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Conference Paper · November 2002

DOI: 10.13140/2.1.4899.4247

5 authors, including:

Rita Diana
Universitas Mulawarman

Deddy Hadriyanto
Universitas Mulawarman

Takeshi Toma
Forestry and Forest Products Research Institute (FFPRI-Japan)

Carbon Stocks of Fast Growing Tree Species and Baselines after Forest Fire in East Kalimantan, Indonesia

Rita Diana[1)], Deddy Hadriyanto[1)], Matoshi Hiratsuka[2)],
Takeshi Toma[3)] and Yasushi Morikawa[2)]

Abstract

In terms of sink activities in CDM, carbon credit is given to net carbon change in the CDM project site; subtraction of carbon in baseline from the carbon in man-made forest. However, there is little information about carbon accumulation from the view point of CDM. This paper deals with the case studies in both natural young secondary forests and man made forest in East Kalimantan, Indonesia. East Kalimantan has high possibility of CDM activity, because of degraded lands extend widely in 1998. The annual carbon accumulations of pioneer secondary forest in Bukit Soeharto Educational Forest (BSEF) ranged from 1.3 to 2.9 t C/ha/yr in 2000. However, the rate was decreased in 2001 except for *Macaranga gigantea* dominated stands. These figures were higher than those of regenerated vegetations in degraded land with herbs, shrubs and *Imperata cylindrica* grassland. On the other hand, annual carbon accumulation of *Acacia mangium*, *Eucalyptus pelitta* and *Gmelina arborea* were 5.9~9.9, 7.1~7.2, and 8.3~12.3 t C/ha/yr respectively. Highly degraded vegetations would be the target site for CDM projects. Naturally regenerated forest are not suitable for CDM project because of their high baseline.

Introduction

Many human activities adding to the concentration of carbon dioxide in the atmosphere has been continuing. This increasing concentration may come from industrial countries with their industrial waste and from developing countries from their negligence of caring environment such as forest and land fire. To reduce carbon dioxide emission by human activities, we rely on the existing vegetation, which is also decreasing in both area and composition. Understanding of forest and vegetation capacity in capturing carbon dioxide, particularly, in the tropics is ultimately important. There are, certainly some variation among many vegetation type of both natural and artificial.

Despite of its high capacity in carbon sequestration, variation of biomass accumulation capacity in the tropics is little known. Carbon capacity may differ according to its locality and species composition. Figures of various vegetation type and land use were collected. Study on carbon stock in Indonesian tropical region particularly in Sumatra region has been initiated (Mudiyarso et al. 2000; Rohani et al. 2000, and Setiawan et al. 2000). In East Kalimantan, biomass changes after fire 1982-1983, were investigated (Yamakura et al. 1986; Toma et al. 2000). This research was conducted in

[1)] Tropical Rain Forest Research Center, Mulawarman Univ., Jln.Ki Hajar Dewantara, Samarinda 75123, Indonesia
[2)] School of Human Science, Waseda Univ., 2-579-15 Mikajima, Tokorozawa, Saitama 359-1192, Japan
[3)] CIFOR, Jln. CIFOR Situ Gede, Sindang Barang, Bogor Barat 16680, Indonesia

both natural young secondary forest after fire and in plantation forest, aiming to view the difference between those two type of vegetation.

Material and methods

Location

Secondary forest site

The observation plots were established in Bukit Suharto Education Forest (BSEF), East Kalimantan. BSEF is located amidst Samarinda-Balikpapan highway approximately 50 km south from Samarinda, at 117°10'E longitude and 0°50'S latitude. The forest has experienced heavy fires for several times since 1983. The damage cause the 1998 fire was considered as the heaviest disaster (Mori, 2000). Before forest fire in 1983, most of the area was classified as tropical lowland dipterocarps forest. The dominant genus were Shorea, Dipterocarpus and Eusideroxylon. After fire about 60% of area became poor secondary forest dominated by fast growing species e.g. Macaranga, Trema, Homalanthus, Mallotus, Nauclea, Piper and many Solanaceae. The average annual rainfall from 1988 to 1998 was 2002 mm with the yearly mean air temperature were 29.9°C for daily maxima and 21.4°C for daily minima. The yearly mean relative humidity was 93.2% for daily maxima and 58.5% for daily minima (Toma et al. 2000).

To measure carbon accumulation, four associations of young secondary vegetation were selected for this research i.e. *Homalanthus populneus*, *Trema orientalis*, *Mallotus paniculatus* and *Macaranga gigantea* association. Plots were established and measured in September 2000. Second measurement was later conducted in September 2001. Experiencing heavy fire early 1998, most vegetation assumed as being 2.5 years old during the first measurement. Plot size was 10m x 10m providing the canopy height was less than 10 m high.

Plantation site

The observation was conducted in Plantation Forest owned by PT. Surya Hutani Jaya (PT. SHJ) in Sebulu, 70 km from north Samarinda, East Kalimantan. The located in between 116°45'E to 117°14'E longitude and 0°11'N to 0°21'S latitude. The soil of the site rich in clay belong to the ultisol (red yellow podzolic) soil group whereas typical lowland podzols could be observed, rich in coarse sandy deposits with annual rain fall 2.114 mm. The research was carried out in 3 and 4 year-old stands of *Acacia mangium*, 4 and 5 year-old stands of *Eucalyptus pelitta* and 3 stands of Gmelina *arborea* with 1, 3 and 5 year-old respectively.

Repeated weeding were done prior planting and 3, 5, 9, 17 months after planting. Herbicide was applied before planting and 11, 15 and 21 months after planting. Fertilization is done before planting and 4 months after planting. The spacing of all stands was 3x3m and was established as a second rotation in *Acacia mangium* plantation area while *Gmelina arborea* 5 year-old stand was established in secondary forest. Enrichment planting usually done in 1-2 month after planting.

Biomass measurement

Biomass were measured on both trees and undergrowth. In accordance to the diameter at breast height (DBH) distribution from preliminary survey of observation Plot. 5-6 sample trees of various diameters were selected for determining the coefficients of an allometric equation. The fresh weight of each organ of trees sample was measured and then small pieces of each organ were collected for calculating fresh and dry weight ratio. Samples were dried at 80^{o}C for 72-96 hours.

The biomass of all trees in the plot was calculated with the following allometric Equation (1)

$$y=ax^{b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

y: dry weight of each organ or whole tree.
x: the square of DBH.
a and *b*: coefficients.

Annual accumulation of carbon was expressed as MAI (mean annual increment) as product of total biomass divided by age of stand. The amount of carbon in tree estimated as the half (50%) of dry matter (JOPP, 2000).

Undergrowth biomass sample were collected on 1m X 1m plot outside of the tree plots. Four sample plots were located outside but close to the trees plot. All undergrowth were harvested and collected using plastic bags and further dried and weighed in the laboratory.

Result and discussion

Secondary forest site

Among those seven sample plots, three of them were dominated by *Macaranga*, two plots by *Homalanthus populneus*, and the other two by *Trema orientalis* and *Mallotus paniculatus*, respectively (Table 1). Those dominant trees developed in the most upper layer of the canopy. Most of *Macaranga* plots (Plot 5, 6 and 7) appeared with less undergrowth individual but higher in weight. Undergrowth in Macaranga plots accounted nearly three times than that in another plots. This may be related to more to canopy closure of wide *Macaranga gigantea* leaves, so that only selected woody undergrowth were grown (Table 1). On the other hand, *Mallotus*, *Trema* and *Homalanthus* plot have less undergrowth biomass.

The total biomass among plots in the secondary forest demonstrates a different figure (Table 2). Among three Macaranga plots (Plot 5, 6, and 7) there were a difference in biomass production. This may be related to the different composition of associated co-dominant species in each plots. The highest biomass production was observed in Plot 7 may due to higher tree density compared to the other two Macaranga plots.

Despite the decrease of mean annual increment (Table 2) in Plot 1, 2, 3 and 4, Macaranga dominated plot (Plot 5, 6 and 7) were increased. During the first measurement in 2000, accumulated biomass of two Macaranga plot were smaller than those other plots. However, if the undergrowth were added Macaranga plot continuously demonstrated higher biomass accumulation.

Plantation forest site

Both biomass and mean annual increment (MAI) in the plantations were higher than natural secondary forest (Table 2, 3). Biomass production varied among all species at the same age. In *A. mangium* for example increase was up to 125.63% compared to only 26.46% of *E. pelitta* within one year period. Surprisingly, increase of biomass production in *G. arborea* was markedly significant. The increase from 1 to 3 year after planting more than 5 times (543.50%) compared to 130.94% from 3 to 5 year after planting (Table 4, 5 and 6). It was likely that both *A. mangium* and *G. arborea* produced much higher biomass compared to *E. pellita* during this young stage. Nevertheless, this significant increase may not represented the real situation considering that in each species the samples of different age were taken from different compartment. In this case, the variation on site quality is obvious. This was also not a sequential or successive measurement.

In term of increment both *A. mangium* and particularly *G. arborea* indicated a constant increase. Meanwhile, a narrow increase occurred on *E. pelitta* where mean MAI was 14.26 in 4 year after planting compared to 14.43 in 5 year after planting. It indicates that for calculating carbon credit those three different species demonstrate different magnitude, and all figure were higher than those in secondary forest (baseline).

Young natural secondary forest, indeed, showed even smaller figure. However, this kind of forest is a transitional toward longer period of climax condition. This is of course, not similar to plantation forest which is shorter cycle and generally simple in species composition.

Under planted trees, undergrowth biomass, up to the age of less than 3 year, production seem similar to that in natural young secondary forest (Table 1) except that in Macaranga association. There was also no significant rate of production increase in line to increase of age (Table 3), so that this figures may represented a matter of variation. This particularly true, because undergrowth sample were not taken in a sequential year but in different plot at the same occasion. Theoretically, undergrowth may reduce after this age due to crown closure of the planted trees. Natural selection may later occur leaving only shadow demanding undergrowth remain.

Supposed that stem roles more as the saving component compared to leaves and branches as a temporary one, stem component accounted as 72.67% and 73.61% of 3 and 4 year *A. mangium*; 73.27% and 88.35% of 4 and 5 year *E. pellita*; and 50.24%, 65.47% and 84.61% of 1, 3 and 5 year *G. arborea* respectively. Despite of some variation among species and age, those figure indicated strongly that the stem component increased in line to the age increase.

Conclusion

Biomass production of young regenerated forest after fire was lower than that of man made forest during the developing stage. However, this successive stage should be considered as a temporary development that take longer time to achieve its maximum yield than fast growing industrial plantation with short rotation. Evaluating baseline in CDM activities should carefully taking into account the variation of vegetation type, species composition and site condition.

Acknowledgements

This study was conducted under research cooperation between Tropical Rain Forest Research Center, Mulawarman University, Samarinda, Indonesia and Waseda University, Tokyo, Japan. This grant was in the auspices of Global Environment Research Program granted by Japan Environmental Agency to whom we express our sincere gratitude.

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Table 1. Average undergrowth biomass production of plots in young secondary forest in BSEF measured in September 2000

Site	Dominant trees	Biomass (t /ha)	Carbon (t C/ha)
Plot 1 Plot 2	*Homalanthus populneus* *Trema orientalis*	8.67*	4.33
Plot 3 Plot 4	*Mallotus paniculatus* *Homalanthus populneus*	6.07*	3.03
Plot 5, 6, and 7	*Macaranga gigantea*	21.77	10.88

* indicates that samples of undergrowth biomass were taken in the adjacent site of both corresponding plots.

Table 2. Changes in above ground biomass of pioneer trees in secondary forest where vegetation were 2.5 year and 3.5 year during the first and second measurement with plot size was $100m^2$

Biomass of 2.5 year secondary forest after fire (measured in 2000)

Plot	Dominant species	Biomass		MAI	
		(t /ha)	(t C/ha)	(t/ha/yr)	(t C/ha/yr)
Plot 1	*Homalanthus populneus*	8.6	4.3	3.4	1.7
Plot 2	*Trema orientalis*	6.4	3.2	2.6	1.3
Plot 3	*Mallotus paniculatus*	12.2	6.1	4.9	2.4
Plot 4	*Homalanthus populneus*	10.9	5.5	4.4	2.2
Plot 5	*Macaranga gigantea*	7.7	3.9	3.1	1.5
Plot 6	*Macaranga gigantea*	7.2	3.6	2.9	1.4
Plot 7	*Macaranga gigantea*	14.4	7.2	5.8	2.9

Biomass of 3.5 year secondary forest after fire (measured in 2001)

Plot	Dominant species	Biomass		MAI	
		(t /ha)	(t C/ha)	(t/ha/yr)	(t C/ha/yr)
Plot 1	*Homalanthus populneus*	11.2	5.6	3.2	1.6
Plot 2	*Trema orientalis*	6.4	3.2	1.8	0.9
Plot 3	*Mallotus paniculatus*	15.2	7.6	4.3	2.2
Plot 4	*Homalanthus populneus*	13.4	6.7	3.8	1.9
Plot 5	*Macaranga gigantea*	11.8	5.9	3.4	1.7
Plot 6	*Macaranga gigantea*	12.6	6.3	3.6	1.8
Plot 7	*Macaranga gigantea*	24.0	12.0	6.9	3.4

Table 3. Average undergrowth biomass production under various age of *G. arborea*, *E. pellita* and *A. mangium* plantation forest in PT. SHJ, Sebulu, Kutai Kartanegara, East Kalimantan measured in January 2002.

Species	**Age** (year)	**Biomass** (t /ha)	**Carbon** (t C/ha)
G. arborea	1	7.23	3.62
G. arborea.	3	2.86	1.43
G. arborea	5	7.14	3.57
E. pellita	4	6.68	3.34
E. pellita	5	7.61	3.81
A. mangium	3	2.77	1.38
A. mangium	4	6.07	3.03

Table 4. Biomass production *of A. mangium* of 3 and 4 year after planting in PT. SHJ, Sebulu, Kutai Kartanegara, East Kalimantan.

Age (year)	**3**			**4**		
Area(m x m)	**15x15**			**21x21**		
Site no.	**1**	**2**	**Mean**	**1**	**2**	**Mean**
Mean DBH (cm)	9.17	8.42	8.80	16.70	17.13	16.92
Basal area(m^2/ha)	8.26	7.52	7.89	24.84	34.61	29.73
Biomass(t /ha)						
Stem	27.72	23.44	25.58	50.35	66.58	58.46
Branch	4.64	3.85	4.25	10.43	15.81	13.12
Leaves	5.62	5.12	5.37	6.41	9.27	7.84
Total above ground	37.98	32.41	35.20	67.19	91.65	79.42
Total (t C/ha)	18.99	16.21	17.60	33.60	45.82	39.71
Annual increment						
Biomass (t/ha/yr)	12.66	10.80	11.73	16.80	22.91	19.85
Biomass (t C/ha/yr)	6.33	5.40	5.87	8.40	11.46	9.93

Table 5. Biomass production of *E. pelitta* of 4 and 5 years after planting in PT. SHJ, Sebulu, Kutai Kartanegara, East Kalimantan.

Age (year)	**4**			**5**		
Area(m x m)	**15x15**			**25x25**		
Site no.	**1**	**2**	**Mean**	**1**	**2**	**Mean**
Mean DBH (cm)	9.93	8.26	9.10	11.61	12.52	12.07
Basal area(m^2/ha)	13.56	8.88	11.22	11.44	13.26	12.35
Biomass(t /ha)						
Stem	52.70	30.87	41.79	57.87	69.56	63.72
Branch	8.39	4.82	6.61	3.24	3.69	3.47
Leaves	10.78	6.49	8.64	4.48	5.39	4.94
Total above ground	71.87	42.18	57.03	65.59	78.65	72.12
Total (t C/ha)	35.93	21.09	28.51	32.80	39.32	36.06
Annual increment						
Biomass (t/ha/yr)	17.97	10.54	14.26	13.12	15.73	14.43
Biomass (t C/ha/yr)	8.99	5.27	7.13	6.56	7.87	7.22

Table 6. Biomass production of *G. arborea* of 1, 3 and 5 years after planting in PT. SHJ, Sebulu, Kutai Kartanegara, East Kalimantan.

Age (year)	**1**			**3**			**5**		
Area(m x m)	**10x10**			**15x15**			**21x21**		
Site no.	**1**	**2**	**Mean**	**1**	**2**	**Mean**	**1**	**2**	**Mean**
Mean DBH (cm)	5.54	3.51	4.53	13.18	13.63	13.41	14.64	14.64	14.64
Basal area(m^2/ha)	3.85	0.96	2.41	11.72	13.65	12.69	23.08	20.04	21.56
Biomass(t /ha)									
Stem	6.88	1.47	4.18	32.38	37.72	35.05	114.67	93.85	104.26
Branch	3.29	0.65	1.97	14.22	16.39	15.31	18.87	15.21	17.04
Leaves	3.81	0.54	2.18	2.93	3.41	3.17	2.00	1.84	1.92
Total above ground	13.98	2.66	8.32	49.54	57.52	53.53	135.54	110.90	123.22
Total (t C/ha)	6.99	1.33	4.16	24.77	28.76	26.77	67.77	55.45	61.61
Annual increment									
Biomass (t/ha/yr)	13.98	2.66	8.32	16.51	19.17	17.84	27.11	22.18	24.65
Biomass (t C/ha/yr)	6.99	1.33	4.16	8.26	9.58	8.92	13.55	11.09	12.32