Species Composition, Diversity and Carbon Stock in Kyaukmasin Reserved Forest

Capacity Building for Developing REDD-Plus Activities

in the Context of Sustainable Forest Management

ITTO REDD+ PROJECT

RED-PD 038/11 Rev.3 (F)

ABSTRACT

Reducing Emissions from deforestation and forest degradation in developing countries (REDD+) has been one of the key issue in international climate negotiations within the United Nations Framework Convention on Climate Change (UNFCCC). To provide a sound scientific base for effort taken to reduce emission from deforestation and degradation (REDD+) good estimates of C stocks are important. Thus, this study was conducted to access the stem density, tree diversity, biomass and carbon stocks in the Kyaukmasin forest and make recommendations for forest management based on priorities for biodiversity protection and carbon sequestration. According to the Jackknife estimator for species richness (trees with DBH ≥ 5 cm), 45 species were recorded in the forest. The Shannon-Wiener diversity index was 3.39. Stem density was 186 tree ha^{-1} while total carbon stock (aboveground, belowground, litter, deadwood, soil) was 312.48 $tCha^{-1}$. *Tectona grandis* was ecologically important species while *Garuga pinnata* had higher carbon storage in Kyaukmasin reserved forest. Investigating the species composition and estimating carbon storage in the natural forests as done in this study would provide the baseline information for proposing appropriate intervention for managing tropical forests under the anticipated REDD+ scheme.

Keywoards: aboveground carbon, belowground carbon, carbon pools, natural forest.

LIST OF CONTENT

Tables

Figures

INTRODUCTION

Background

Tropical deforestation is a source of greenhouse gas (GHG) emissions, accounting for up to one-third of global emissions (Houghton 2005). Deforestation and degradation in the tropics have caused the loss of biodiversity and ecosystem services (Foley et al. 2007; Costanza et al. 1997). These huge emissions and biodiversity loss prompted the intergovernmental Panel on Climate Change (IPCC) to recognize the urgent need for preventing carbon emissions from tropical forests as largest and most immediate carbon stock impact in the short term (IPCC 2007). Now a day, Reducing Emissions from deforestation and forest degradation in developing countries (REDD) has been one of the key issue in international climate negotiations within the United Nations Framework Convention on Climate Change (UNFCCC).

REDD+ scheme focus not only on reducing carbon emissions from deforestation and degradation but also on safeguarding biodiversity and socio-economics of forest-dependent communities. So, monitoring of tree diversity and forest structure is pre-requisites for understanding and managing forest. Knowledge on their structure and dynamics are necessary in order to understand how forest ecosystems organize and function (Nebel et al. 2001). Beside, understanding the condition of species composition and diversity before any plan take a principle in stand is necessary (Farhadi et al. 2013).

Detailed ground-based quantifications of total carbon stocks in tropical forests are few despite their importance in science and ecosystem management (Sierra, et al., 2007). Estimating carbon stocks and their distribution in different ecosystem pools is important to understand the degree to which C is allocated to labile and stable components. This information is useful to estimate the amount of C that is potentially emitted to the atmosphere due to land use changes as well as from natural or human-caused fire events. Estimates of carbon stocks in tropical ecosystems are of high relevance for understanding the global C cycle, the formulation and evaluation of global initiatives to reduce global warming, and the management of ecosystems for C sequestration purposes. However, detailed knowledge about the absolute and relative distribution of C stocks in tropical forests is still limited (Houghton, 2005). That why this study was designed to measure baseline carbon stocks in natural forest for supporting REDD readiness in Myanmar.

Objectives

The objectives of this research are;

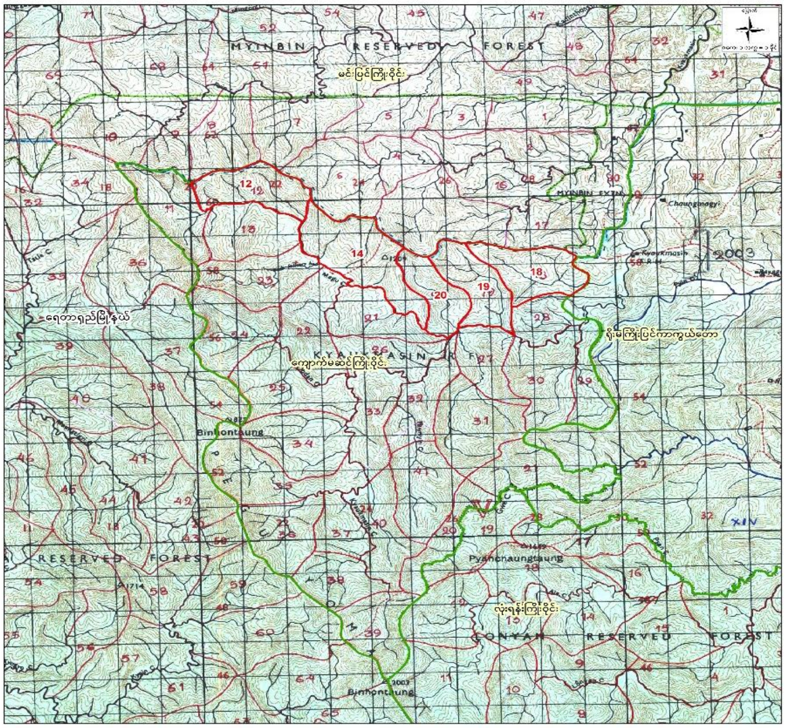
- to investigate species diversity and species composition,
- to estimate carbon storage capacity in each pools (aboveground, belowground, litter, deadwood, soil).

CHAPTER 3

METHOD

Study area

The study was conducted in Kyaukmasin Reserved Forest, Yaetashe Township in Myanmar. Yaetashe Township is located between 17° 23´ N and 95° 49´ E**.** Mean maximum and minimum monthly temperatures were 33°C and 4°C, respectively, the mean annual rainfall was about 1895 mm.



Legend

🟩 Reserved Forest Boundary

🟥 Compartment Boundary

🟦 River/ stream

Figure 1. Location of Kyaukmasin Reserved Forest

Forest Inventory

The vegetative data for this study were collected from Compartment 20, Kuaukmasin Reserved Forest, Yartarshe Township. Diameter at breast height (dbh) of all trees (dbh≥ 5 cm) were measured in compartment 20. Plant species identification was achieved by using the "A Checklist of the Trees, Shrubs, Herbs and Climbers of Myanmar" (Kress, Defilipps, Farr, & Kyi, 2003), local name and taxonomic experts.

In order to measure the 5 carbon pools, six square sample plots 1600 m^2 (40m x 40m) were constructed. The diameter breast height (dbh ≥ 20 cm) and high (Ht ≥ 1.3m) of all trees were measured in the sample plot.

Each sample plot was divided into four equal square subplots of 20m x 20m. The subplots were named as compartment A1, A2, A3 and A4. In one compartment, tree (20 cm ≥ dbh ≥ 5 cm, Ht ≥ 1.3m) and deadwood (dbh > 10 cm, Ht or length > 1.3m). Snag, log, stump are counted as a deadwood.

A 100 m^2 (10m x 10m) subplots were allocated in the corner of a two compartments, A2 and A3. Such subplots were also named as sub-compartment B1 and B2 and bamboo clump were measured in these sub-compartment. Within the sub-compartment B1 and B2, 25 m^2 (5m x 5m) subplots were set up to measure the sapling (dbh ≤ 5 cm, Ht ≥ 1.3m). It was refer to as C1 and C2. In order to collected shrub and litter layer, 4 m^2 (2m x 2m) subplots, D1 and D2, were laid out at the corner of sub-compartment.

For the soil organic carbon (SOC), six points were selected and 100 cm^3 of soil samples were collected in 10 cm depth intervals (to a total depth of 30 cm) at each point starting at 0cm. Representative soil samples from the reserved forest were pooled, sealed in a plastic bag and transported to the laboratory of the Forest Research Institute (FRI) in Yezin, Myanmar for testing.

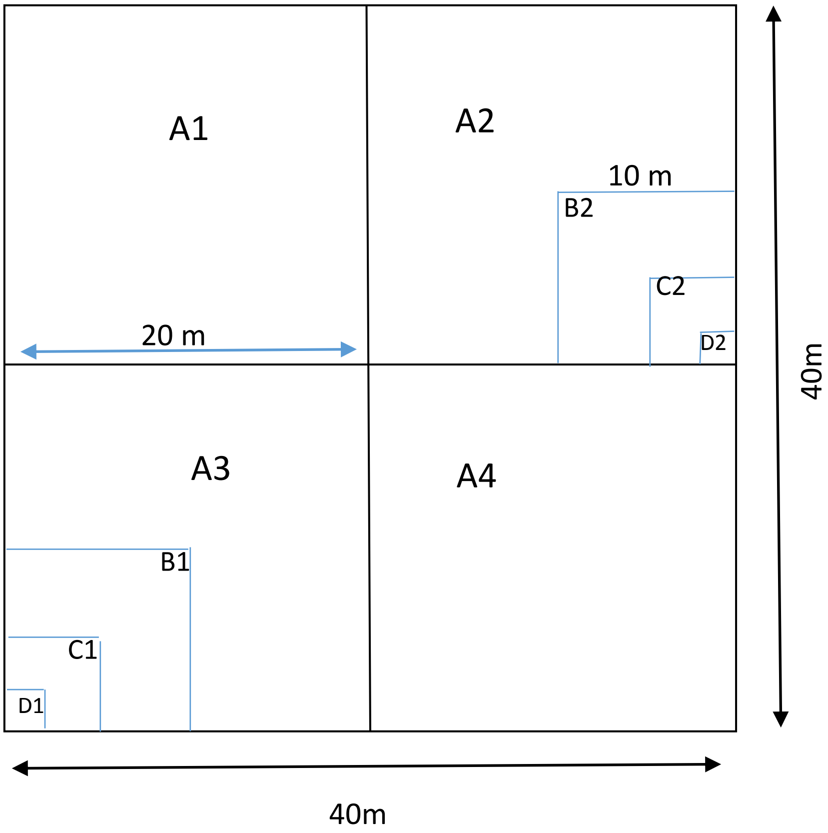


Figure 2. The layout of the sample plot

Vegetative analysis

1. Important Value Index (IVI)

To access the ecological important or significance of a species, important value index was used in this study. Important value index (IVI) was calculated for each species by adding up relative density (RD) + relative frequency (RF) + relative coverage (RC) or relative basal area (RBA), thus permitting a comparison of the ecological significance of species in a given forest types. Density is the number of individuals per species, frequency is the occurrence or absence of a given species in a sample plot. Coverage is considered as an equivalent of the space a tree is occupying in the stand, which is calculated as the basal area of a species. The IVI was calculated as:

$$\text{Importance value (IV)(\%)} = \text{RD} + \text{RF} + \text{RBA}$$

$$\text{Relative density (RD) (\%)} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative frequency (RF) (\%)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

$$\text{Relative basal area (RBA)(\%)} = \frac{\text{Basal area of a species}}{\text{basal area of all species}} \times 100$$

2. Simpson’s diversity index (D)

Simpson’s diversity index gives more weight to those species which occur more frequently (Lamprecht 1989). Simpson’s index ranges from 0 to 1. The closer it is to 1, the less diverse the community. The index is usually expresses as **1 – D** because diversity decrease as D increase.The formula measuring the species diversity is as follows:

$$D = \sum_{i=1}^{s} \left[\frac{n_i \, (n_i - 1)}{N \, (N - 1)}\right]$$

Where D is the **Simpson’s index of diversity**, n, is the number of individuals of species “ I “ in the sample, s is the number of species in the sample $\sum ni$, N is the total number of individuals in the sample (Simpson, 1949).

3. Shannon Wiener diversity index (H')

Shannon diversity index (H') was used to provide the quantitative estimates of plant diversity.

$$H' = \sum_{i=1}^{s} -(P_i)(\ln P_i)$$

Where H' is the **Shannon-Wiener function**, S is the number of species, Pi is the proportion of total sample belonging to " ith " species, and ln is the theoretical maximum value of diversity ($\log_2$) (Magurran, 1988).

4. Shannon evenness index (E)

Evenness indices, which are a structural composition index reflecting the dominance of species were calculated using the following formular:

$$E\ (\%) = 100\left(\frac{H'}{\ln H_{max}}\right)$$

Where E is the **Shannon' s Evenness**, H' is the Shannon-Wiener function, H_{max} is the ln(S)- the theoretical maximum value of diversity by a given number of total species (S) found in the sample .

Carbon measurement

1. Measurement of aboveground carbon

Diameter at breast height (DBH) and height of all trees (DBH ≥ 5 cm) were measured in each plot. Aboveground carbon (AGC) (tonne C·ha^{-1} or tC hereafter) was estimated using the equation below (S. Brown, 1997)

$$\mathrm{AGC} = \mathrm{VOB} \times \mathrm{WD} \times \mathrm{BEF} \times \mathrm{CC} \tag{1}$$

where, VOB (m^3·ha^{-1}) is stand volume over bark. WD (Mg·m^{-3}) is wood density (WD = 0.57 Mg·m^{-3}) for tropical forests (S. Brown, 1997). Carbon content default value (CC) 0.47 was used (IPCC, 2006). BEF is the biomass expansion factor, determined from (S. Brown, 1997).

$$\mathrm{BEF} = \mathrm{e}^{\left[3.213\text{-}506 \times \mathrm{Ln}(\mathrm{BV})\right]} \tag{2}$$

where, BV is the biomass of inventoried volume in ton·ha^{-1}, calculated as the product of stand VOB (m^3·ha^{-1}) and wood density, WD (WD = 0.57 Mg·m^{-3}) for tropical forests (S. Brown, 1997).

2. Measurement of belowground carbon

For this study, an allometric equation developed by Carins (Cairns, Brown, Helmer, & Baumgardner, 1997) was used to calculate belowground carbon (BGC),

$$\mathrm{BGC} = \mathrm{e}^{[-1.0587 + 0.8836 \times \mathrm{Ln}(\mathrm{AGB})]} \times \mathrm{CC} \tag{3}$$

where, AGB = aboveground biomass in ton.

Carbon content default value (CC) 0.47 was used to estimate the carbon content of tree biomass as proposed by the IPCC (IPCC, 2006). The root/shoot ratios of the dry biomass (as well as carbon) will be calculated for each species.

3. Measurement of litter layer carbon

Litter layer were collected from 2 subplots, D1 and D2, having size of 4m^2 (2 m x 2 m) were established in each sample plot. All litter layer inside the frame were collected and weighed in the field. The litters were mixed thoroughly and samples (approximately 200 g) were collected in each subplot. Collected samples were oven-dried (80^{o}C) until constant weights were obtained (Kenzo et al., 2009). The biomass of each sub-plot was calculated by the ratio of dry and fresh weight of the sample. A carbon content default value of 0.47 was used to estimate the carbon content of tree biomass as proposed by the IPCC (IPCC, 2006).

$$\text{Biomass (kg)} = \frac{\text{Sample dry weight}}{\text{Sample fresh weight}} \text{ X Total fresh weight} \tag{4}$$

4. Measurement of deadwood carbon (Coarse woody debris)

The volumes of all fallen logs and standing dead trees greater than 10 cm diameter were measured within the 20 m x 20 m plots. Full enumeration was the preferred method within the 20 m x 20 m, because some plots contained the majority of their CWD debris in a few large, misshapen and partially decayed logs (Stewart and Burrows, 1994). It was deemed more appropriate to carefully measure all logs than to marginally reduce within-plot measurement time, incurring the risk of not counting them, and increasing sampling error. Full enumeration also enables tracking of standing trees through time should they fall or be blown over.

Standing dead trees and logs were identified by species whenever possible, and were categorized into one of three broad decomposition classes: (a) bark largely intact;

(b) bark and twig lost, but shape of trunk remaining intact; and (c) shape no longer maintained, and trunk sinking into ground. Two measurements of diameter were made at right angles to one another at both ends of each log, and length was measured.

Where a log protruded outside a plot, its length was taken only to the point of exit, and its diameter was measured at that point. Similarly, when a log tapered to below 10 cm diameter, its length was taken only to that point. The diameters of the trunk and major branches of standing dead trees were estimated by eye. The volume of each log was calculated as:

$$\mathrm{LV} = \frac{\pi \times l}{32}\left[(a+b)^2 + (c+d)^2\right]$$

where the log has length l, orthogonal diameters of a and b at one end, and c and d at the other. The C-stock is estimated by multiplying log volume by the deadwood density. Deadwood density decreases considerably as logs decay, because the shape is largely retained while the log becomes increasingly hollowed by saprophytic organisms.

For each log in a plot that could be identified by species, a species-specific basic wood density was multiplied by the appropriate decay-stage modifiers to obtain a dead-wood density. As it was difficult to identify all logs to species a mean fresh-wood density (490 kg/m^3) was used. The decay stage modifiers: Stage I, bark largely intact, 0.82; Stage II, bark and twig lost, but shape of trunk remaining intact, 0.66; Stage III, shape no longer maintained, and trunk sinking into ground , 0.47 were used (Coomes et al., 2002). The biomass of all CWD (CWD-B) in the plot was derived using the equation as:

CWD biomass = ∑ (log volume) x (fresh-wood density) x (decay-stage modifier)

Carbon content of each CWD was calculated as 47% of dry weight (biomass).

5. Measurement of Bamboo carbon

Investigate the occurrence of bamboo in the plots (Subplot B_1 and B_2). Identify the bamboo species and record it along with the number of bamboo trees, diameter, and height. In the case bamboos are in clumps, record the average diameter, height, and the number of bamboo trees in clumps. Biomass of a bamboo is calculated by the following allometric equation and the carbon stock is calculated by multiplying the carbon conversion factor 0.47 recommended by IPCC.

$$Y = 0.189D^{1.956}$$

where: D is the diameter at breast height [cm], Y is the aboveground bamboo biomass (kg).

For the belowground bamboo biomass, the ratio of 0.27 was applied in this study by following the ratio that applied in “Myanmar Country Report on Bamboo Resources, 2005,” published by FAO. Accordingly, the estimation of underground biomass carbon stocks are estimated by the following equation;

$$Bamboo\ belowground\ biomass = Bamboo\ aboveground\ \ biomass \text{ x } 0.27$$

6. Measurement of sapling carbon

Dbh and total height were recorded for all sapling (dbh ≤ 5cm and ht ≥ 1.3m) in the subplot C_1 and C_2. Measuring of the biomass followed the destructive method (IPCC 2003). Sample trees were felled, the root were excavated and fresh weight were measured. Sample were taken from each component for biomass estimation. Samples from each component were pooled, sealed in a plastic bag, and transported to the laboratory of the Forest Research Institute (FRI) in Yezin, Myanmar. Samples were dried in an oven at 80 C for a week until constant weights were obtained (Kenzo et al., 2009). The biomass of a tree was calculated by the ratio of dry and fresh weight of the samples. A carbon content default value of 0.47 was used to estimate the carbon content of the tree's biomass as proposed by the IPCC (2006).

7. Measurement of understory carbon

The understory biomass including seedling, grass, shrub, climber and herb was determined directly using harvesting method, and fresh weight were measured. Samples were collected to determine moisture content and calculate dry weight. Samples were oven-dried at 80 °C for at least 48 hrs, and weighted The total dry weight of biomass fuel as live and dead parts were converted from fresh weight and dry weight ratios from the sampling area based on the following equation. C-stock in biomass was calculated based on IPCC 2006 by multiplying the 0.47 conversion factor to the biomass (IPCC, 2006).

$$Total\ DW\ (kg\ m^2) = \frac{Total\ FW\ (kg) x\ Subsample\ DW\ (g)}{Subsample\ FW\ (g) x\ Sample\ area\ (m^2)}$$

8. Soil organic carbon

Soil organic carbon (SOC) of 30 cm depth was estimated in each forest type (Batjes, 1996; IPCC, 2006). A 100 cm^3 of soil samples were taken from each different layer (0-10 cm, 10-20cm, 20-30cm). Intergovermental Panel on Climate Change (IPCC, 2006) recommended that the minimum sampling depth should be 30 cm depth. Likewise, this is the most common reference depth used in related studies (Mohanraj et al., 2011; Oo, 2009). Therefore, 30 cm depth was selected in order to facilitate comparison with international literatures. Each soil sample was placed in a plastic bag and sealed in the field. Then all samples were taken to the Forest Research Institute, Myanmar for testing.

Soil bulk density (g cm^{-3}) was determined by getting the quotient of the dry weight of the soil (gram) and bulk volume of the soil (cm^3). The weight of soil (Ws) for each soil layer was calculated by multiplying the volume (m^3) of soil per hectare (Vs) and the soil bulk density (BD) (g cm^{-3}).

$$\mathbf{Ws = Vs \times BD} \tag{7}$$

To estimate the soil organic matter (OM) content, a soil sample were analyzed by loss on ignition (LOI) method, and at conversion factor of 0.58 was used to convert OM to SOC (Konen, Jacobs, Burras, Talaga, & Mason, 2002)

$$\text{Organic matter content } (\%) = \frac{\text{weight before ignition} - \text{weight after ignition}}{\text{weight before ignition}} \times 100 \tag{8}$$

Per ha SOC was estimated by multiplying the weight of soil per ha in metric ton (Ws) and the content of SOC in percent (% SOC) (Batjes, 1996; Lal, 2000).

$$\mathbf{CD = Ws \times \%SOC} \tag{9}$$

where: *CD* is the carbon density (Mg/ha or ton/ha), *Ws* is the weight of soil (Mg or tons) and *SOC* is the soil organic carbon (%).

$$\boldsymbol{Vs = l \times w \times d} \tag{10}$$

where: *Vs* = the volume of soil (m^3), *l* = the length of soil equivalent to 100 m, *w*= the width of the soil equivalent to 100 m, and *d* = the depth of the soil equivalent to 30 cm (0.3m).

RESULTS AND DISCUSSION

Species Composition and Diversity

Based on the inventory data, 45 species were found in Kyaukmasin Reserved Forest. Mean stand density 186 trees ha^{-1} was recorded in the study area. Mean basal area was 21.57 m^{2} ha^{-1} and mean volume was 242.83 m^{3}ha^{-1}. The mean tree height was 12.3 m and mean DBH was 30.2 cm. The forest occupied the high value of Shannon-Wiener index and Simpson diversity index, 3.39 and 0.95, respectively. Both diversity indexes indicated that the species diversity of the forest is the high. If the percentage of evenness j (%) was close to 1.0, the species in the forest were abundant. Shannon's evenness (j), 89.27%, shows that Kyaukmasin forest have high species diversity.

Table 1. Characteristic of Kyaukmasin RF

Parameter	Kyaukmasin RF
Mean dbh (cm)	30.2
Mean Ht (m)	12.3
BA (m^{2}ha^{-1})	21.5
Vol (m^{3}ha^{-1})	242.8
Stand Density (trees ha^{-1})	186
Species richness (ha^{-1})	45
Simpson's diversity index (1-D)	0.95
Shannon-Wiener function (H')	3.39
Species Evenness (j)	89.27

Table 2. Fifteen highest species Important Value Index of Kyaukmasin Reserved Forest

Scientific Name	**SD (tree ha^{-1})**	**R.A (%)**	**R.F (%)**	**R.B.A (%)**	**IVI (%)**
Tectona grandis	32	17.32	5.49	15.24	12.68
Garuga pinnata	7	3.91	3.30	14.97	7.39
Xylia xylocarpa	4	2.23	3.30	12.10	5.88
Schleichera oleosa	7	3.91	3.30	8.07	5.09
Mitragyna rotundifolia	10	5.59	4.40	3.23	4.40
Vitex pubescens	8	4.47	3.30	2.86	3.54
Heterophragma adenophylla	6	3.35	3.30	3.66	3.44
Anogeissus acuminata	8	4.47	3.30	1.81	3.19
Albizia lucidior	6	3.35	2.20	2.47	2.67
Terminalia chebula	3	1.68	3.30	2.99	2.65
Shorea siamensis	6	3.35	1.10	3.29	2.58
Cratoxylum ligustrinum	7	3.91	2.20	1.30	2.47
Lagerstroemia villosa	5	2.79	3.30	1.29	2.46
Millettia multifolia	5	2.79	3.30	1.26	2.45
Derris robusta	4	2.23	2.20	2.77	2.40
Others	65	34.64	52.75	22.70	36.69
Total	**186**	**100**	**100**	**100**	**100**

SD = Stand Density, RA = Relative Abundance, RF = Relative Frequency, RBA = Relative Basal Area, IVI = Important Value Index

To assess the ecologically important species, the important value index (IVI) was used. The highest IVI value belonged to the species *Tectona grandis* in the investigated forest. *Tectona grandis* was the most frequently occurring species and most important species with Important Values Index (IVI) of 12.68 % represented by 32 individual trees with relative frequencies of 5.49 % and Relative Abundance (RA) of 17.32 % (Table 3). The second and third important species are *Garuga pinnata* (7.39% IVI, 3.91% RA) and

Xylia xylocarpa (5.88% IVI, 2.23 % RA). The result of our study suggests that *Tectona grandis* is an ecologically important species of Kyaukmasin reserved forest.

The number of individual in DBH size distribution of tree in the forest decrease with an increase in DBH. The DBH distributions showed that a high proportion of trees present belonged to the small diameter class. A few trees in diameter classes > 70 cm were found in the forests. The abundance of lower DBH tree suggested that the study are have a good regeneration to be able to replace when the old one die. The findings indicate where tree density was generally higher in small DBH classes compared to large DBH classes, this is a secondary forest characteristic. The pattern of relative basal area (RBA) is slightly decrease by increasing DBH classes. The diameter classes 30 - 40 cm and over 100 cm occupied the large basal area per ha.

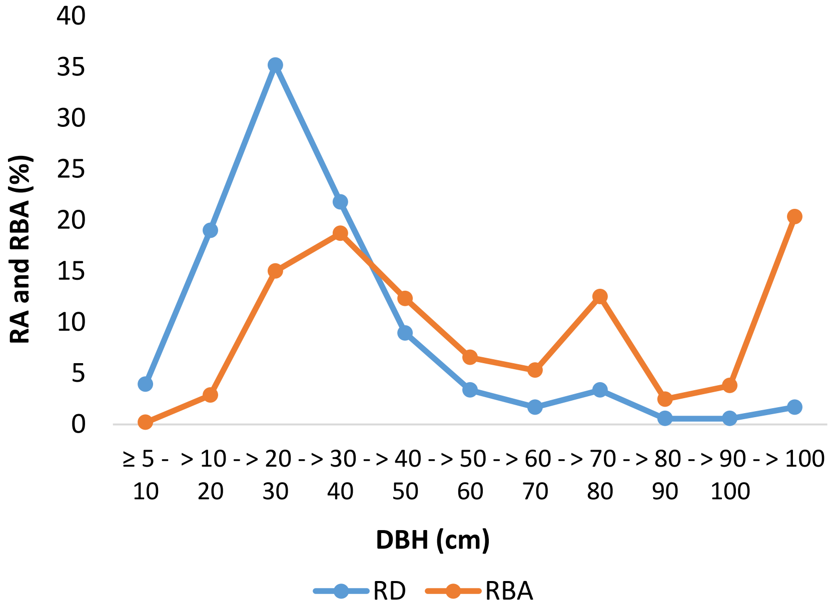


Figure 3. Relative Abundance and Relative Basal Area according to DBH class

Carbon Stock

1. Aboveground Carbon

1.1 Carbon stock in dominant species

In Kyaukmasin Reserved Forest, the highest AGC was found in *Garuga pinnata*, 25.02 tCha^{-1}, followed by *Tectona grandis*, 15.11 tCha^{-1} and *Xylia xylocarpa* 14.31 tCha^{-1}. Though mean DBH of *Xylia xylocarpa* (73.7 cm) is larger than *Garuga pinnata* (65.4 cm), the stand density of *Xylia xylocarpa* (3 tree ha^{-1}) is lower than *Garuga pinnata* (18 tree ha^{-1}). The stand density influences on the carbon storage of the tree (Perea Cordero and Kanninen, 2003) as well as forest. In term of stand density, *Tectona grandis* (32 tree ha^{-1}) was higher than *Garuga pinnata* (7 tree ha^{-1}) but mean DBH size of *Tectona grandis* (33.4 cm) was smaller than *Garuga pinnata* (65.4 cm). Therefore, the result indicating that tree size effect on the carbon storage of forest. The accumulation of biomass and carbon related to different tree diameter (Brown, 1997) and Biomass and carbon per tree increase geometrically with increasing diameter (Brown, 1997). Dominant 15 tree species occupies 86 % of total carbon stock.

Table 3. Fifteen highest carbon storage species in Kyaukmasin Reserved Forest

Scientific Name	**Mean DBH (cm)**	**Mean Ht (m)**	**SD (tree ha^{-1})**	**BA (m^2 ha^{-1})**	**Vol (m^3 ha^{-1})**	**AG-C (tC ha^{-1})**
Garuga pinnata	65.4	21.7	7	3.23	53.68	25.02
Tectona grandis	33.4	13.8	32	3.29	32.42	15.11
Xylia xylocarpa	73.7	16.1	4	2.61	30.72	14.31
Schleichera oleosa	46.6	11.6	7	1.74	17.24	8.03
Heterophragma adenophylla	32.9	12.6	6	0.79	10.89	5.07
Holoptelea integrifolia	77.6	36.7	1	0.49	10.83	5.04
Bombax ceiba	49.5	18.3	2	0.50	7.47	3.48
Terminalia chebula	49.0	16.7	3	0.65	7.27	3.38
Derris robusta	35.7	12.5	4	0.60	7.26	3.38
Mitragyna rotundifolia	27.4	13.0	10	0.70	6.22	2.90
Bombax insigne	42.1	13.9	3	0.54	6.17	2.87
Vitex pubescens	26.8	11.1	8	0.62	5.67	2.64
Shorea siamensis .	37.3	10.6	6	0.71	4.56	2.12
Hymenodictyon orixense	39.3	17.5	2	0.29	4.10	1.91
Albizia lucidior	31.7	11.7	6	0.53	3.87	1.80
Other	23.1	10.5	82	4.30	34.48	16.07
Total	**30.2**	**12.3**	**186**	**21.57**	**242.83**	**113.20**

SD = Stand Density, BA = Basal Area, Vol = Volume, AG-C = Aboveground Carbon

1.2 Carbon allocation in diameter class

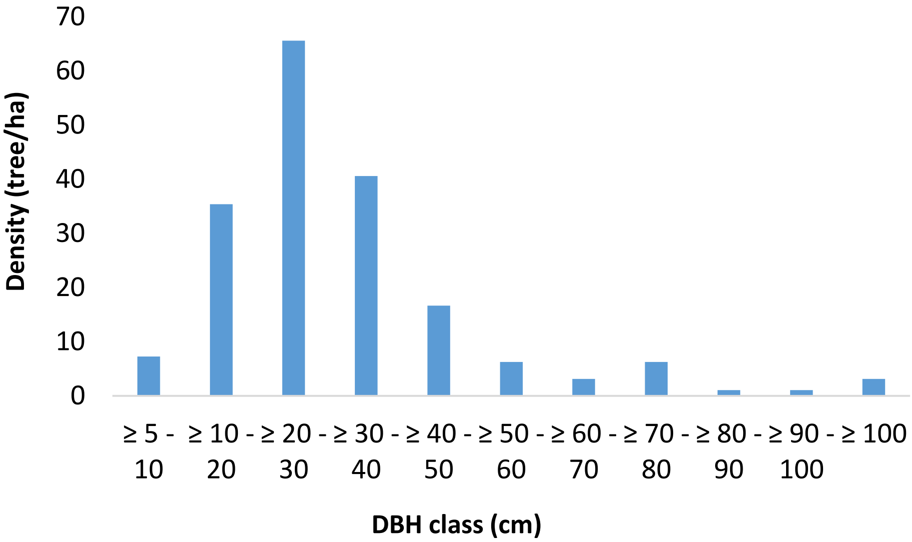


Figure 4. Tree density according to DBH class

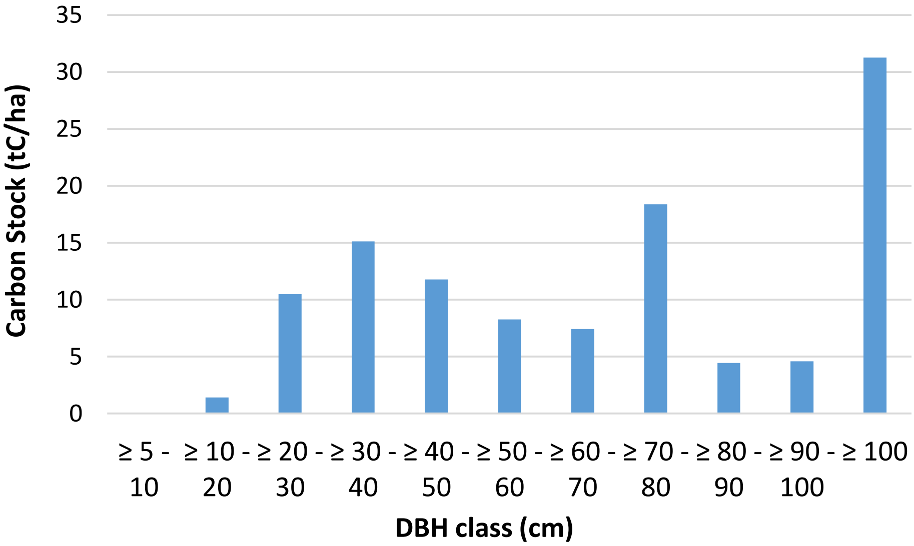


Figure 5. Carbon allocation in different DBH classes

The most aboveground carbon accumulation was found in the tree size class at ≥ 100 cm in the forest because these tree size classes had the highest stem volume and basal area (Figure 5). The high stand density was found in small DBH classes and a few tree in large DBH class (Figure 4). Therefore this study found that high stand density with small trees are not much effect on carbon stock of the forest if compare with low stand density with large tree. It support the statement of Brown (S. Brown, 1997), he mentioned that the accumulation of the biomass and carbon per tee is geometrically related with DBH size. The percentage data of tree density and aboveground carbon were presents in **Table 4**. The largest number of stem are found in DBH class ≥ 5 – 40 cm. But the highest carbon storage, more than 50% of total aboveground carbon, was found in ≥ 100 cm and ≥ 70 – 80 cm DBH class.

Table 4. A Comparison of the percentage of tree density and carbon sequestration potential in each DBH size class

DBH Classes (cm)	**Density (tree ha^{-1})**	**Density (%)**	**Aboveground Carbon (tC ha^{-1})**	**Aboveground Carbon (%)**
≥ 5 - 10	7	4	0.06	0
≥ 10 - 20	35	19	1.41	1
≥ 20 - 30	66	35	10.47	9
≥ 30 - 40	41	22	15.12	13
≥ 40 - 50	17	9	11.77	10
≥ 50 - 60	6	3	8.27	7
≥ 60 - 70	3	2	7.43	7
≥ 70 - 80	6	3	18.39	16
≥ 80 -90	1	1	4.45	4
≥ 90 - 100	1	1	4.57	4
≥ 100	3	2	31.26	28
	186		**113**	

2. Belowground carbon (Root Carbon)

Bray (Bray, 1963) and Cairn (Cairns et al., 1997) suggested that biomass allocation to roots can be estimated based on aboveground allometries. Belowground carbon was calculated based on aboveground carbon by using Cairn equation (Cairns et al., 1997). In the forest, 36.91 $tCha^{-1}$ is allocated in the root, around 30 percent of aboveground carbon. The root to shoot ration obtained in the present study was within the range of 9% to 33% for forest and woodland (Coomes & Grubb, 2000). It may be due to the available soil moisture is strongly correlated with root biomass allocation, with water stress causing greater biomass allocation to root (Murphy and lugo, 1986; Sanford and cuevas, 1996).

3. Litter Layer Carbon

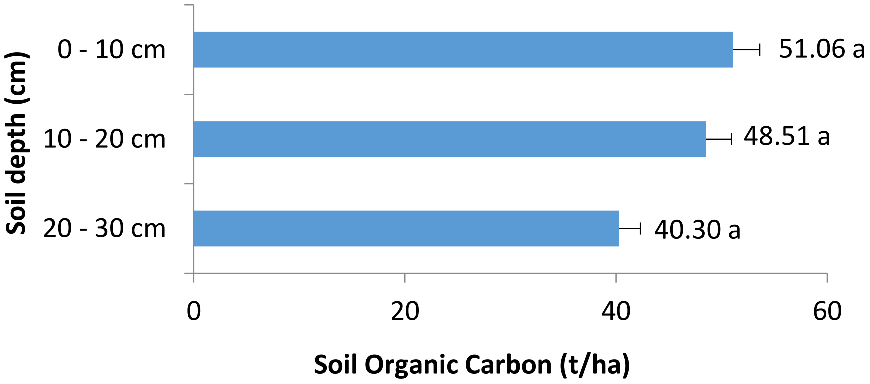
Litter is defined as all detached and dead leaves, flowers, fruits, seeds, bark fragments, and deadwood less than 2,5 cm in diameter (Jaramilo, 2003). It was found that litter layer carbon in the forest, 5.19 ± 2.8 t Cha^{-1}. This finding was higher than the India forest 0.16 to 3.26 $tCha^{-1}$ (Mohanraj, 2011), deciduous forest in Alaungdaw Kathapa National Park, Myanmar [1] (Oo, 2009), 3.8 $tCha^{-1}$ and Natural secondary forest in China, 3 $tCha^{-1}$ (Zheng et al., 2007). Because the dominant species in the forest is *Tectona grandis* (12.68%, IVI). The leave of *Tectona grandis* are large and decomposition rate is slower than small leave, thus, compile in the forest floor. Therefore, Kyaukmasin reserved forest accumulate higher carbon than other studies.

4. Deadwood Carbon

Full enumeration (>10cm diameter of standing and fallen deadwood) was done within the 20m x 20m plot and these measurements converted to per-hectare C-stocks. The carbon stock in the deadwood was 30.85 ± 10.69 tC ha^{-1}. Deadwood carbon stock in this study was close to deadwood of the watershed area in New Zealand, 30.2±27.6$tCha^{-1}$, (Staley, 2010) and similar with South Island forests in New Zealand, 29.0 $tCha^{-1}$ (Coomes et al., 2002). And this research findings was in line with Clark (Clark et al., 2002) who mentioned that the estimates of CWD stocks in tropical forest from 0 to > 60 tha^{-1} in term of biomass, 0 to > 30 $tCha^{-1}$ in term of carbon. Dead wood patterns and dynamics vary with biophysical factors, disturbance history and management practices (Kennedy et al., 2008).

5. Soil Organic Carbon

The total soil organic carbon (up to 30 cm) accumulated by Kyaukmasin Reserved Forest is 122.22 ± 5.41 ton ha^{-1}. Soil organic carbon accumulations are decreasing in increasing soil depth. The top soil layers are occurred higher SOC than other layers but no significantly different among soil depth.



Note: Different letters indicate the significant differences in SOC among the soil depths according to Ducan's multiple range tests at 5% level of probability. The letters are the rank order from highest to lowest value (alphabetically).

Figure 6. Soil Organic Carbon by soil depths

The average SOC results per hectare for the **upper 30 cm** of Kyaukmasin reserved forest (122.22 ± 5.41 ton ha^{-1}) was less than the results obtained by Mohanraj who estimates SOC in mixed forest, 148.86 $tCha^{-1}$, deciduous forest, 246.02 $tCha^{-1}$ and Evergreen forest, 209.54 $tCha^{-1}$ in the upper 30 cm of Kolliforest eastern Ghats, India (Mohanraj et al., 2011). Moreover, this findings also less than the estimated values for Oo (Oo, 2009) **for 0-30 cm** of 181.0 $tCha^{-1}$ for Oktwin Teak bearing forest, 192.4 $tCha^{-1}$ for Latpanpin Community forest and 195.2 $tCha^{-1}$ for Alaungdaw Kathapa national Park forest.

The soil organic carbon may be influenced by forest density and altitude. The soil organic carbon content may depend upon physiography or location of the study soil profile (Dadhwal, Palria, & Chhabra, 2003) and land use change (Post & Kwon, 2000), conversion of closed forests to open forests (Jose, Koshy, & Joes, 1972). Moreover, root biomass and litter production constitute important factors affecting the soil organic carbon (Zheng et al., 2007).

6. Total Carbon Stock in Kyaukmasin Reserved Forest

Total average carbon stocks in the study forest were estimated at 312.48 $tCha^{-1}$ and the highest percentage of carbon was allocated to the soil. The trend of carbon storage in the forest was soil > aboveground > belowground > deadwood > litter. The proportion of carbon storage was shown in **Figure 7.** In the investigated forests, around 39 percent of carbon was accumulated in the soil. Aboveground carbon allocation is around 37 percent of total carbon and belowground was 12 % of total carbon. Deadwood (coarse wood debris) store 10 percent of total carbon stock and litter layer accumulated 2% of total carbon. The largest SOC stock are found in the soil, as expected.

Table 5. Carbon stock in each component

	tC ha^{-1}	**SE**
Aboveground (Stem)	113.20	20.58
Belowground (Root)	36.91	6.11
Sapling	2.49	2.09
Undergrowth	0.99	0.21
Bamboo	0.62	0.22
Litter layer	5.20	2.83
Deadwood	30.85	10.69
Soil	122.22	5.41
Total	**312.48**	**31.59**

Table 6. Carbon stock in each carbon pool

	Aboveground	**Belowground**	**Litter**	**Deadwood**	**Soil**	**Total**
tC ha^{-1}	117.30 (20.38)	36.91 (6.11)	5.20 (2.83)	30.85 (10.69)	122.22 (5.41)	312.48 (5.41)

*Aboveground = Tree aboveground carbon, sapling carbon, undergrowth carbon, bamboo carbon

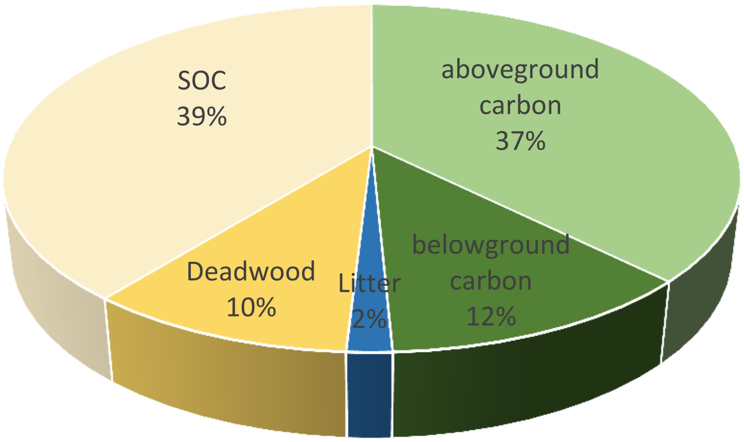


Figure 7. Percentage of carbon content in each pool

CONCLUSION

This study designed to estimate species composition, diversity and carbon stocks in the Kyaukmasin reserved forest, Yetarshe Township. Forest inventory was conducted in the compartment No.20 Kyaukmasin reserved forest. 45 species are recorded in the study area. There were plentiful trees with small DBH, suggesting that natural regeneration capacity for this forest is good. The study also shows that the forest have a high degree of floristic heterogeneity. Our study findings suggested that the forest was rich in terms of tree species and large trees still remained in the forests. The distribution of trees in the forest displays an inverse J distribution where stem frequencies decrease with the increase in DBH, indicating stable condition of naturally regenerated trees in the study sites. In order to know the current carbon stock, this study estimated 5 carbon pools (aboveground, belowground, litter, deadwood and soil) in the forest. Among carbon pools, soil store highest carbon followed by aboveground carbon and belowground carbon, deadwood and litter. The storage of higher C in the forests emphasizes the importance of maintaining and increasing the number of reserved area.

Effective forest restoration strategies need to know the condition of the forest, tree species composition, and stand structures. Information provided in our study is useful for introducing future policy interventions, conservation measures, and forest restoration in Kyaukmasin reserved forest. This study provides a baseline carbon storage of the deciduous forest in Yaetashe Township. However, species diversity, density and carbon stocks may vary for different forests and different ecological region, which are topics of further research.

REFERENCES

Batjes, N. H. (1996). Total carbon and nitrogen in the soils of the world. European Journal of Soil Science, 47, 151–1633.

Bray, J. R. (1963). Root production and the estimation of net productivity. Canadian Journal of Botany, 41(1), 65–72.

Brown, S. (1997) Estimating Biomass and Biomass Change of Tropical Forests: A Primer. FAO Forestry Paper-134, Rome.

Cairns, M. A., Brown, S., Helmer, E. H. and Baumgardner, G. A. (1997). Root biomass allocation in the world's upland forests. Oecologia, 111, 1–11.

Cairns, M. A., Brown, S., Helmer, E. H. and Baumgardner, G. A. (1997). Root biomass allocation in the world's upland forests. Oecologia, 111, 1–11.

Clark, D. B., Clark, D. A., Brown, S., Oberbauer, S. F. and Veldkamp, E. (2002). Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. Forest Ecology and Management, 164(1-3), 237–248.

Coomes, D. A. and Grubb, P. J. (2000). Impacts of root competition in forests and woodlands : A theoretical framework and review of experiments. Ecological Monographs, 70(2), 171–207.

Coomes, D. A., Allen, R. B., Scott, N. A., Goulding, C. and Beets, P. (2002). Designing systems to monitor carbon stocks in forests and shrublands. Forest Ecology and Management, 164, 89–108.

Costanza, R., Arge, R., Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., d O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P and Belt, M. (1997). Natural, 387, 235-260.

Dadhwal, V. K., Palria, S. and Chhabra, A. (2003). Soil organic carbon pool in Indian forests. Forest Ecology and Management, 173, 187–199.

Farhadi, P., Soosani, J., Alijani, V and Adeli, K (2013). Comparison of the Quercus brantii and Pyrus glabra boiss species structure in Zagros forests (Case Study : Ghalehgol Forest , Khoramabad City , Iran) Department of Forestry , Lorestan University , Iran

Foley, J. A., Asner, G. P., Costa, M. H., Coe, M. T., DeFries, R and Gibbs, H. K. (2007). Amazonia revealed: forest degradation and loss of ecosystem goods and services in the Amazon Basin, Front Ecol Environ, 5(1): 25-32.

Houghton, R. A., & Hole, W. (2005). Aboveground Forest Biomass and the Global Carbon Balance**, Global Change Biology**, 11, 945–958. doi:10.1111/j.1365-2486.2005.00955.x

Intergovernmental Panel on Climate Change (IPCC) (2006) Guidelines for National Greenhouse Gas Inventory: Agri- culture, Forestry and Other Landuse. Vol 4, IPCC (Intergovernmental Panel on Climate Change).

Intergovernmental Panel on Climate Change. (2003). Good Practice Guidance for Land Use , Land-Use Change and Forestry. (J. Penman, M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, et al., (Eds.). Intergovernmental Panel on Climate Change National Green House Gas Inventory Program. Japan.: Technical Suport Unit, Institute for Global Environmental Strategies.

IPCC. (2007c). Climate Change 2007: Synthesis Report. Summary for Policymaker. In L. Bernstein, P. Bosch, O. Canziani, Z. Chen, R. Christ, et al (Ed.). In **Summary for Policymakers**. **Report** adopted section by section at Intergovernmental Panel on Climate Change (IPCC) Plenary XXVII, Valencia, Spain, 12-17 November 2007.

Jaramillo, V. J., Kauffman, J. B., Renteria-Rodriguez, L., Cummings, D. L. and Ellingson, L. J. (2003). Biomass, carbon, and nitrogen pools in Mexican tropical dry forest landscapes. **Ecosystems**, 6, 609–629.

Jose, A. I., Koshy, M. and Joes, A. I. (1972). A study of the morphological, physical and chemical characteristics of soils as influenced by Teak Vegetation: 1. Indian Forester, 98, 338–345.

Kennedy, R. S. H., Spies, T. A. and Gregory, M. J. (2008). Relationships of dead wood patterns with biophysical characteristics and ownership according to scale in Coastal Oregon, USA. Landscape Ecology, 23(1), 55–68.

Kenzo, T., Furutani, R., Hattori, D., Kendawang, J. J. T., Anaka, S., Sakurai, K. and Ninomiya, I. (2009). Allometric equations for accurate estimation of aboveground biomass in logged-over tropical rainforests in Sarawak , Malaysia. J For Res, 14, 365–372.

Kenzo, T., Furutani, R., Hattori, D., Kendawang, J. J. T., Anaka, S., Sakurai, K. and Ninomiya, I. (2009). Allometric equations for accurate estimation of aboveground biomass in logged-over tropical rainforests in Sarawak , Malaysia. J For Res, 14, 365–372.

Konen, M. E., Jacobs, P. M., Burras, C. L., Talaga, B. J. and Mason, J. A. (2002). Equations for predicting soil organic carbon using loss-on-ignition for North Central U.S. Soils. Soil Science Society of America Journal, 66(6), 1878.

Kress, W. J., Defilipps, R. A., Farr, E., & Kyi, Y. Y. (2003). **A checklist of the trees, shrubs, herbs and climbers of Myanmar**. Department of Systematic Biology--Botany, National Museum of National History, 2003. Contributions from the United States National Herbarium. Washington, DC

Lal, R. Kimble J. M. and Stewart, B. A. (Eds.) (2000). Advance in Soil Science. Global climate Change and Tropical Ecosystems. Florida, US.: CRC Press. Boca Raton.

Lamprecht, H. (1989). **Silviculture in the tropics: tropical forest ecosystems and their species-Possibilities and methods for their long-term utilization**. Institute for Silviculture of the University of Gottingon. Germany.

Magurran, A.E. (1988) **Ecological Diversity and Its Measurement**. Croom Helm, London, 178. [29]

Mohanraj, R., Saravanan, J. and Dhanakumar, S. (2011). Carbon stock in Kolli forests, Eastern Ghats (India) with emphasis on aboveground biomass, litter, woody debris and soils. iForest - Biogeosciences and Forestry, 4(2), 61–65.

Murphy, P. G. and Lugo, A. E. (1986). Ecology of tropical dry forest. Annual Review of Ecology and Systematics, 17(1), 67–88.

Nebel, G., Dragsted, J and Vega, A. S. (2001). Litter fall, biomass and net primary production in flood plain forests in the Peruvian Amazon. Forest Ecology and Management, 150: 93-102.

Oo, T. N. (2009). Carbon sequestration of tropical deciduous forests and forest plantations in Myanmar. The Republic of Korea: Seoul National University.

Post, W. M. and Kwon, K. C. (2000). Soil carbon sequestration and land-use change: Processes and potential. Global Change Biology, 6, 317–328.

Sanford, R. J. and Cuevas, E. (1996). Root growth and rhizosphere interactions in tropical forestsTropical Forest Plant Ecophysiology. In S. S. Mulkey, R. L. Chazdon and A. P. Smith (Eds.). Tropical forest plant ecophysiology (pp. 268–300). Boston, MA: Springer US.

Sierra, C. A., Jorge, I., Orrego, S. A., Moreno, F. H., Harmon, M. E., Zapata, M., Colorado, G. J., Lara, W., Restrepo, D., Berrouet, L., Loaiza, L. and Benjumea, J. F (2007) Total carbon stocks in a tropical forest landscape of the Porce region , Colombia. Forest Ecology and Management, 243: 299-309.

Simpson, E.H. (1949) Measurement of Diversity. Nature, 163, 688.

Staley, C. E. (2010). Modelling of above-ground and belowground carbon in a New Zealand Native Forest at the Watershed Scale. New Zealand: Lincoln University.

Stewart, G.H.; Burrows, L.E. 1994. Coarse woody debris in old-growth temperate beech (Nothofagus) forests of New Zealand. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 24: 1989-1996.

Zheng, H., Ouyang, Z., Xu, W., Wang, X., Miao, H., Li, X. L., & Tian, Y. (2007). Variation of carbon storage by different reforestation types in the hilly red soil region of southern China. **Forest Ecology and Management**. 255 (3-4) 1113-1121.