ha, and 728 tree/ha for 1, 3, 5, and 7 years old stands, respectively. In this study area, apart from the age factor, the high level of stocks in tree biomass in older stands (Figure 4-a) could also be influenced by the enhanced growth due to decreasing competition as a result of thinning.

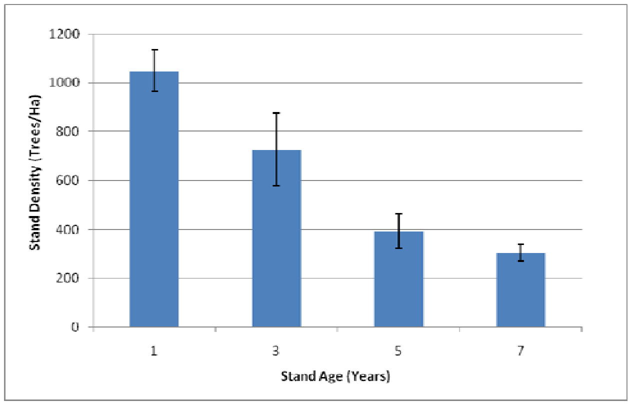

Figure 6. Stand density of *Acacia mangium* plantation forest

The carbon stocks from understorey biomass were 0.55 Mg/ha, 1.18 Mg/ha, 1.75 Mg/ha, and 2.05 Mg/ha for 1, 3, 5, and 7 years old stands, respectively. The higher level of understorey at older stands was affected by thinning activity. Widening space between trees as a result of thinning can cause increase of sunlight entering into forest floor so the understorey grows more rapidly at lower tree density (Rahayu *et al.*, 2003).

The carbon stocks from litter were 0.53 Mg/ha, 3.19 Mg/ha, 2.76 Mg/ha, and 0.85 Mg/ha for 1, 3, 5, and 7 years old stands, respectively. The value of litter carbon stocks in 3 years old stand was higher than in older stands. Litter in a stand could be originated from litter-falls of living trees as well as thinning remains in the form of slashed branches and leaves. As stands get older, the repeated thinning makes the tree density decreases and this makes the amount of biomass taken out, and consequently the amount of remains left, also decreases. Meanwhile, the low level of litter carbon stock in the one year old stand was due to management of land in the early phase of tree planting. In this phase, the trees were intercropped with vegetables through a sharing arrangement between the forest company and local farmers. To protect the crop, the litter was usually taken out from the field by the farmers.

Necromass is dead standing trees or dead trees on the ground which is important component of carbon storage (Hairiah and Rahayu, 2007). However, necromass at this site was only found in 3 years old amounting of 0.0067 Mg/ha.

The pattern of carbon stock accumulation in *Acacia mangium* from this study can be compared with that of other fast growing species commonly used for forest plantation like pine (*Pinus merkusii*). At his study site in pine plantation forests in BKPH Leuwiliang, Bogor, West Java, Heriansyah (2005) found that the level of tree carbon stocks (aboveground and belowground) at 5 years old stands, which is slightly comparable with 5 years old stand in this study, was 14.37 Mg/ha. Both *Pinus merkusii* and *Acacia mangium* have good wood quality which can be exploited for pulp, sawn timber, and fuel wood. *Acacia mangium* has been suggested to have more rapid growth than pine (Perhutani, 1993, *cited in* Djumakking, 2003), consequently it can accumulate carbon faster. This research also supports this view, at least when we consider the growth in the first five years. The comparison demonstrates that the rate of carbon accumulation from *Acacia mangium* in this study (6.73 Mg/ha/year) is higher than that of *Pinus merkusii* reported by Heriansyah (2005), which is 2.8 Mg/ha/year. Total CO_2 can be calculated by multiplying total carbon stock by a simple ratio (44/12 = 3.66 is ratio of CO_2 to C, derived from atomic weights of carbon {12.011} and oxygen {15.9994}) (Butthep et al, 2008). Thus the rate of CO_2 sequestration from *Acacia mangium* is 24.67 Mg/ha/year.

GENERAL CONCLUSIONS

The amount of total carbon stocks in *Acacia mangium* plantation forest at Parung Panjang, West Java were 44.87 Mg/ha, 73.53 Mg/ha, 77.81 Mg/ha, and 72.88 Mg/ha for 1, 3, 5, and 7 years old stands respectively. This study also found that the major contributor to total carbon stocks in *Acacia mangium* stand up to 7 years old was soil carbon and then followed by aboveground tree biomass. The rate of carbon accumulation from *Acacia mangium* during the first seven years growth was 6.73 Mg/ha/year and this is equivalent with the amount of carbon sequestration of 24.67 Mg/ha/year.

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