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Estimation of Carbon Storage of Different Forest Types to Support REDD+ in Myanmar

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မြန်မာနိုင်ငံ၏ သစ်တောပြုန်းတီးခြင်းနှင့် သစ်တောအတန်းအစားလျော့ကျခြင်းမှ ကာဗွန်ထုတ်လွှတ်မှုလျော့ချခြင်းလုပ်ငန်းများဆောင်ရွက်ရာတွင် အထောက်အကူပြုစေရန် သစ်တောများ၏ ကာဗွန်စုပ်ယူသိုလှောင်မှုကို လေ့လာခြင်း

ဒေါက်တာယုယအေး၊ ဦးစီးအရာရှိ
မူမူအောင်၊ လက်ထောက်သုတေသနအရာရှိ
သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်းချုပ်

ကမ္ဘာ့ပေါ်တွင် မှန်လုံအိမ်ဓါတ်ငွေ့ လျော့ချရေးလုပ်ငန်းများ ဆောင်ရွက်ရာတွင် သစ်တောများသည် အရေးပါသောအခန်းကဏ္ဍတွင် ပါဝင်နေသောကြောင့် ကမ္ဘာ့ရာသီဥတု ပြောင်းလဲမှု လျော့ချရေးအဖွဲ့၏ လုပ်ငန်းများတွင် သစ်တောပြုန်းတီးခြင်းနှင့် သစ်တော အတန်းအစားကျဆင်းခြင်းမှ ကာဗွန်ထုတ်လွှတ်မှုလျော့ချခြင်း (REDD+) လုပ်ငန်းများသည် အဓိကအခန်းကဏ္ဍမှ ပါဝင်လျက်ရှိသည်။ သစ်တောပြုန်းတီးခြင်းကြောင့် ကာဗွန်ထုတ်လွှတ်မှု လျော့ချရေးလုပ်ငန်းများ အောင်မြင်စေရန် သစ်တောအမျိုးအစားအလိုက် သစ်မျိုးများပါဝင် ပေါက်ရောက်မှုနှင့် ကာဗွန်စုပ်ယူစုဆောင်းမှုများကိုသိရှိရန်လိုအပ်လျက်ရှိသည်။ ထို့ကြောင့် သစ်တောအမျိုးအစားအလိုက် ကာဗွန်စုပ်ယူစုဆောင်းနိုင်မှုကိုသိရှိရန် အတွက် ပဲခူးရိုးမရှိ ရွက်ပြတ်ရောနှောတောနှင့် ပုပ္ပါးတောင်ရှိတောင်ပေါ်/အမြဲစိမ်းတော တို့တွင် ကာဗွန်တိုင်းတာ ခြင်းများဆောင်ရွက်ခဲ့ပါသည်။ နမူနာကွက် (၂)ဟက်တာအရ ပျမ်းမျှ အပင်အရေအတွက်သည် ရွက်ပြတ်ရောနှောတောတွင်တစ်ဟက်တာလျှင် ၂၀၉ ပင်နှင့် တောင်ပေါ်/အမြဲစိမ်းတောတွင် တစ်ဟက်တာလျှင် ၈၀၄ပင် တွေ့ရှိရပါသည်။ ကာဗွန် သိုလှောင်မှုကို လေ့လာရာတွင် ရွက်ပြတ်ရောနှောတောတွင် တစ်ဟက်တာလျှင် ၁၃၅.၃၀တန် နှင့် တောင်ပေါ်/အမြဲစိမ်းတောတွင် တစ်ဟက်တာလျှင် ၂၀၀.၂၂ တန် ရှိကြောင်း တွေ့ရပါသည်။ ဤလေ့လာမှုအရ သစ်တောကာဗွန် သိုလှောင်နိုင်မှုသည် သစ်ပင်အရေအတွက်၊ အပင်များ၏ ပျမ်းမျှအချင်း၊ သစ်သား၏ သိပ်သည်းဆပေါ်တွင် မူတည်လျက်ရှိသည်။ သစ်တောအမျိုး အစားအလိုက် ကာဗွန်သိုလှောင်နိုင်မှု ခြားနားခြင်း၊ သစ်တောအမျိုးအစား တူသော်လည်း နေရာဒေသပေါ်မူတည်၍ ကာဗွန်သိုလှောင်နိုင်မှု ခြားနားခြင်းတို့ကြောင့် အခြားနေရာ ဒေသများတွင်ရှိသော သစ်တောများ၏ ကာဗွန်သိုလှောင်မှုကို လေ့လာသင့် ပါသည်။

အဓိကစကားလုံးများ။ ပင်စည်ပိုင်းဇီဝဒြပ်ထု၊ ကာဗွန်သိုလှောင်မှု၊ သဘာဝတော၊ သစ်မျိုးပါဝင်မှု

Estimation of Carbon Storage of Different Forest Types to support REDD+ in Myanmar

Yu Ya Aye[1]*, Mu Mu Aung[2]

Abstract

Recognizing the increasingly important role of tropical forests in greenhouse gas emissions reductions, the reducing emissions from deforestation and forest degradation, conservation of forests, sustainable management of forests, enhancement of forest carbon stocks in developing countries (REDD+) become a critical mechanism under the UNFCCC. Information on tree species and their distribution is needed for successful implementation of forestry carbon projects. Until recently, a handful studies have been done to estimate carbon stocks in Myanmar despite high deforestation rates in recent years. Therefore this study was conducted in natural forest types, deciduous forest in Bago Mountain and dry hill/evergreen forest in Popa Mountain. Based on data from 2-ha sample plots, average stem density was209 trees ha^{-1} in deciduous forest and 804 tree ha^{-1} in dry hill forest. Results of the carbon estimation showed that dry hill forest stored 200.22 $tCha^{-1}$whilethe deciduous forest stored 135.30 $tCha^{-1}$. The result of this study suggests that stand density, diameter size and wood density are affect the forest carbon stock. Due to different carbon storage capacity in different forest types and different ecological region, there is a need for further research to estimate carbon stock in other regions.

Key Words: Aboveground biomass, carbon stock, natural forest, species composition

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Estimation of Carbon Storage of Different Forest Types to support REDD+ in Myanmar

1. Introduction

Global warming by 2 ◦C is likely to be inevitable (K. Richardson et al., 2009) and such a warming would have serious negative impacts on ecosystems, their functions and society at large (Smith et al., 2009). There is the risk that with continued climate change tropical forests could turn from a carbon sink into a carbon source (Fischlin et al., 2007). Forests play a twofold role in climate change by sequestering large quantities of carbon: while growing trees absorb carbon dioxide from the air and store carbon by the process of photosynthesis, forests can become a major emissions source when the stored carbon is released into the atmosphere by means of forest degradation and deforestation activities (Jayant A & Nilels, 2008). Fifty-two percent of world's forests are concentrated in the tropic which have the highest rate of deforestation (Brown, Sathaye, Cannell, & Kauppi, 1996). Tropical deforestation is considered the second largest source of greenhouse gas (GHG) emission accounting for an estimated 17% of global greenhouse gas emissions—more than the global transport sector (IPCC, 2007). Avoiding tropical deforestation has great potential to reduce GHG emissions (Service C, 2012).

Reducing deforestation is, thus, a high-priority mitigation option within tropical regions(IPCC, 2007). Therefore, 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 was a key agenda item discussed during the December 2009 conference of parties (COP) meeting in Copenhagen. The resulting 'Copenhagen Accord', signed by the United States, China, India, Brazil and South Africa, recognized natural forest protection as key to reducing global carbon emissions. Before engaging in an international agreement for REDD, tropical forest nations will need to evaluate their ability to curb deforestation (Oestreicher et al., 2009). Tropical forests are highly threatened by human activities, such as land clearing for settlement; agricultural land expansion, timber harvesting and fuelwood collection, and their activities are responsible for deforestation and forest degradation (Htun, Mizoue, & Yoshida, 2011). Therefore, it is of crucial importance to estimate forest carbon storage in tropical region. Myanmar has one of the highest proportions of forest cover in mainland South East Asia, 48% of the total area, with high deforestation rate (0.93%

annually) (FAO, 2010). Although high forest cover there are limited information on carbon storage capacity and carbon emissions from the forest. Therefore, this study was conducted to estimate current carbon stock in different forests in order to provide baseline information for carbon trading accountability in the future.

2. Objectives

The main objective of this study was to measure baseline carbon stocks of the study area for supporting REDD readiness in Myanmar. The specific objectives are;

- To investigate the species composition, species diversity and stand structure of the different forest types
- To estimate carbon storage capacity of different forest ecosystems
- To highlight the important role of forest carbon stock in combating global warming

3. Materials and Methods

The research was carried out in deciduous forest in Bago Mountain and hill forest in Popa Mountain. Data from 25 sample plots of 400 m^2 (20 m × 20 m) each were collected in each forest type. Diameter at breast height (DBH) and height of all trees (DBH ≥ 5 cm) were measured in each plot. Plant species identification was achieved by using the "A Checklist of the Trees, Shrubs, Herbs and Climbers of Myanmar" (Kress et al. 2003), local name and taxonomic experts. Due to carbon stored in the aboveground is the most directly impacted by deforestation (Gibbs, Brown, Niles, & Foley, 2007), this study estimated aboveground carbon stock.

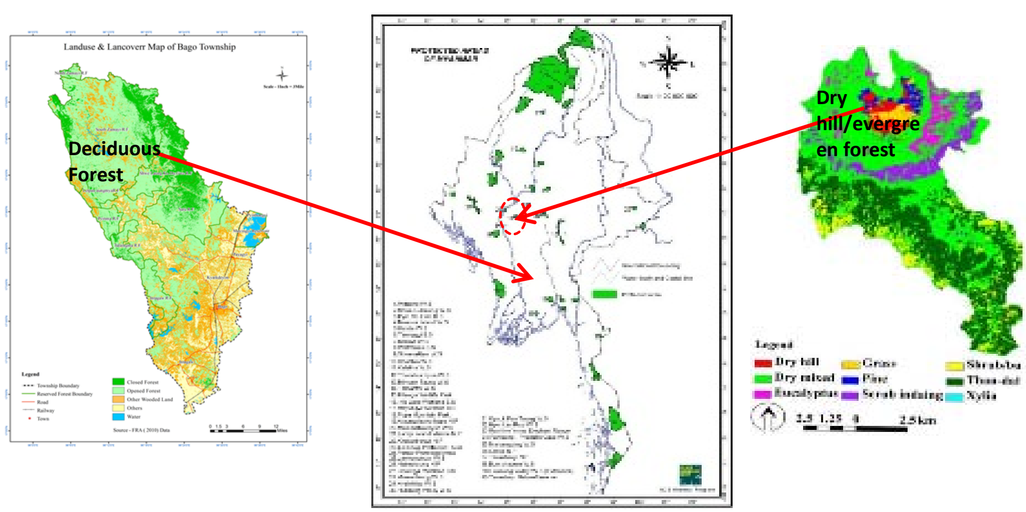

Figure 1. Location of the study area

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:

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

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

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

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

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).

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 “ i^{th} “ species, and ln is the theoretical maximum value of diversity (log_2) (Magurran, 1988).

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 (Krebs, 1989).

Measurement of aboveground carbon

Data from 100 sample plots of 400 m^2 (20 m × 20 m) were collected in dry mixed deciduous forest, dry dipterocap forest, dry forest and dry hill forest in Popa Mountain Park (Korea Forest Service 2007). Diameter at breast height (DBH) and height of all trees (DBH ≥ 5 cm) were measured in each plot. Aboveground carbon (AGC) (tonne $C \cdot ha^{-1}$ or tC hereafter) was estimated using the equation below (S. Brown 1997).

$$AGC = VOB \times WD \times BEF \times CC \qquad (1)$$

where, VOB ($m^3 \cdot ha^{-1}$) is stand volume over bark. WD ($Mg \cdot m^{-3}$) is wood density. WD for all tree species were taken from (Zanne et al. 2009) and (ICRAF 2010), using genus level averages where species specific data were not available following Chave et al., (Chave et al. 2006) and Bryan et al., (Bryan et al. 2010) and plot level averages for the cases where species could not identified following (Mattsson et al. 2012). Carbon content default value (CC) 0.47 was used (IPCC 2006). BEF is the biomass expansion factor, determined from (S. Brown 1997).

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

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

4. Results

4.1 Species composition and stand structure of different forest

Based on data from 25 sample plots, 46 species belonging to 22 families are found in deciduous forest in Bago Mountain. Mean stand density is 209 trees ha^{-1} and mean volume was 115.91 $m^3 \cdot ha^{-1}$. In dry hill/evergreen forest in Popa Mountain, 40 species belonging to 29 families were recorded. The mean tree height was 13.20 m, mean DBH was 24.03 cm and mean volume was 610.71 $m^3 \cdot ha^{-1}$. Mean stand density was 804 trees ha^{-1} for the ≥ 5cm DBH threshold (Table 1).

The deciduous forest occupied the high value of Shannon-Wiener index and Simpson diversity index, 3.32 and 0.94, respectively. Both diversity indexes indicated that the species diversity of the deciduous forest is the high. The dry hill/evergreen forest occupied Shannon-Wiener index, 2.41 and Simpson diversity index, 0.84 suggestion that the dry hill/evergreen forest was the simple community in term of species composition. The species in deciduous forest were abundant, and the percentage of evenness j (%) was close to 1.0. Therefore, Shannon's evenness (j) shows that deciduous forest have high species diversity.

Table 1. Characteristics of different forest types

Parameter	Deciduous Forest	Hill/Evergreen Forest
Mean dbh (cm)	32.78	24.03
Mean Ht (m)	18.05	13.20
BA ($m^2 ha^{-1}$)	24.77	47.80
Vol ($m^3 ha^{-1}$)	347.10	610.71
Stand Density (trees ha^{-1})	209	804
No. of families (ha^{-1})	22	29
Species richness (ha^{-1})	46	40
Simpson's diversity index (1-D)	0.94	0.84
Shannon-Wiener function (H')	3.32	2.41
Species Evenness (j)	86.69	65.36

To assess the ecologically important species, the important value index (IVI) was used. In the deciduous forest, the most frequently occurring and most important species are *Tectona grandis* with important values of 10.50 represented by 25 individual trees with relative frequencies of 5.30 %. The second and third abundant species were *Mitragyna rotundifolia* (9.06 % important value index, IVI) and *Lagerstroemia speciosa* (7.87% IVI) (Table 2).

The highest IVI value belonged to the species *Vitex canescens* in the Dry hill/evergreen forest. *Vitex canescens* was the most frequently occurring species and most important species with Important Values Index (IVI) of 29.13 % represented by 263 individual trees with relative frequencies of 12.72 % and Relative Density (RA) of 32.71% (Table 3). The second and third important species are *Rapanea af. Neriifolia* (13.14% IVI, 19.90% RA) and *Bixa orellana L* (7.06% IVI, 7.84% RA). The result of our study suggests that *Techtona hamiltoniana* is an ecologically important species of Dry hill/evergreen forest.

Table 2. Ten highest species important Value Index (IVI) in Deciduous Forest

Scientific Name	R.A (%)	R.F (%)	R.B.A (%)	IVI (%)
Tectona grandis L.f	11.90	5.30	14.28	10.50
Mitragyna rotundifolia (Roxb.) Kuntze	12.38	9.85	4.94	9.06
Lagerstroemia speciosa	10.48	4.55	8.58	7.87
Entada pursaetha	5.24	5.30	9.51	6.69
Millettia pendula Benth.	3.33	4.55	6.70	4.86
Xylia xylocarpa (Roxb.) Toub	1.90	3.03	7.61	4.18
Dalbergia cultrata Grah.	3.33	3.79	5.22	4.11
Homalium tomentosum	4.29	3.03	3.80	3.71
Stereospermum colais (Buch.-Ham. ex Dillwyn) Mabb.	4.29	4.55	2.05	3.63
Cordia dichotoma Forst.	2.86	3.79	3.22	3.29
Others	40.00	52.27	34.07	42.12
Total	100	100	100	100

Table 2. Ten highest species important Value Index (IVI) in Dry Hill Forest

Scientific Name	RA (%)	RF (%)	RBA (%)	IVI (%)
Vitex canescens Kurz	32.71	12.72	41.96	29.13
Rapanea af. Neriifolia (Seib & Zucc) Mez.	19.90	8.09	11.43	13.14

Scientific Name	RA (%)	RF (%)	RBA (%)	IVI (%)
Bixa orellana L.	7.84	9.25	4.09	7.06
Eriobotrya bengalensis (Roxb.) Hook. f.	3.98	5.78	6.63	5.46
Syzygium cumini (L.) Skeels.	2.74	8.09	4.65	5.16
Wendlandia tinctoria DC.	5.35	6.36	2.75	4.82
Croton roxburghianus N.P.Balakr	5.47	4.62	3.10	4.40
Litsaea glutino (Lour)C.B.Cl.	3.73	3.47	5.48	4.23
Cinnamomum obtusifolium (Roxb.) Nees	3.36	4.62	1.29	3.09
Cissus discolor Blume	2.49	5.20	0.40	2.70
Others	12.44	31.79	18.22	20.82
Total	**100**	**100**	**100**	**100**

In both stand, the largest numbers of trees are found in the lower diameter class showing the inverse j-shape pattern (Figure 2 and 3). The abundance of lower DBH trees suggested that the study areas have good regeneration. Few trees were found in the large DBH class (Figure 4 and 5). 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 diameter classes 60.1-70 cm and 25.1-30cm occupied the largest basal area per ha in deciduous forest and dry hill/ evergreen forest, respectively. A few trees in diameter classes >70 cm were found in both forests. The pattern of relative basal area (RBA) in dry hill/ evergreen forest are slightly decrease by increasing DBH classes, therefore, suggestion that less human disturbance in the dry hill/evergreen forest occurred above 1000m, being less accessible. Besides, Popa Mountain is Protected Area while Bago Mountain is timber production area.

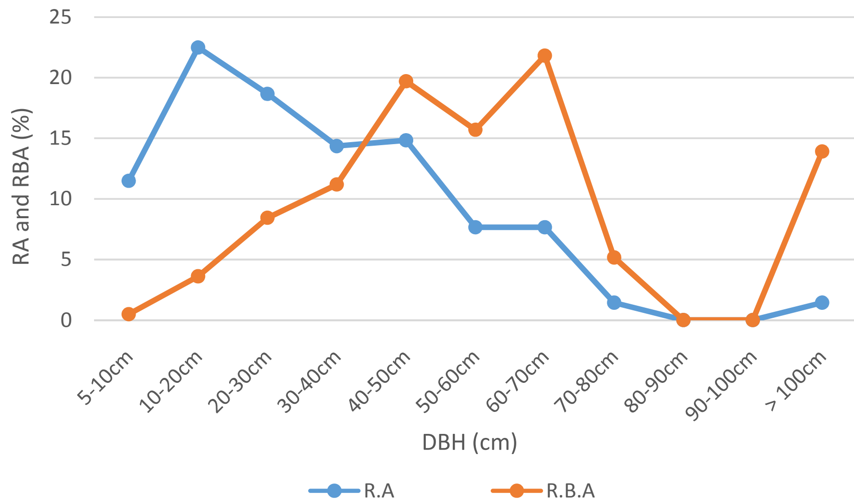

Figure 2. Relative abundance and relative basal area according to DBH class in deciduous forest

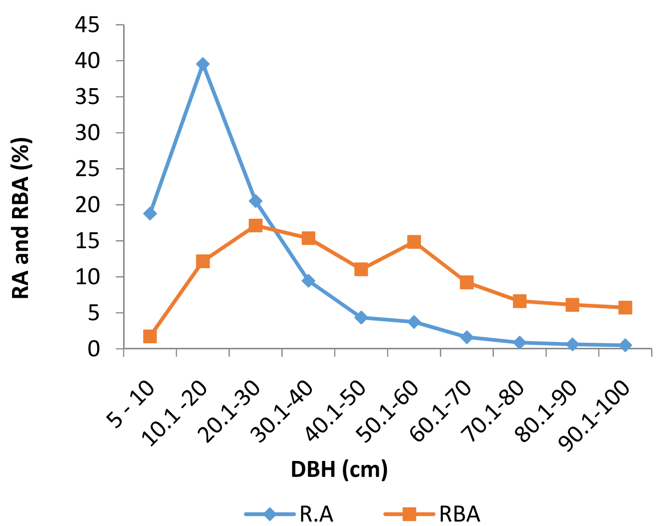

Figure 3. Relative abundance and relative basal area according to DBH class in dry hill forest

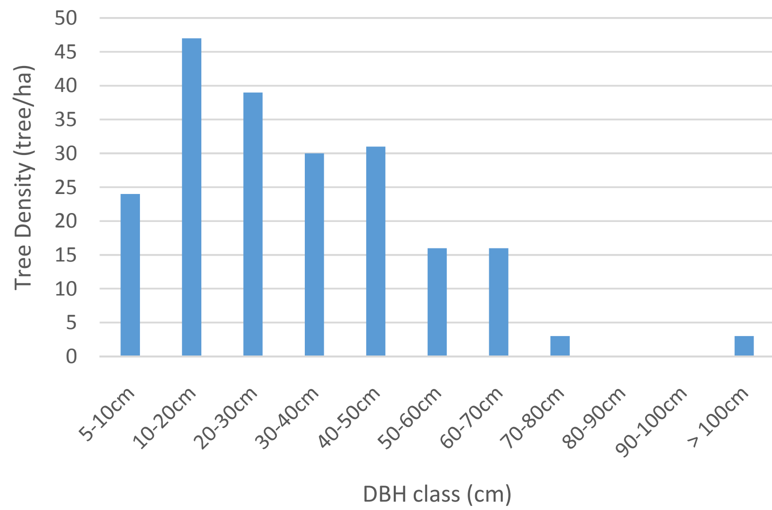

Figure 4. Tree density according to DBH class in Deciduous forest

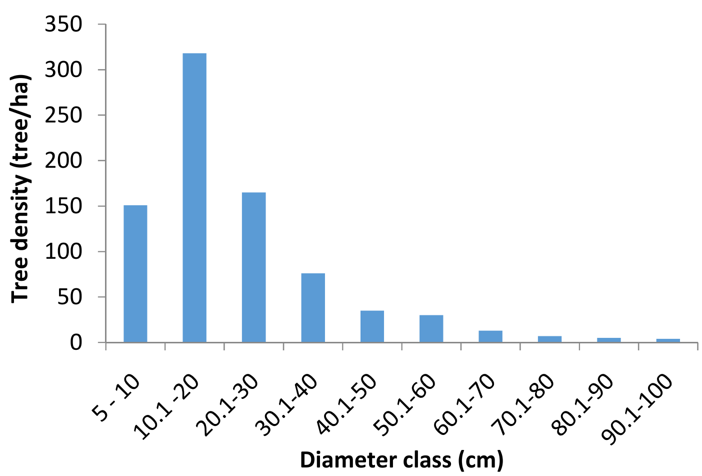

Figure 5. Tree density according to DBH class in dry hill/evergreen forest

4.2. Carbon Stock

The aboveground carbon density of deciduous forest is 135.30 $tCha^{-1}$. The mean DBH, 32.78 cm, was the large in the deciduous forest but the stand density, 209 m^2ha^{-1}, was low. The dry hill/evergreen forest contained 200.22 $tCha^{-1}$ of aboveground carbon stock and mean DBH was 24.03 cm . The stand density in dry hill/evergreen forest was 804 trees ha^{-1}. This may be due to the carbon accumulation being related to stand density.

In the deciduous forest, the dominant species is *Tectona grandis* which occupied the highest IVI value (10.50 %) and highest carbon stock (19.78 $tCha^{-1}$) (Table 3). Followed by

Entada pursaetha with an IVI value of 6.69 % and carbon stock 14.95tCha^{-1}. *Lagerstroemia speciosa* store 11.58 tCha^{-1} and *Xylia xylocarpa* stored 11.49 tCha^{-1}. Mean DBH of *Entada pursaetha* (47.56 cm) is larger than *Tectona grandis* (40.56 cm), the stand density of *Entada pursaetha* (11 treeha^{-1}) is lower than *Tectona grandis* (25 tree ha^{-1}).

Vitex canescens occupied highest basal area (20.07 m2·ha^{-1}) and volume (284.52 m3·ha^{-1}) in dry hill/evergreen forest (Table 4). *Vitex Canescens* also accumulate the highest carbon stock, 82.21 tC ha^{-1}, followed by *Eriobotrya bengalensis* 22.76 tC ha^{-1} and *Rapanea af Nerrifolia* 19.52 tC ha^{-1}. Therefore, in the DHEF *Vitex canescens* is the dominant species and occupied the highest IVI value and the highest carbon stock.

Table 3. Ten highest species carbon storage in Deciduous Forest

Scientific Name	**Mean DBH (cm)**	**SD (trees ha^{-1})**	**BA (m^2 ha^{-1})**	**Vol (m^3 ha^{-1})**	**AG-C**
Tectona grandis L.f	40.56	25	3.54	54.68	19.78
Entada pursaetha	47.59	11	2.36	41.33	14.95
Lagerstroemia speciosa	25.52	22	2.13	32.01	11.58
Xylia xylocarpa (Roxb.) Toub	66.50	4	1.89	31.76	11.49
Millettia pendula Benth.	53.29	7	1.66	26.62	9.63
Dalbergia cultrata Grah.	42.29	7	1.29	19.26	6.97
Homalium tomentosum Benth.	32.11	9	0.94	14.91	5.39
Mitragyna rotundifolia (Roxb.) Kuntze	20.62	26	1.23	14.80	5.35
Terminalia tomentosa	48.00	4	0.78	11.48	4.15
Amoora wallichii King	64.50	2	0.66	11.35	4.10
Others		91	8.29	115.91	41.92
Total		208	24.77	374.10	135.30

Table 4. Ten highest species carbon storage in Dry Hill/evergreen Forest

Scientific Name	Mean DBH (cm)	SD (trees ha^{-1})	BA (m^2 ha^{-1})	Vol (m^3 ha^{-1})	AG-C
Vitex canescens Kurz	24.93	263	20.07	284.52	82.21
Eriobotrya bengalensis (Roxb.) Hook. f.	27.84	32	3.17	57.19	22.76
Rapanea af. Neriifolia (Seib & Zucc) Mez.	18.63	160	5.47	50.42	19.52
Syzygium cumini (L.) Skeels.	32.36	22	2.23	24.49	10.68
Flacourtia cataphracta Roxb.	52.80	5	1.14	20.36	9.99
Litsaea glutino (Lour)C.B.Cl.	30.25	30	2.62	25.79	8.30
Holarrhena pubescens Wall. ex G. Don	55.00	3	0.79	14.88	5.76
Wendlandia tinctoria DC.	16.74	43	1.31	13.11	5.36
Sapium baccatum Roxb.	74.00	4	1.74	24.22	4.75
Croton roxburghianus N.P.Balakr	19.75	44	1.48	11.18	4.27
Others		198	7.8	84.56	26.62
Total		804	47.83	610.72	200.22

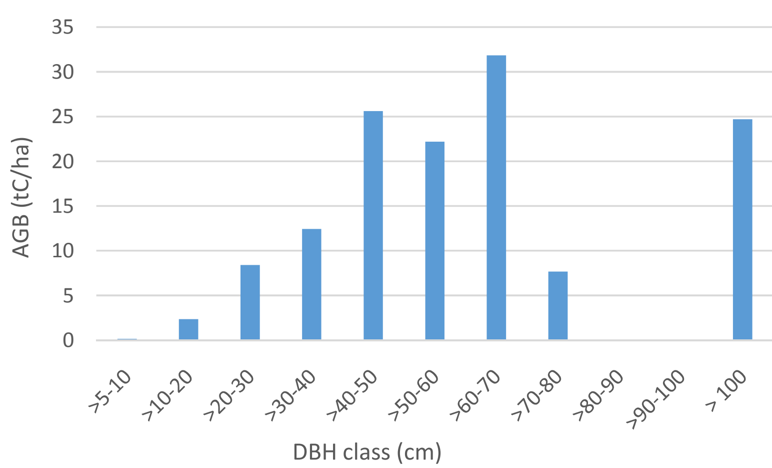

Figure 5. Aboveground Carbon Stock according to DBH class in deciduous forest

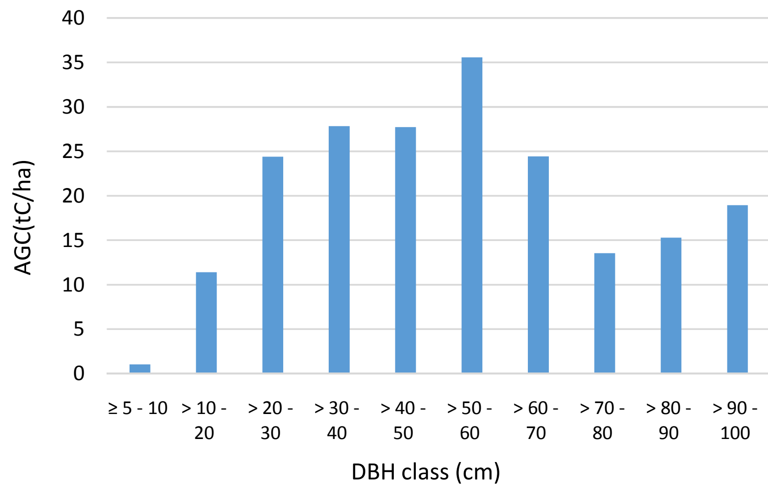

Figure 6. Aboveground Carbon Stock according to DBH class in dry hill/evergreen forest

5. Discussion

In all the forest stands, the greater numbers of trees were observed in the small diameter class. This indicates that the density of smaller trees in a stand is sufficient to replace the current population of larger trees. The diameter distribution of the trees followed the inverse J-shape pattern indicating that stands are developing and regeneration is occurring in the forest.

In term of carbon stock, the dominant species is *Tectona grandis* which occupied highest carbon stock (19.78 $tCha^{-1}$) in the deciduous forest. Though mean DBH of *Entada pursaetha* (47.56 cm) is larger than *Tectona grandis* (40.56 cm), the stand density of *Entada pursaetha* (11 $treeha^{-1}$) is lower than *Tectona grandis* (25 tree ha^{-1}). The stand density influences on the carbon storage of the tree (Perea Cordero and Kanninen, 2003) as well as the forest. In dry hill/evergreen forest, *Vitex canescens* is the dominant species and occupied the highest IVI value and the highest carbon stock. Though *Rapanea af Nerrifolia* is the second highest IVI, *Eriobotrya bengalensis,* the fourth highest IVI, occupied more carbon stock. It may be due to mean DBH and the wood density effect on the carbon storage capacity. The mean DBH of *Eriobotrya bengalensis* is 27.84 cm and WD is 0.73 Mgm^{-3} while the mean DBH of *Rapanea af Nerrifolia* is 18.63 am and WD is 0.71 Mgm^{-3}. The accumulation of biomass and carbon related to different wood density (Elias & Potvin, 2003) and tree diameter (S. Brown, 1997). Biomass and carbon per tree increase geometrically with increasing diameter (S. Brown, 1997).

Tree species composition of each forest also affected forest carbon stock. Wood density is different in different species. If the species could not identified, this study used wood density at the genus level; the variation of wood density among the genera is higher than within a single genus (Baker et al., 2004; Basuki, 2012; Chave et al., 2006). In this study, tree carbon stock was estimated by using volume over bark and the wood density of the species. Therefore tree species composition and tree size strongly affect the estimation of forest carbon stock.

This study also analyzed the carbon allocation in DBH classes. The maximum carbon was stored in the 40-60 cm DBH class in DHEF (31.6%). Although the young individuals belonging to the 5-20 cm DBH class dominated in all of the forests in terms of density, the AGB accumulation was greater in the 40-60 cm diameter class. In the hill forest, 88.3% of trees were found at the DBH< 40cm and stored 32.3 % of total carbon stock. Eleven point seven percent of the total number of trees were found in DBH > 40cm and stored 67.7% of total carbon. The tree distribution and carbon allocation patterns of the DHEF in this study is similar to that of the dry evergreen forests in Thailand in which the trees are less than 40 cm DBH and have 91.95% of total number of trees, with 22.76% of the total carbon. As well, the DBH > 40 cm trees comprise 9.05 % of the total number of trees, and contain 77.24% of the total carbon. In the DBH of the study area, many trees were found with DBH < 40cm but having high carbon storage at DBH > 40cm. This is because the basal area in large trees is greater than in small trees.

The deciduous forest contained 135.30 $tCha^{-1}$ of aboveground carbon while the dry hill/evergreen forest stored 200.22 $tCha^{-1}$. This is probably due to the dry hill/evergreen forest having the high tree density, 804 trees ha^{-1}, whereas the deciduous forest has the less tree density, 209 trees ha^{-1}. Tree species composition and tree density of each forest affected forest carbon stock. Various authors have mentioned that the accumulation of biomass and carbon in the forest is influenced by stock density (S. Brown et al., 1989; S. Brown, 1997; Perez Cordero & Kanninen, 2003). Likewise, Tree species composition and wood density is different in different species.

6. Conclusion

This study designed to estimate carbon stocks in natural forest. Forest inventory data from 50 sample plots were used to assess tree biodiversity and to estimate carbon stocks. Forest inventory was conducted in different forest types, namely dry mixed deciduous forest in Bago Mountain and dry hill/evergreen forest in Popa Mountain. The distribution of trees in both forest types 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. The density of trees was 209 trees ha^{-1} in the deciduous forest in Bago Mountain and trees ha^{-1} dry hill/evergreen forest in Popa Mountain. In term of aboveground carbon stock, the deciduous forest have 135.30 $tCha^{-1}$ and the deciduous forest stored 200.22 $tCha^{-1}$. The result of this study suggests that stand density and species composition effect on the forest carbon stock. Carbon storage capacity are different in different forest types and different ecological region, further study on estimation of carbon stock in other region are recommended.

It may be due to timber extraction in Bago Mountain because deciduous forest in Bago Mountain is productive forest but the hill forest in Popa Mountain is protected forest.

The maximum carbon was stored in the 40-60 cm DBH class (31.6%) dry hill/evergreen forest. Although the young individuals belonging to the 5-20 cm DBH class dominated in the forests in terms of density, the AGB accumulation was greater in the 40-60 cm diameter class. The occurrence of high basal area and high density of trees in the largest size class suggested that the dry hill/evergreen forest occupied high carbon stock.

7. References

Baker, T. R., Phillips, O. L., Malhi, Y., Almeidas, S., Arroyo, L., Fiore, A. Di, et al. (2004). Variation in wood density determines spatial patterns in Amazonian forest biomass. **Global Change Biology**, 10, 545–562.

Basuki, T. M. (2012). **Quantifying tropical forest biomass**. Netherlands: University of Twente.

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

Brown, S., Gillespie, A. J. R. and Lugu, A. E. (1989). Biomass Estimation Methods For Tropical Forests with Applications to Forest inventory Data. **Forest Science**, 35(4), 881–902.

Brown, S., Sathaye, J., Cannell, M., & Kauppi, P. E. (1996). Mitigation of carbon emissions to the atmosphere by forest management. Commonwealth Forestry Review. ***Common Wealth Forestry Review***, *75*(1), 80–112.

Bryan, J., Shearman, P., Ash, J. and Kirkpatrick, J.B. (2010) Estimating Rainforest Biomass Stocks and Carbon Loss from Deforestation and Degradation in Papua New Guinea 1972-2002: Best Estimates, Uncertainties and Research Needs. **Journal of Environmental Management**, 91, 995-1001. http://dx.doi.org/10.1016/j.jenvman.2009.12.006

Chave, J., Muller-Landau, H.C., Baker, T.R., Easdale, T.A., Steege, H. and Webb, C.O. (2006) Regional and Phylogenetic. Variation of Wood Density across 2456 Neotropical Tree Species. **Ecological Applications**, 16, 2356-2367. http://dx.doi.org/10.1890/1051-0761(2006)016[2356:RAPVOW]2.0.CO;2

Elias, M. and Potvin, C. (2003). Assessing inter- and intra-specific variation in trunk carbon concentration for 32 neotropical tree species. **Can. J. For. Res**., 33, 1039–1045.

FAO. (2010). **Global Forest Resource assessment**. FAO (Food and Agriculture Organization of the United Nations).

Fischlin, A., Midgley, G. F., Price, J. T., Leemans, R., Gopal, B., Turley, C., et al. (2007). Ecosystems , their properties , goods and services. In C. E. H. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden (Ed.), In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Vol. 48, pp. 211–272). Cambridge: Cambridge University Press.

Gibbs, H. K., Brown, S., Niles, J. O., & Foley, J. a. (2007). Monitoring and estimating tropical forest carbon stocks: making REDD a reality. **Environmental Research Letters**, *2*(4), 045023. doi:10.1088/1748-9326/2/4/045023

Htun, N. Z., Mizoue, N., & Yoshida, S. (2011). Tree Species Composition and Diversity at Different Levels of Disturbance in Popa Mountain Park, Myanmar. **Biotropica**, *43*(5), 597–603.

ICRAF (2010) **World Agroforestry Wood Density Database**.

IPCC. (2007). **Climate Change 2007. In Summary for Policymakers** (pp. 12–17). IPCC (Intergovernmental Panel on Climate Change).

Jayant A, S., & Nilels, A. (2008). Reducing Deforestation and Trading Emissions: Economic Implications for the post-Kyoto Carbon Market (No. 08-016).

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

Kress, W.J., Defilipps, R.A., Farr, E. and Kyi, Y.Y. (2003) **A Checklist of the Trees, Shrubs, Herbs and Climbers of Myanmar**.

Lamprecht, H. (1989) **Silviculture in the Tropics: Tropical Forest Ecosystems and Their Species-Possibilities and Methods for Their Long-Term Utilization**. Deutsche Gesellschaft Fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn, 296.

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

Perez Cordero, L. D., & Kanninen, M. (2003). Aboveground biomass of Tectona grandis plantations in Costa Rica. **Journal of Tropical Forest Science**, *15*(1). 199-213.

Richardson, S. J., Peltzer, D. A., Hurst, J. M., Allen, R. B., Bellingham, P. J., Carswell, F. E., et al., (2009). Deadwood in New Zealand ' s indigenous forests. **Forest Ecology and Management**, 258, 2456–2466. doi:10.1016/j.foreco.2009.08.022

Service C. (2012). **Forest carbon market**. Retrieved from http://www.eoearth.org/view/article/152814

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

Smith, J. B., Schneider, S. H., Oppenheimer, M., Yohe, G. W., Hare, W., Mastrandrea, M. D., et al., (2009). **Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern"**. Proceedings of the National Academy of Sciences of the United States of America, 106, 4133–4137. doi:10.1073/pnas.0812355106

Zanne, A.E., Lopez-Gonzalez, G., Coomes, D.A., Ilic, J., Steven, J., Lewis, S.L., Miller, R.B., Swenson, N.G., Wiemann, M.C. and Chave, J. (2009) **Global Wood Density Database. Identifier**.