ESTIMATION OF CARBON STOCKS AT TIMIMBANG FOREST RESERVE, SABAH

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SUMMARY

The increased in carbon dioxide (CO_2) emissions become global concerned due to its contribution to the earth's climate change. Forest plays a significant role in mitigating this change through its capacity to sequester CO_2 from atmosphere and also to store carbon in plant biomass. A study was conducted with the aim to estimate the carbon stock of forest in Sabah. A total of 58 research plots (circular plot with 20 meter radius) have been established in different stratums at Timimbang Forest Reserve Part A and B, Sabah. All trees with diameter size of more than 10cm found within the plot are measured its diameter at 1.3 meter height and identified. Estimation of above ground biomass of individual tree was done using an allometric equation developed by Brown (1997). The value of the biomass was then converted into carbon with assumption that 50% of the biomass is carbon. It was found that the values for carbon stock density in different forest stratum classes range from 27.9-204.08 t/ha. The average density of carbon stock for Timimbang Forest Reserve A and B is 108.67 t C/ha or 1.2 million ton for the whole area.

INTRODUCTION

Nowadays, global warming issue becomes the global concerned especially in the context of climate change. The issue focused on the causes, effects and how to fix the increasing of carbon emission and other GHG's gases. According to IPCC (Intergovernmental Panel on Climate Change), without any initiative to fix the issue, they predicted that the earth temperature expected to rise by 1.4 to 5.8C^0 in the end of 21st century. Burning fossil fuel emitted almost 60% of carbon dioxide in atmosphere and was the main cause of issue. Secondly was caused by land use change and deforestation which mainly occurred in tropics, contribute up to 1.8Gt or 20% global carbon dioxide emission annually (Baumert et al., 2004;. Dumanski, 2004). Another 20% is from emission of other GHG's gases such as N_2O, $CH_{4,}$ and F-gases.

As forest is concerned, these unique ecosystems provide various of roles not only in timber and non timber production for economic benefit but forest significantly function to form a major component of the carbon reserves in the world's ecosystems. In the term of "carbon sequestration", forest absorbs CO_2 from atmosphere through photosynthesis process and storing carbon in biomass and soil (Trexler and Haugen, 1994; Brown et al., 1996;Watson et al., 2000). Through the function of forest in sequestered and storing carbon, about two third of the terrestrial carbon is sequestered in the forests. In addition, Forest reacts to variation of climate and provides five pools of carbon, involved above-ground biomass, belowground biomass, litter, dead wood and soil organic carbon. However, the rate of carbon sequestration and carbon stocking are differ according to the forest stand growth and condition. Forest biomass owned long lives of growing capacity and in directly accumulates carbon over decades and centuries. Differ situation happened to other plants and crops, which have short lives and release most of the carbon in the end of a season. Even though forest biomass owned a long lives growing capacity and storing higher carbon, but it actually fragile when human activities such as deforestation taken part. Deforestation activities include land use change, indiscriminate logging and accidently forest fires. All these activities will cause the forest carbon released quickly, under such circumstances it become carbon source instead of carbon sink.

Like other countries, Malaysia had taken part in mitigate the carbon emission issue by being a signatory to The United Nations Framework Convention on Climate Change (UNFCCC) is committed to develop, periodically update, publish, and make available to the Conference of Parties (COP) its national inventories of emissions by sources and removals by sinks of all GHGs. The inventories are an essential aspect of studies of carbon stocks and the effects of deforestation and carbon sequestration on the global carbon balance and also provide valuable information for many global issues. The inventory carbon are also useful measure for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions.

Research project "carbon stocks assessment in sustainable forest management in Sabah" was approved and funded by the Ministry of Nature Resources and Environment under the RMK-9 Federal Devlopment Programmed. This five years (2006-2010) project has been allocated RM 1 million with main objective to assess the carbon sequestration and carbon stock in sustainable forest management in Sabah. This research has been conducted in several forest reserves in Sabah includes Timimbang Forest Reserve.

PROJECT SITE AND METHODOLOGY

STUDY AREA

Timimbang Forest Reserve was located in Beluran District of Sabah. Timimbang Forest Reserve (TFR) with total area of 11465ha was divided into two parts namely TImimbang Forest Reserve A (7927 ha) and Timimbang Forest Reserve B (3538ha) with geographic location between 6^0 3'- 6^0 10'N and 117^0 7'-117^0 16'E. TFR was a logged forest; however restoration and other forest management programmed being conducted. In year 2007, Sabah Forestry Department has done stratification for TFR. This stratification is interpreted based on 2.5m SPOT 5 Image. Both part of TFR was stratified into 3 forest strata, which is stratum 3, 4 and 5 indicate ranked from poor forest, very poor forest and treeless forest.

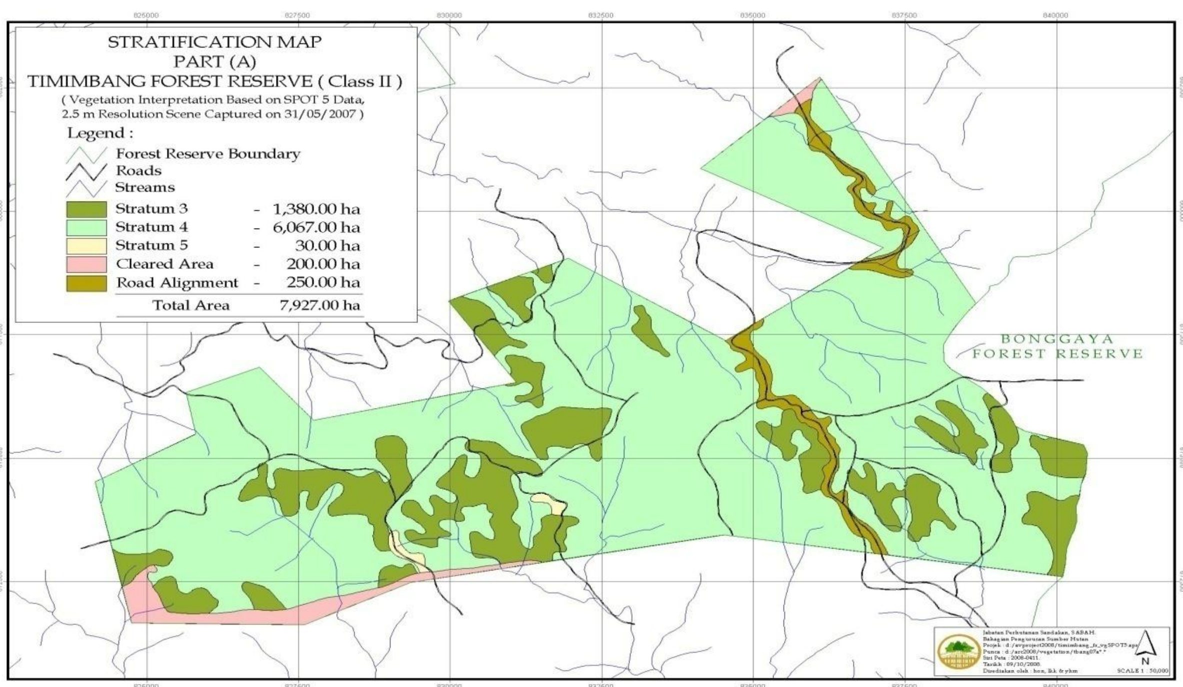

Figure 1: Timimbang Forest Reserve A

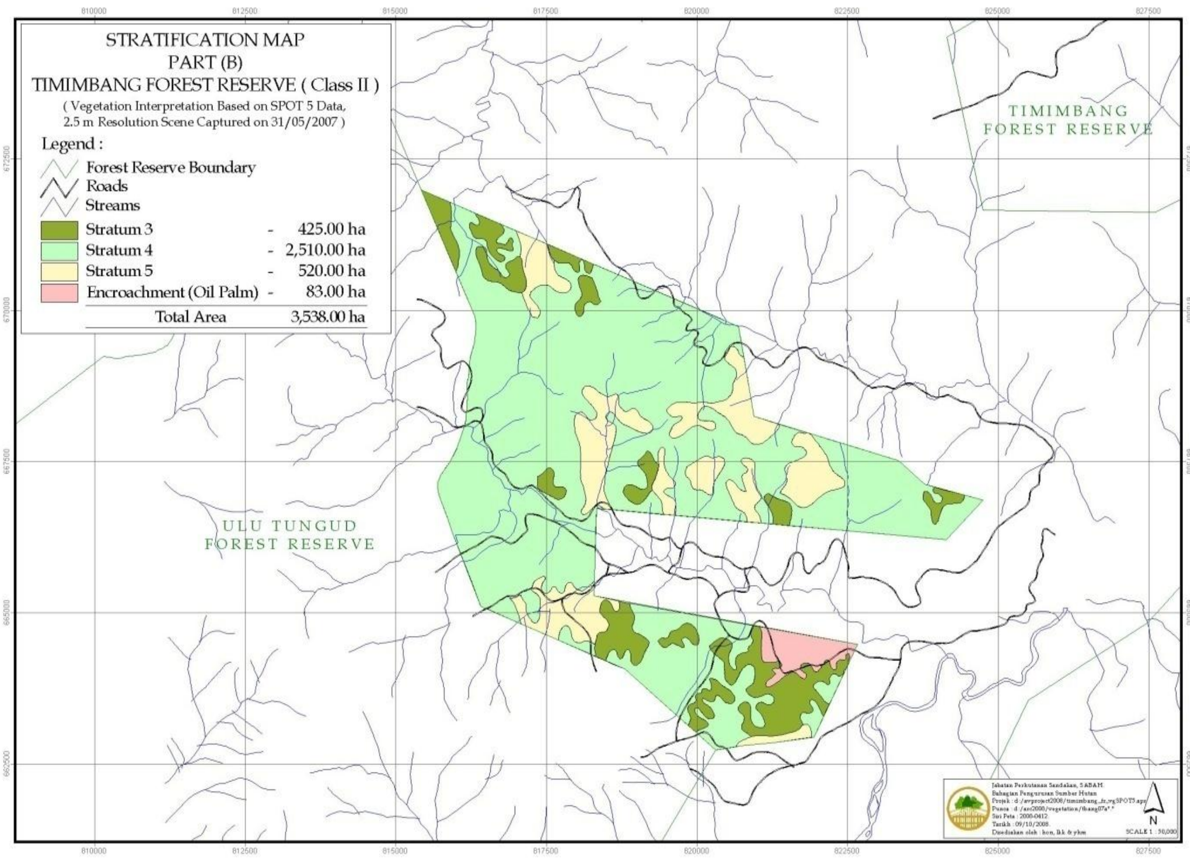

Figure 2: Timimbang Forest Reserve B

Field data collection

Field work for carbon assessment was conducted from May to December and fully completed at the end of December 2009. A total of 58 sampling plots were established with stratified random sampling design. 33 plots established in TFR part A and another 25 in part B. Sampling plot is in circular plot with 20m radius or 0.126ha per plot was used for the reason. Global positioning system (GPS) reading using Garmin GPSmap 60CSx was taken at the centre of the plot for easy marking of the plot in the map and also to facilitate when locating the plot in the field in future field work. For data collection, all individual trees of more than 10cm dbh existed within plots were measured its diameter at 1.3 height, trees were identified in the same time. The trees assessment begins at north 0° compass bearing, and sweeping in clockwise direction (Figure 3).

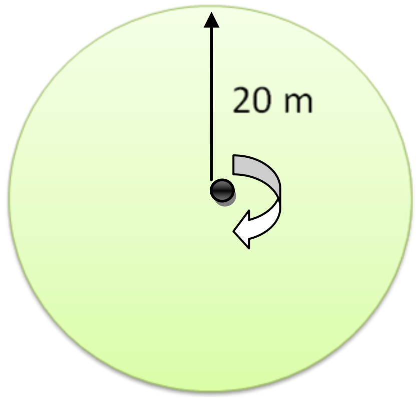

Figure 3: Sampling plot

Estimation of aboveground biomass (AGB) and carbon stock

Estimation of aboveground biomass of individual trees was done using an allometric equations developed by Brown (1997). The value of aboveground biomass was then converted into carbon with assumption that 50% of the biomass is carbon. Below was the allometric equation use to estimate the AGB.

$$\text{Weight (kg)} = \exp(-2.134 + 2.53 \times \ln(\text{dbh}))$$

RESULTS:

Distribution of plots

In this study, 58 sampling plots were established; below table was the distribution of sampling plots established in 3 different stratum classes at Timimbang Forest Reserve (TFR) A&B (table 1).

Table 1: Number of plots in different stratum classes

Stratum classes	# Plots (TFR A)	# Plots (TFR B)
3	6	4
4	24	17
5	3	4
Total	**33**	**25**

Aboveground biomass (AGB) and carbon stock

Timimbang Forest Reserve part A (TFR A)

The field work for TFR A was conducted in May to July. From the result shown in Table 2, AGB density value found highest in stratum 3 with 408 t/ha compared to stratum 4 and 5 with highest AGB value 368 and 252 t/ha. Same situation goes to carbon stock values; since the total carbon stock value was adopted by assumption 50% of AGB is carbon. Carbon stocks in these 3 stratums range from 41-204 C t/ha with the average 119.85 C t/ha. After the carbon stock value was converted into total area covered by the respective stratum classes, the largest carbon stocks was found in stratum 4 with 0.72 million tons carbon, as compared to stratum 3 and 5 with 0.17 million tons and 2370 tons respectively. Estimated total carbon stocks for the whole TFR A was almost 0.9 million tons. The summary of AGB and carbon stocks for 3 different forest stratums shown in Figure 4 and Table 2.

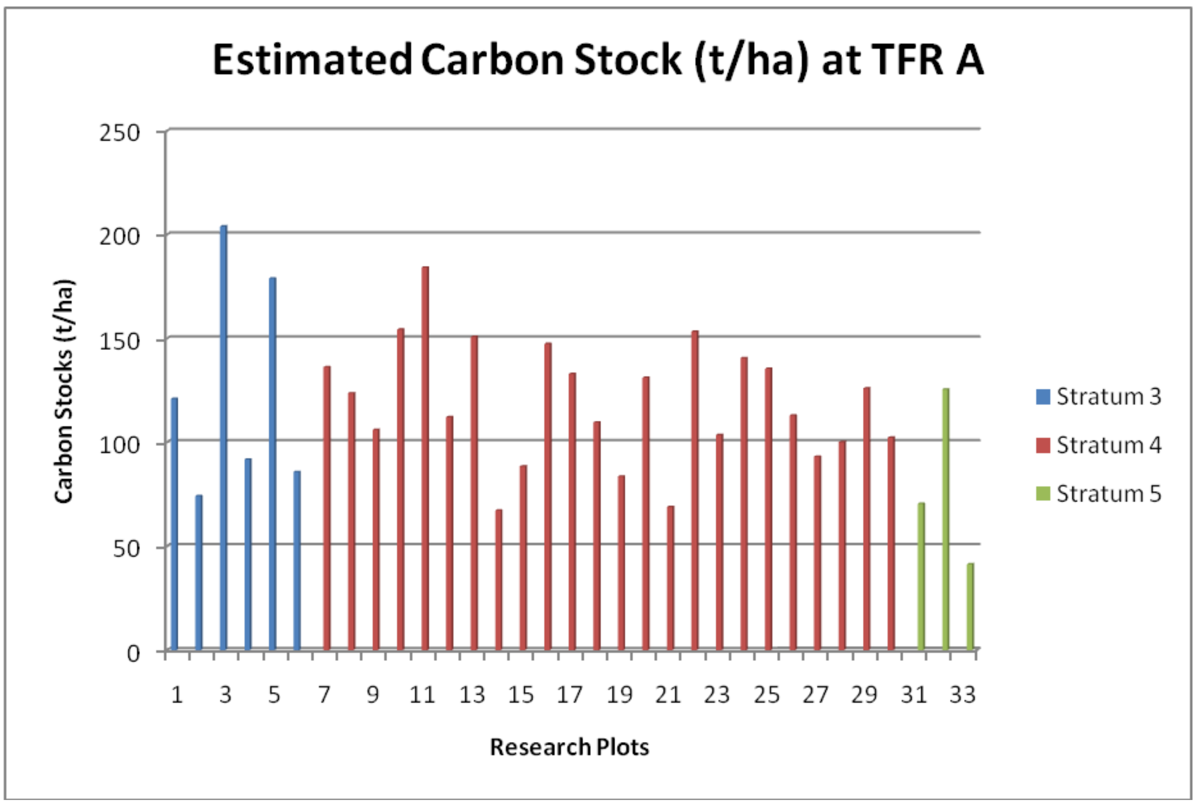

Figure 4: Estimated carbon stocks (C T/ha) at Timimbang Forest Reserve Part A

Table 2: The estimated AGB and carbon stocks for 3 different stratums classes.

Stratum	Total area (ha)	AGB ranges (t/ha)	Average AGB T/ha	C ranges (C t/ha)	Average carbon (C t/ha)	Total C
3	1380	148-408	252.04	74-204	126.02	173907.6
4	6067	134-368	236.66	67-184	118.65	719849.55
5	30	82-252	157.86	41-126	79.11	2373.3
TOTAL (t/ha)						**896130.45**

Timimbang Forest Reserve part B (TFR B)

For TFR B, field work was conducted in October to December 2009. Unlike TFR A, AGB and carbon stock density at TFR B found highest in stratum 4 with average carbon stocks 90.21 t/ha than in stratum 3 with 74.5 C t/ha (Table 3). Carbon stocks in these 3 different stratum ranges from the lowest 27.9 C t/ha in stratum 5 to the highest 123.06 C t/ha in stratum 4 (Figure 4). For TFR B, Average of carbon stocks was 84.18 C t/ha. The summary of carbon stocks for 3 different stratums in TFR B is as table 3. An estimated total carbon stock for the whole TFR B was almost 0.3 million tons.

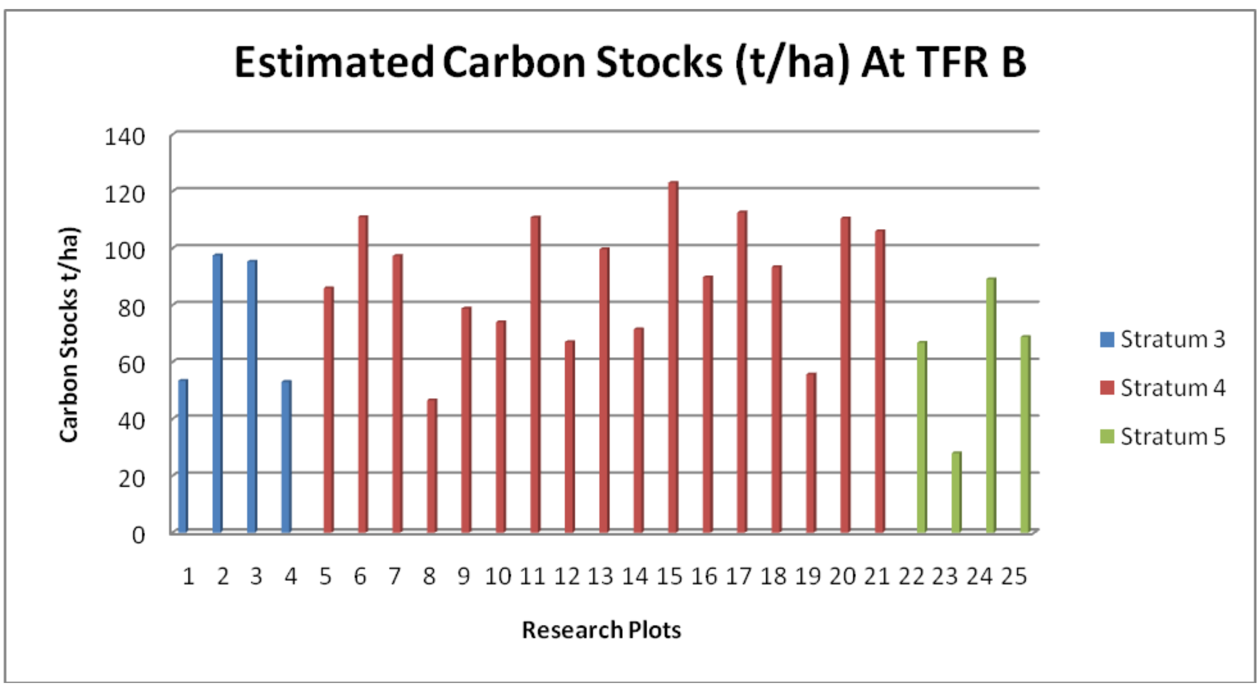

Figure 5: Estimated carbon stocks (C t/ha) at Timimbang Forest Reserve Part B

Table 3: Summary of carbon stocks for 3 different stratums.

Stratum	Total area (ha)	AGB ranges (t/ha)	Average AGB T/ha	C ranges (C t/ha)	Average carbon (C t/ha)	Total C
3	425	106-196	149	53-98	74.5	31662.5
4	2510	76-246	180.42	38-123	90.2	226402.0
5	520	56-178	126.02	28-89	63.01	32765.20
TOTAL (t/ha)						**290829.7**

Carbon stock distribution in different diameter classes

Timimbang Forest Reserve Part A

In this study, measured trees was grouped into 5 classes according to the DBH of trees which include 10cm-19cm, 20-29cm, 30-39cm, 40-49cm and greater than 50cm. The number of trees and carbon stock for different diameter classes in each stratum are shown in Table 4 and 5. From this study, trees in group 10-19cm dbh found highest in every single stratum with 63-76% of the total number in each stratum. However, in the case of carbon stock, diameter classes (40-49cm and >50cm) presented higher carbon stock compared to other diameter classes with 14-49% (40-49cm) and 12-46% (>50cm)of the total carbon stocks in all stratums.

Table 4: Number of trees distribution by dbh size class among stratum categories

	Number of Trees / ha					
Stratum	**10 - 19 cm**	**20 - 29 cm**	**30 - 39 cm**	**40 - 49 cm**	**>50 cm**	**Total**
3	318	56	18	11	13	**416**
4	367	116	53	25	16	**577**
5	454	122	61	41	9	**687**

Table 5: Carbon stock distribution by dbh size class among stratum categories

Stratum	Carbon stock (t/ha)					
	10 - 19 cm	20 - 29 cm	30 - 39 cm	40 - 49 cm	>50 cm	Total
3	22.66	23.42	28.72	36.26	14.96	**126.02**
4	18.71	21.89	24.59	21.86	31.6	**118.65**
5	16.07	9.66	7.88	8.85	36.72	**78.19**

Timimbang Forest Reserve Part B

For TFR B, trees in diameter classess (10-19cm) also contributed the highest number of trees with percentage ranges from 63-84% of the total number trees in all stratums. The least number of trees found in diameter classes (40-49cm) with percentage 0.7 to 3.5% of total number of trees in all stratums. Bigger trees contribute highest carbon stock value, ddb catogery greater than 50cm contribute up to 24-34% of total carbon stocks in all stratums. The number of trees distribution and carbon stocks of all diameter classes was shown in table 6 and 7.

Table 6: Number of trees distribution by dbh size class among stratum categories

Stratum	Number of Trees / ha					
	10 - 19 cm	20 - 29 cm	30 - 39 cm	40 - 49 cm	>50 cm	Total
3	429	113	24	4	10	**580**
4	387	161	34	16	16	**614**
5	239	60	18	12	14	**343**

Table 7: Carbon stock distribution by dbh size class among stratum categories

Stratum	Carbon stock (t/ha)					
	10 - 19 cm	20 - 29 cm	30 - 39 cm	40 - 49 cm	>50 cm	Total

3	21.33	20.40	11.52	3.01	18.23	**74.5**
4	18.30	16.45	16.49	13.93	25.02	**90.2**
5	11.72	11.0	7.52	11.36	21.54	**63.01**

Discussion:

Forest ecosystem provides 5 pools of carbon include aboveground biomass, belowground biomass, litter, soil and deadwood. Among these 5 pools, aboveground biomass hold the largest carbon stock compared to other. Therefore, biomass is easily being destructed due to human activities such as deforestation and degradation. In this study, total AGB value was estimated by using allometric equation which developed by Brown (1997). This equation was generated and specifically for broadleaf forest of tropical regions. Calculation of AGB and carbon stock using equation is more practical because is more cheaper, least time and environmental friendly, instead of using technique destructive sampling (cut trees and weigh it).

Timimbang Forest Reserve part A&B was stratified into 3 stratums by using remote sensing method. The stratification was based on crown cover of the trees. According to Brown (2002), from the creation of remote sensing, forest biomass can be easily estimated through satellite or aerial images, but the ground data collection is needed to develop a statistical relationship or calibration with satellite observed vegetation indices.

From the result shown in TFR A, the average density of carbon stocks was in accordance with the stratification. However, in TFR B, the AGB and carbon stock value was not representing the stratification stratum, when average carbon stocks value in stratum 4 found highest than in stratum 3 with difference of 15.7 C t/ha. In stratum 4, total number of trees much abandoned than in stratum 3 with different of 34 trees. In addition, the number of large diameter trees (>40cm) was high, and directly contribute the biggest carbon stocks than in stratum 3. This scenario may cause by total number of sampling plot used in study is not enough to represent the stratum. Other factor affected this scenario may from the stratification of using remote sensing. The interference of clouds during stratification will do affect the inaccurate stratification of stratum.

In Ramachandran *et al* (2007) study, geospatial technology was used to estimate carbon stock in Kolli hills natural forest Eastern Ghats Tamil Nadu India, reported average carbon stock 108 T C/ha was found in their study. In our study, an average carbon stock of TFR was 108.67 C t/ha, no significantly difference of average carbon stocks. The average carbon stocks value reported by Ramachandran *et al* is actually higher than in our study that is because in their study, only diameter trees from 30cm above was taken into account to estimate aboveground biomass and carbon stocks. The difference of study site might differ in terms of forest type which includes stands volume, trees species and etc. Refer to our study, average of carbon stock for 10-29.9cm diameter trees can contribute average of 35.27 C t/ha. If they estimate carbon stocks from diameter trees from 10cm above, it can increase the value of carbon stock to ~143.27 T C/ha (after added 35.27 T C/ha) assuming that similar number of forest stand (diameter 10-29.9cm) existed in both study.

Long term study conducted by Put *et al* (2008) in Malaysia, they predicted that carbon stocks for the next cycle of harvest in forest with improved management (SFM and RIL practiced) are projected at least 30 ton per hectare than conventional logging. Refer to this statement, Timimbang Forest Reserve Part A and B with total size about 10932 hectares forested area, an additional of 0.3 million tons of carbon could be sequestered compare to conventional logged forest if improved management implemented.

In this study, estimation of carbon stocks was limited to aboveground biomass. This estimation would be more complete by estimates other pools of carbon which involved below ground biomass, litter, dead wood and soil organic carbon. Further research required improved methodology and technique to estimate carbon stocks. Due to various sites condition and species, this study can be repeated with modification made to the allometric calculation in answering question relevant to the sites specific. Application of other technique to estimate carbon stocks such as remote sensing data survey is useful to shorten the time frame in data collection.

Conclusion:

Total forested area for Timimbang Forest Reserve A was 10923ha and estimated can stock carbon as much as 1.2 million tons of carbon and average carbon stocks 108.67 C t/ha. Forest condition with higher number of smaller trees can contribute additional carbon sequestration in the forest when these trees growing up without any disturbance and silviculture treatment being applied. Enrichment planting and restoration programmed that currently being conducted will do increase the carbon stocks of the forest reserve.

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