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Estimation of Carbon Storage of Two Dominant Species in Deciduous Dipterocarp Forest in Chatthin Wildlife Sanctuary, Myanmar

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Abstract: The carbon storage of two dominant species, vegetation and litter layer were assessed in Deciduous Dipterocarp forest in Chatthin Wildlife Sanctuary, Myanmar. A total of 37 tree species was found in the study area. Among the tree species, two dominant species were *Dipterocarpus tuberculatus* Roxb., and *Shorea obtusa* Wall. Biomass allometric equations for estimating the aboveground biomass were developed based on direct measurements of 40 individuals of those two species while allometric equations for estimating the belowground biomass were also developed through measuring 10 sample trees of those species. The carbon content of *D. tuberculatus* was 24.15 ton ha^{-1} while that of *S. obtusa* were 12.25 ton ha^{-1}, respectively. In addition, the carbon contents of undergrowth vegetation and litter were 8.12 ton ha^{-1} and 3.7 ton ha^{-1}, respectively. The best fit equation for estimating total biomass of *D. tuberculatus* was Log Y = 1.6058 + 0.9631 Log X, where R^2 = 0.97 and that of *S. obtusa* was Log Y = 1.8069 + 0.9377 Log X, where R^2 = 0.94. The equations derived from this study can be applied to estimate the carbon storage of *D. tuberculatus* and *S. obtusa* in Deciduous Dipterocarp forest in Myanmar.

Keywords: Carbon storage, Deciduous Dipterocarp forest, Allometric equation, *Dipterocarpus tuberculatus*, *Shorea obtuse*

1. Introduction

While forests produce wood raw materials as a primary function for the fulfillment of forest factories, forests also have other important functions: absorbing Carbon Dioxide (CO_2) in the atmosphere, producing Oxygen (O_2), setting ground water system, and other ecological benefits. Strategies from forestry sector with the purpose of mitigating world climate change can provide multiple benefits such as biodiversity conservation, carbon sequestration, and sustainable rural development (Fearnside and Laurance, 2004). In particular, the world's tropical forests play a vital role in the global carbon cycle because they contain 428 Pg (1 Pg = 10^{15} g) of vegetation and soil (Watson *et al*., 2007and Houghton, 2007). About 42.92% of total forest area is covered with forests and Deciduous Dipterocarp forests are of 1321.87 thousand hectares (4.16%) of total forest area (Forest Department, 2010). These forests occur on marginal sites with the shallow soil of low water holding capacity and low organic matter contents. Deciduous Dipterocarp forests play a crucial role not only in the socio-economic development of a region but also in the environment conservation.

Due to the overexploitation of forest resources in Myanmar, total area of degraded forests accounts for 9.9 million hectares, representing 13.7% of the total land area (Forest Department, 2015). Nowadays, deforestation and forest degradation contribute to global climate change. In order to address this global issue, Reducing Emission from Deforestation and Forest Degradation and Enhancement of Forest Carbon Stocks (REDD+) is becoming a promising inspiration. Because Myanmar is a forest-rich country, it has a great potential for future carbon market through afforestation and reforestation, conservation of existing forests and plantations as carbon sinks. Therefore, effective investigations and research activities are essential to explore the status of carbon storage of tree species. The accurate

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estimation of carbon storage in specific sites as well as in specific forest tree species is very rare in Myanmar. Accordingly, this situation might be difficult to obtain incentives from REDD+. In Myanmar, carbon stock assessment is still poor and little is known about the carbon sequestration potential of natural forest.

Tree allometric equations in this study were developed by establishing the relationship between tree parameters such as Diameter at Breast Height (DBH) and Height (H). Once an allometric equation has been developed for different classes of trees, one only needs to measure DBH and/or H to estimate the biomass of individual trees. The objectives of this study are to estimate the carbon storage of two dominant tree species (i.e., *Dipterocarpus tuberculatus* Roxb. and *Shorea obtusa* Wall.), and undergrowth vegetation and litter layer in Deciduous Dipterocarp forest in Chatthin Wildlife Sanctuary, Myanmar, and also to develop biomass allometric equations for estimating carbon storage of those two species.

2. Materials and methods

1.1 Study area

This study was conducted in Chatthin Wildlife Sanctuary, which is located within Kanbalu and Kawlin Townships of Sagaing Region in upper Myanmar (Fig. 1). The total area of Chatthin Wildlife Sanctuary which was designated as a wildlife sanctuary in 1941 is 26,820 ha. The major objective for the establishment of the sanctuary is to preserve endangered Cervus eldi Thamin which can be found only in Myanmar.

Chatthin Wildlife Sanctuary has a flat to undulating topography with an average elevation of about 200 m. The soil is alluvial sands and gravels, mixing with sandstones. The climate of the area is generally characterized by a cool dry season, a hot dry season and a monsoon season. The sanctuary is a fragment of a monsoon Dipterocarp ecosystem known locally as Indaing. The forest types such as low Indaing forest, upper mixed deciduous forest and grass savanna matric forest can be found in the sanctuary.

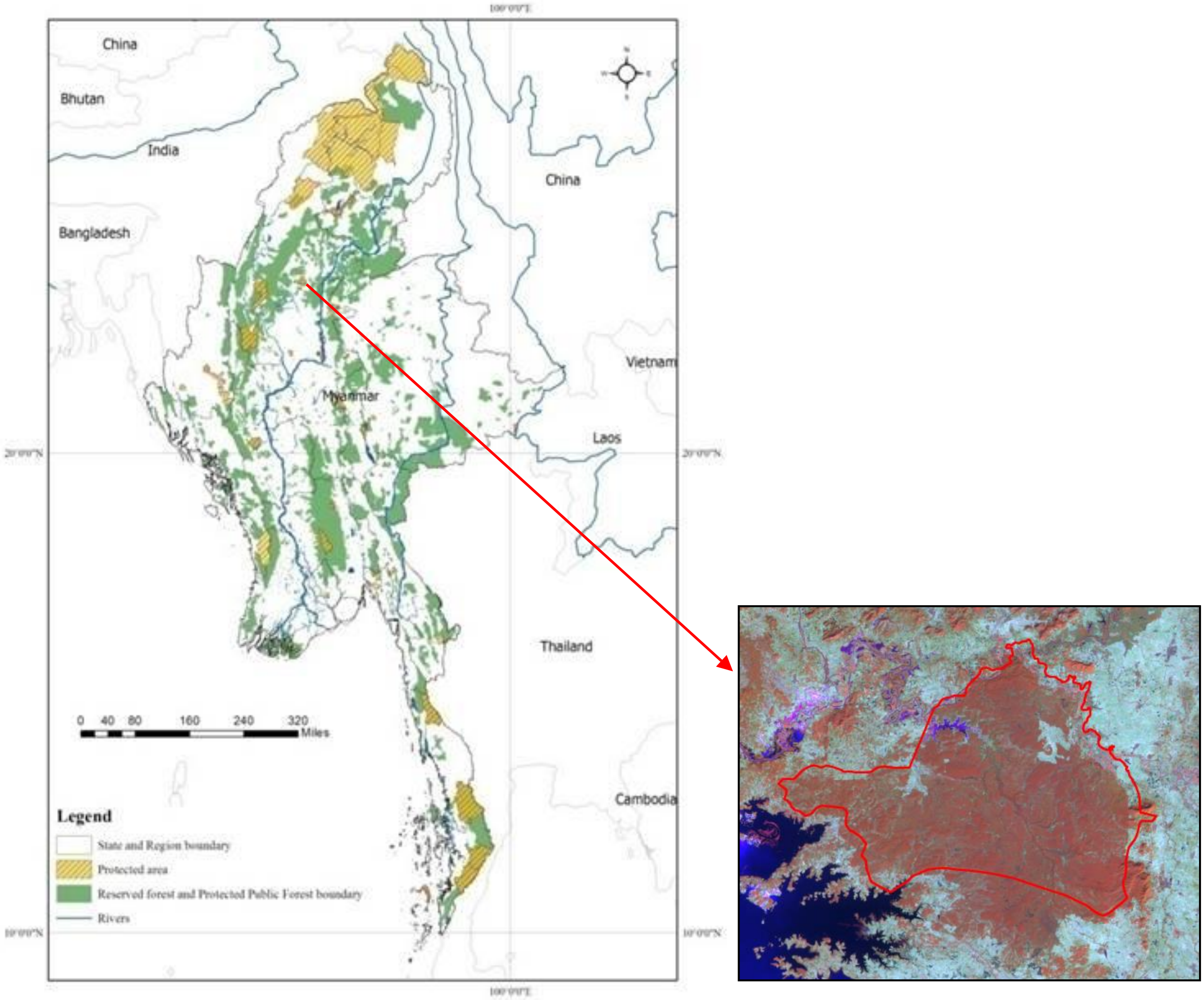

Figure 1. Map of Myanmar with the location of the study area

1.2 Measurement of Carbon Storage

Stratified random sampling in rectangular shape was applied to lay out the sample plots in the study area. Firstly, 5 sampling plots were randomly allocated on the map of Chatthin Wildlife Sanctuary prior to conducting forest inventory. Based on the average height of trees and topography, 5 plots measuring 50 m × 20 m (0.1 ha of each) were established in the field according to the GPS points of sampling plots marked on the map. In each sample plot, H and DBH of trees (DBH ≥ 5 cm) were measured. The names of tree species were measured by the use of diameter tape. Tree height was measured using Sunnto Clinometer. The vernacular names of tree species were recorded and changed into scientific names by using a checklist of tree, shrub, herb and climber of Myanmar published by Kress *et al*., (2003).

According to the inventory data, *Dipterocarpus tuberculatus* Roxb., and *Shorea obtusa* Wall., were the most dominant species in the study area. In total, 40 trees of different diameter classes representing those dominant species were harvested for aboveground biomass estimation. Then, 5 individuals of each tree species were sampled to excavate all of the roots for estimating belowground biomass.

For measuring saplings (DBH < 5 cm and H > 130 cm), two sub-plots having size of 20 m × 5 m were established in each sample plot while another two sub-plots having the size of 5 m × 2 m were also allocated to measure seedlings (H < 130 cm). Samples from different components of each sample tree were chosen and dried in an oven at 80ºC for a week until constant weights were obtained (Korea Forest Research Institute, 2007; Kenzo *et al*., 2009). Dry weight of each sample was calculated by the ratio of dry weight to fresh weight of the samples.

For estimating carbon storage of undergrowth and litter layer, 4 sub-compartments measuring 2 m × 2 m were also formed at the corner of each sub-plot (20 m × 5 m). All sub-samples were pooled, sealed in plastic bags and transported to oven-dry in the laboratory of Forest Research Institute (FRI) in Yezin, Myanmar. In this study, sub-sampling of representative samples of different components of trees was conducted according to guidelines for establishing regional and allometric equations for biomass estimation through the destructive sampling technique of Dietz and Kuyah (2011).

2. Data Analysis

Based on 40 sample trees, allometric equations between dependent variables (component biomass) and independent variables (DBH and H) were developed by using simple linear regression. Data on dry weight of all biomass components of sample trees were used to develop prediction equations from easily measurable parameters (DBH and H). All data were transformed using Log to the base 10, since they were commonly done to linear data of this type (Kranenzel *et al*., 2003). The forms of allometric equations were Log Y = a + b Log X (Perez Cordero and Kanninen, 2003). Preliminary analysis of alternative equations indicated that the allometric equation Log Y = a + b Log X (where, Y is biomass (g), X is DBH (cm) or H (m) or DBH.H (cm.m) or DBH^2 (cm^2) or DBH^2.H (cm^2.m) and a and b are (correlation coefficients estimated by regression) best fitted data. The equation with the highest correlation among all equations was used for all trees in estimating biomass. All regressions were done by using Microsoft Excel 2007 and SPSS version 18 for Windows. The carbon content default value of 0.5 was used to estimate the carbon content of tree biomass as proposed by IPCC (1996).

3. Results

3.1 Species composition

Although the main purpose of Chatthin Wildlife Sanctuary is to conserve Cervus eldi Thamin, it also provides a habitat for flora and fauna. According to the inventory data, 37 tree species were found in the study site. The total stand density was 1,352 trees ha^{-1} while mean DBH was 11.79 cm and mean height was 8.63 m. Among 37 trees species, *D. tuberculatus* and *S. obtusa* were the most two dominant species. *D. tuberculatus* was the most dominant species in Deciduous Dipterocarp forest which showed 41.42 % of dominance followed by *S. obtusa* which occupied 21.01% of dominance in the study site (Table 1).

Table 1. Tree species distributed in the study area

Vernacular name	Scientific name	Trees per hectare	Mean DBH (cm)	Mean H (m)	% of tree density
In	*Dipterocarpus tuberculatus*	560	13.74	9.92	41.42
Thit-ya	*Shorea obtusa*	284	12.64	9.11	21.01
Lin-yaw	*Dillenia parviflora*	52	13.45	8.11	3.85
Mondaing	*Kokoona littoralis*	50	10.06	8.83	3.70
Khabaung	*Strychnos nux-vomica*	44	8.06	8.59	3.25
Taukkyan	*Terminalia tomentosa*	42	15.12	10.29	3.11
Lunbo	*Buchanania latifolia*	42	10.42	8.43	3.11
Ingyin	*Shorea siamensis*	28	10.48	9.27	2.07
Didu	*Bombax insigne*	22	11.03	9.03	1.63
Hmanni	*Gardenia erythroclada*	20	10.12	7.44	1.48
Panga	*Terminalia chebula*	20	10.52	9.72	1.48
Yinzat	*Dalbergia fusca*	18	13.84	8.82	1.33
Than-that	*Stereospermum funbriatum*	18	15.00	8.43	1.33
Thadi	*Ptotium serratum*	12	12.39	9.55	0.89
Thitsi	*Melanorrhoea usitata*	12	18.05	11.18	0.89
Thabye	*Eugenia contracta*	12	8.10	7.15	0.89
Inchin	*Aporusa macrophylla*	10	8.41	4.94	0.74
Yin-daik	*Dalbergia cultrata*	10	9.71	9.08	0.74
Te	*Diospyros burmanica*	10	11.94	8.47	0.74
Nabe	*Lannea coromandelica*	10	14.30	9.93	0.74
Thitswele	*Engelhardtia spicata*	8	13.45	10.97	0.59
Gyo	*Schleichera oleosa*	8	13.38	7.77	0.59
Zibyu	*Emblica officinalis*	8	7.03	7.16	0.59
Seikchibo	*Bridelia retusa*	8	8.80	6.93	0.59
Thit-linda	*Heterophragma sulfureum*	6	10.93	8.23	0.44
Chinbyit	*Bauhinia malabarica*	6	12.32	7.21	0.44
Nibasae	*Morinda citrifolia*	4	12.90	7.62	0.30
Thitpyu	*Wendlandia glabrata*	4	10.83	8.08	0.30
Ye-si	*Rosa bracteata*	4	7.65	5.19	0.30
Thitni	*Amoora cucullata*	4	8.76	8.23	0.30
Naywe	*Flacourtia cataphracta*	4	11.50	8.38	0.30
Se-gyi	*Gymnanthemum volkameriifolium*	2	9.55	6.4	0.15
Hnaw	*Adina cordifolia*	2	24.2	12.19	0.15
Ondon	*Litsea glutinosa*	2	11.15	9.75	0.15
Bambwe	*Careya arborea*	2	9.24	7.62	0.15
Sha-ma	*Phyllanthus albizzioides*	2	17.83	12.19	0.15
Kywemagyolane	*Stereospermum suaveolens*	2	9.55	9.14	0.15
	Total	1352	11.79	8.63	100

3.2 Biomass and carbon allocation

The DBH classes of two dominant species were arranged in ascending order. The DBH of *D. tuberculatus* ranged from 5.10 cm to 50 cm while the DBH of *S. obtusa* ranged from 4.94 cm to 52.87 cm, respectively. Tree heights ranged from 3.05 m to 17.68 m in *D. tuberculatus* and 1.83 m to 20.12 m in *S. obtusa*. The mean total biomass of sample trees of *D. tuberculatus* and *S. obtusa* were 53.62 kg and 57.71 kg, respectively. The mean aboveground biomass was 41.82 kg and 45.90 kg, respectively. The mean root biomass was 11.80 kg and 11.81 kg while the stem biomass had 33.47 kg and 34.61 kg, respectively. The mean branch biomass was 6.87 kg and 9.84 kg while the mean leaf biomass was 1.48 kg and 1.45 kg, respectively (Table 2).

The biomass of *S. obtusa* was higher than *D. tuberculatus* at the individual tree level. Redondo-Brenes and Montagnini (2006) stated that the accumulation of biomass and carbon storage of individual tree may be related to differences in wood specific gravity and growth patterns of fast and slow growing species. A higher estimation of biomass was related to higher wood density and the lower wood density usually showed a lower biomass estimate (Kenzo*et al*., 2009). The wood densities of *D. tuberculatus*and *S. obtusa* were 0.58 g cm^{-3} (Vathana, 2012) and 0.72 g cm^{-3} (Kyi, 2003), respectively. Therefore, the total biomass of *S. obtusa* was higher than that of *D. tuberculatus* at the individual tree level even though both are slow growing species.

Table 2. The mean biomass accumulation of sample trees of two dominant species in Deciduous Dipterocarp forest

Component biomass	*Dipterocarpus tuberculatus*(kg)	% of total biomass (kg)	*Shorea obtusa* (kg)	% of total biomass (kg)
Leaf	1.48	2.75	1.45	2.51
Branch	6.87	12.81	9.84	17.06
Stem	33.47	62.43	34.61	59.97
Aboveground	41.82	77.99	45.90	79.54
Root/ Belowground	11.80	22.01	11.81	20.46
Total biomass	53.62	100	57.71	100

3.3 Development of allometric regression equations for two dominant species

This study developed the allometric equations for tree components (leaves, branches, stem and roots to estimate carbon storage and biomass accumulation by using variables of DBH, DBH^2, DBH.H, DBH^2.H and H through linear regression. In the species of *D. tuberculatus*, linear regression of the total biomass as a function of DBH.H and DBH^2.H indicated a relatively high correlation (r^2=0.97). In the species of *S. obtusa*, there was also the highest coefficient for allometric relationships between the total biomass and DBH^2.H (r^2=0.94). Moreover, the regression analysis also showed the level of significance ($p < 0.001$) for the biomass allometric equations (Table 3). Therefore, the developed allometric equations could be undoubtedly used to estimate the total biomass. This study contributed to the development of site-specific allometric equations for the accurate estimation of total tree biomass of *D. tuberculatus* and *S. obtusa* which were two dominant species in Deciduous Dipterocarp forest in Chatthin Wildlife Sanctuary, Myanmar.

Table 3. Results of regression analysis for estimating plant part biomass derived from using the data of 20 sample trees of *Dipterocarpus tuberculatus* (Log Y = a + b Log X)

Dependent variable(Y)	Independent variable (X)	No. of tree	a	b	Adjusted R^2	Significance level
Leaf biomass (g)	DBH		0.4308	2.4604	0.85	$p<0.001$
	DBH^2		0.4308	1.2302	0.85	$p<0.001$
	$DBH^2.H$	20	0.2506	0.8931	0.84	$p<0.001$
	DBH.H		0.2108	1.3709	0.82	$p<0.001$
	H		0.4125	2.6089	0.66	$p<0.001$
Branch biomass (g)	DBH		0.4393	3.0197	0.92	$p<0.001$
	DBH^2		0.4393	1.5098	0.92	$p<0.001$
	$DBH^2.H$	20	0.2982	1.0699	0.87	$p<0.001$
	DBH.H		0.2973	1.6191	0.82	$p<0.001$
	H		0.6967	2.9172	0.60	$p<0.001$
Stem biomass (g)	DBH		1.6680	2.5877	0.91	$p<0.001$
	DBH^2		1.6680	1.2938	0.91	$p<0.001$
	$DBH^2.H$	20	1.3846	0.9701	0.97	$p<0.001$
	DBH.H		1.2865	1.5162	0.98	$p<0.001$
	H		1.3205	3.0779	0.90	$p<0.001$
Aboveground biomass (g)	DBH		1.7029	2.6410	0.94	$p<0.001$
	DBH^2		1.7029	1.3205	0.94	$p<0.001$
	$DBH^2.H$	20	1.4461	0.9795	0.98	$p<0.001$
	DBH.H		1.3653	1.5218	0.98	$p<0.001$
	H		1.4614	3.0262	0.86	$p<0.001$
Root or belowground biomass (g)	DBH		1.3118	2.4873	0.88	$p<0.001$
	DBH^2		1.3118	1.2436	0.88	$p<0.001$
	$DBH^2.H$	20	1.0672	0.9233	0.92	$p<0.001$
	DBH.H		0.9895	1.4354	0.91	$p<0.001$
	H		1.0749	2.8597	0.81	$p<0.001$
Total biomass (g)	DBH		1.8602	2.5951	0.94	$p<0.001$
	DBH^2		1.8602	1.2976	0.94	$p<0.001$
	$DBH^2.H$	20	1.6058	0.9631	0.97	$p<0.001$
	DBH.H		1.5253	1.4970	0.97	$p<0.001$
	H		1.6159	2.9807	0.86	$p<0.001$

Table 4. Results of regression analysis for estimating plant part biomass derived from using the data of 20 sample trees of *Shorea obtusa* (Log Y = a + b Log X)

Dependent variable (Y)	Independent variable (X)	No. of tree	a	b	Adjusted R^2	Significance level
Leaf biomass (g)	DBH		0.4820	2.5009	0.76	p<0.001
	DBH^2		0.4820	1.2505	0.76	p<0.001
	DBH^2.H	20	0.3040	0.9099	0.86	p<0.001
	DBH.H		0.3076	1.3766	0.88	p<0.001
	H		0.6444	2.4837	0.84	p<0.001
Branch biomass (g)	DBH		-0.2603	3.8420	0.72	p<0.001
	DBH^2		-0.2603	1.9210	0.72	p<0.001
	DBH^2.H	20	-0.3900	1.3495	0.76	p<0.001
	DBH.H		-0.3170	2.0071	0.76	p<0.001
	H		0.3395	3.4474	0.65	p<0.001
Stem biomass (g)	DBH		1.7749	2.5884	0.94	p<0.001
	DBH^2		1.7749	1.2942	0.94	p<0.001
	DBH^2.H	20	1.7499	0.8882	0.95	p<0.001
	DBH.H		1.8284	1.3055	0.92	p<0.001
	H		2.3309	2.1629	0.74	p<0.001
Aboveground biomass (g)	DBH		1.7192	2.7465	0.93	p<0.001
	DBH^2		1.7192	1.3733	0.93	p<0.001
	DBH^2.H	20	1.6871	0.9443	0.95	p<0.001
	DBH.H		1.7678	1.3893	0.92	p<0.001
	H		2.2958	2.3091	0.74	p<0.001
Root or belowground biomass (g)	DBH		1.1789	2.6974	0.93	p<0.001
	DBH^2		1.1789	1.3487	0.93	p<0.001
	DBH^2.H	20	1.1764	0.9176	0.92	p<0.001
	DBH.H		1.2693	1.3427	0.88	p<0.001
	H		1.8159	2.1934	0.69	p<0.001
Total biomass (g)	DBH		1.8326	2.7333	0.93	p<0.001
	DBH^2		1.8326	1.3666	0.93	p<0.001
	DBH^2.H	20	1.8069	0.9377	0.94	p<0.001
	DBH.H		1.8901	1.3780	0.91	p<0.001
	H		2.4215	2.2821	0.73	p<0.001

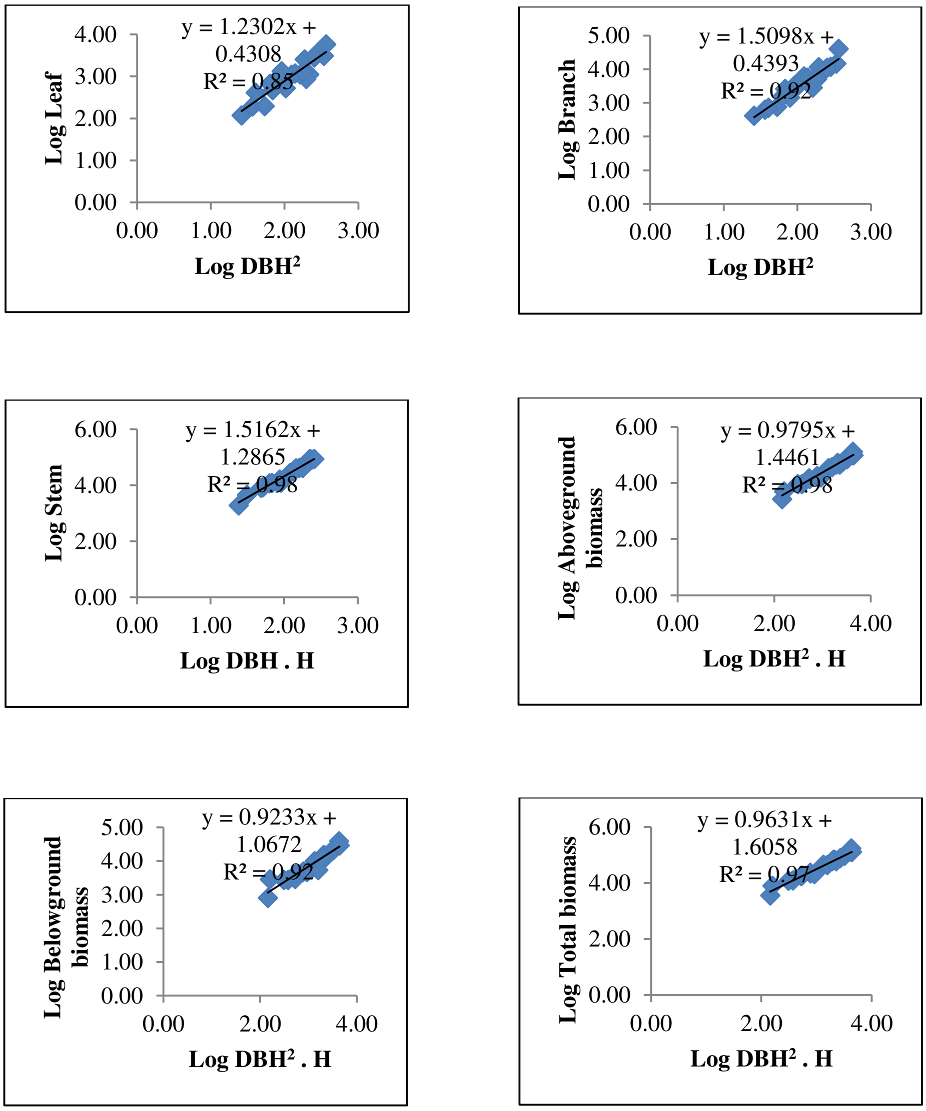

Figure 2. The best allometric relationships between tree component biomass and independent variables of *Dipterocarpus tuberculatus*

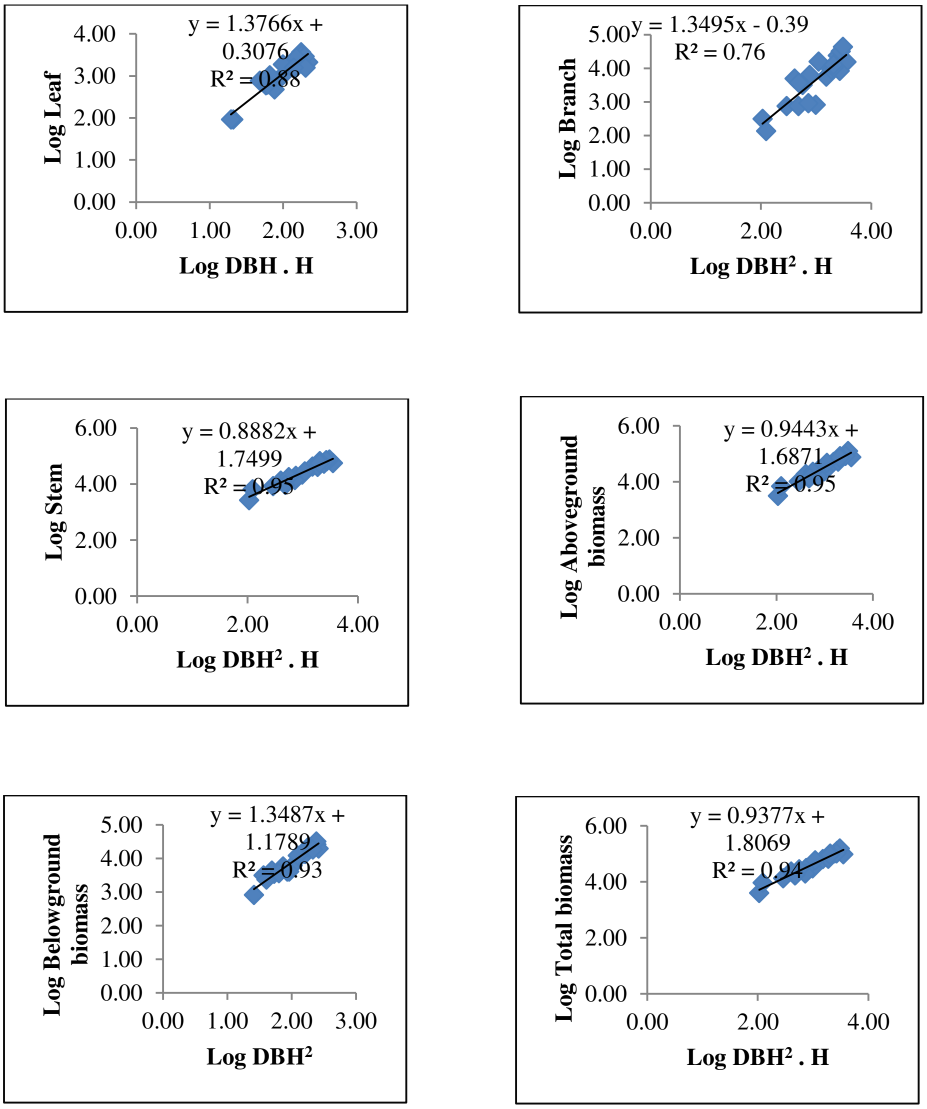

Figure3.The best allometric relationships between tree component biomass and independent variables of *Shorea obtuse*

3.4 Development of Root to Shoot Ratio

Root biomass may constitute 30 percent of the total aboveground biomass and play an important role in the environment (Brown *et al*., 1999). Kraenzel *et al*., 2003 reported that the amount of carbon stored in the roots is still unknown for many species although it is often substantial in a tree. The root to shoot ratio can be used to estimate the belowground biomass of a tree. The root to shoot ratio of *D. tuberculatus* was 0.28 while that of *S. obtusa* showed 0.26. As a result, *D. tuberculatus* stored 28% of tree carbon in the root system while *S. obtusa* stored 26% of total tree carbon in the roots.

Oo (2009) stated that the root to shoot ratio of tropical tree species in Myanmar ranged from 0.15 – 0.28. Aye (2011) found that the commercial plantation species of *Xylia xylocarpa* and *Pterocarpus macrocarpus* have the root to shoot ratio of 0.22 and 0.17, respectively. Regardless of the species, Specht and West (2003) stated that the root to shoot ratio ranged from 0.22 to 0.30 in Australia.

3.5 Estimation of carbon storage

The equations that showed the highest coefficient (r^2) were used to estimate biomass and carbon storage (Fig. 2 and Fig. 3). The biomass accumulation of *D. tuberculatus* was 48.3 ton ha^{-1}, wherein the total biomass was contributed by leaf biomass (1.34 ton ha^{-1}), branch biomass (6.8 ton ha^{-1}), stem biomass (29.46 ton ha^{-1}), root biomass (10.69 ton ha^{-1}), respectively. The total biomass of *D. tuberculatus* allocated the amount of 2.78 % in leaves, 14.08 % in branches, 61 % in stems and 22.14 % in roots. The biomass accumulation of *S. obtusa* was 24.49 ton ha^{-1}, wherein the total biomass was contributed by leaf biomass (0.68 ton ha^{-1}), branch biomass (5.57 ton ha^{-1}), stem biomass (12.19 ton ha^{-1}) and root biomass (6.05 ton ha^{-1}) respectively. The component biomass allocated the amount of 2.79 % in leaves, 22.75 in branches, 49.76 % in stems and 24.7 % in roots.

The carbon contents of *D. tuberculatus* and *S. obtusa* were 24.15 ton ha^{-1} and 12.25 ton ha^{-1}, respectively. Mohammed and Amin (2007) found that the total carbon storage of *D. tuberculatus* in the natural forest was 9.08 ton ha^{-1} which was followed by *Tectona grandis*(6.51 ton ha^{-1}), *Artocarpus chaplasha* (2.66 ton ha^{-1}) and *A. lacucha* (2.26 ton ha^{-1}), respectively. Vathana (2012) reported that the carbon storage of *D. tuberculatus* was 42.9 ton ha^{-1} and that of *Terminalia tomentosa* was 9.3 ton ha^{-1} and that of *Pentacme siamensis* was 8.7 ton ha^{-1}, respectively in Seima Protection Forest. Haripriya (2000) estimated that the total carbon storage of deciduous forest in India accumulated 15.2 ton ha^{-1}. This study showed that the total carbon storage of *D. tuberculatus* was higher than that of *S. obtusa*.

The biomass and carbon of saplings and seedlings were 2.3 ton ha^{-1} and 1.15 ton ha^{-1}, respectively. Saplings of tree species were found as highly density in the study area while the density of seedlings of tree species was relatively low. It may be mainly due to wild fire which commonly occurred in dry hot season. The biomass and carbon storage of under-vegetation were 13.94 ton $ha^{-1}$and 6.97 ton ha^{-1}, respectively. Since data collection was conducted in rainy season, the biomass of under-vegetation reached its peak. The total biomass and carbon content of litter layer were 7.41 ton $ha^{-1}$and 3.71 ton ha^{-1}, respectively. Since the tree density was very high in this area, some trees suffered from overpopulation which causes natural thinning effect in the study area and therefore, many standing dead trees were found in the sanctuary. Undergrowth (including saplings, seedlings, grasses, weeds, shrubs, herbs and climbers) stored the carbon content of 8.12 ton ha^{-1}. The carbon content of litter layer (including dead standing trees, dead wood and dry leaves) was estimated to the amount of 3.7 ton ha^{-1}. Oo (2009) reported that carbon storage of undergrowth and litter was 6.7 ton ha^{-1} and 3.8 ton ha^{-1} in tropical deciduous forest in Myanmar. Vathana (2012) estimated that the carbon storage of undergrowth vegetation and litter layer of tropical deciduous forest was 0.4 ton ha^{-1} and 1.5 ton ha^{-1}, respectively. The average carbon storage of litter layer of major Chinese forest type was amounted to 8.21 ton ha^{-1} (Zhou *et al*., 2000).

4. Summary and Conclusion

The total carbon storage of *D. tuberculatus* was 24.15 ton ha^{-1} while that of *S. obtusa* was 12.25 ton ha^{-1}, respectively. The total carbon storage of undergrowth vegetation and litter layer in the study area was 8.12 ton ha^{-1} and 3.7 ton ha^{-1}, respectively. The biomass allometric equations for *D. tuberculatus* and *S. obtusa* showed a relatively high coefficient of the relationship between DBH^2.H and total biomass (r^2= 0.97 and 0.94, respectively). The species-specific allometric equations developed by this study could be undoubtedly applied to estimate the carbon storage for these two species.

Based on 40 sample trees harvested, this study found that the highest percentage of biomass was allocated in stem which was followed by roots, branches and leaves at the tree level. *D. tuberculatus* occupied the highest stand density (42.42%) among the tree species in Deciduous Dipterocarp forest. Thus, the carbon storage of *D. tuberculatus* (24.15 ton ha^{-1}) was significantly higher than that of *S. obtusa* (12.25 ton ha^{-1}). However, at the individual tree level, the biomass accumulation of *S. obtusa* (57.71 kg) was higher than that of *D. tuberculatus* (53.62 kg). There were 8.12 ton ha^{-1} and 3.7 ton ha^{-1} of carbon stock in undergrowth vegetation and litter layer, respectively. It was also observed that the total carbon content (11.82 ton ha^{-1}) of undergrowth and litter layer was nearly the same amount of the carbon content (12.25 ton ha^{-1}) of *S. obtusa*. Thus, tree species, undergrowth and litter layer play an important role as a carbon sink in Deciduous Dipterocarp forest.

Since carbon sequestration is considered as a priority in Chatthin Wildlife Sanctuary, silvicultural treatments such as pruning, thinning and natural regenerating operations should be taken to increase tree size and volume which can absorb large amount of carbon from the atmosphere. In this study, the equations derived from this study could not be used for estimating carbon content of other species. For estimating the carbon storage of other species, additional sample tests will be required in order to construct site-specific and species-specific allometric equations.

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