CHAPTER 3

VEGETATION STRUCTURE, ABOVEGROUND BIOMASS AND CARBON STOCK IN TROPICAL DECIDUOUS FOREST

The vegetation structure in dry dipterocarp forest (DDF) and mixed deciduous forest (MDF) is described in this chapter. A diversity of plant in both DDF and MDF was obtained a qualitative and quantitative for compare with the other forest region. Family and species list of plant were classified in four of the plot set up in this site. The diameter at breast height (DBH) and height (Ht) are conducted for used to estimate the aboveground biomass of vegetation in this site. The aboveground biomass (AGB) of tree and bamboo was estimate by allometric equation.

3.1 Materials and Methods

3.1.1 Experiment Plot Set Up

Four study plots of 40m × 40m were setup in DDF and an MDF. The number of individuals and associate aboveground biomass of tree at DBH> 4.5 cm and bamboo were collected in the sub-plot of 20m × 20m size located at the left corner of the main 40m × 40m plot, while sapling of DBH < 4.5, and Ht > 1.3 m were from four sub-plots of 10m × 10m size. The data on seedling with total height lesser than 1.3 m, other understory (grass, herb, shrub, climbers) and litter (both leaf and small twig) were collected from four 1m × 1m subplots (Figure 3.1).

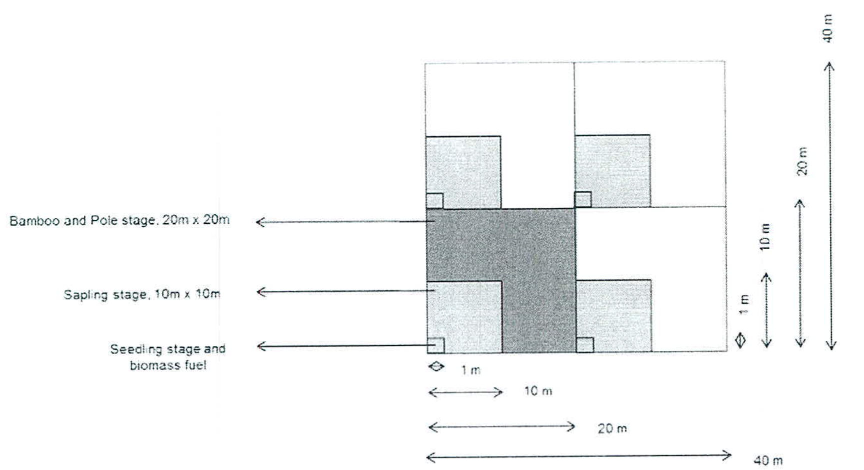


Figure 3.1 Plot set up for vegetation structure determination and aboveground biomass estimation in both DDF and MDF at the study sites

3.1.2 Determination of Vegetation Structure

All species of trees were conducted in sub-plots of 20m × 20m in a DDF and an MDF. For each species, general information of forest vegetation including plant family, scientific name, as well as common name, were logged. Theoretically, the evolution characteristics of trees, shrub, ivy, etc., differ by the growth patterns and vegetative individual composition. The differences rely not only in the growth dynamic pattern but also in the variation of environment parameters suitable to each plant species. Information on species and its evolution pattern is useful to better understand the plant growth and species density influencing the amount of above-ground biomass and biomass fuels during forest fires.

Qualitative assessment of plant vegetation

Characteristics of qualitative assessment methods in the forest vegetation in the area are a list of plants in the site study. The general species list information of forest vegetation will include a family of plant, scientific name, and a common name. The life forms characteristics of plants as trees, shrub, and climbers etc. have a many differences of the nature of growth patterns of each individual vegetation. Not only the nature of growth patterns but also a different of environment factor in plant species with different needs. The information of species list and life forms will help us know the characteristics plant growth and number of plant species influencing the amount of forest fuels.

Quantitative assessment of plant vegetation

Quantitative method is necessary to investigate the number of plant species information to compare with the other forest land. A parameter to quantify plant species information is as frequency, abundance, and density of plants species in the sampling plots.

a) Frequency of plants

Frequency of plants is evaluated based on the distribution of one species of all plants in the study area. Plants are distributed randomly in all the plots are converted to the maximum frequency of 100%. If some plant species are found only in the distribution at some plot, its at low frequency. The relationship frequency of plant species is show in Equation 3.1.

$$Frequency\ of\ Species\ i = \left(\frac{Number\ of\ sampling\ plot\ found\ species\ i}{Total\ number\ of\ sampling\ plot}\right) \times 100 \qquad \text{Equation 3.1}$$

b) Abundance of plants

Abundance of plants mean the number of plants in the sampling plot of plants found them per number of sampling plot of plant found them can be written the following relationship that is shown in Equation 3.2.

$$Abundance\ of\ Species\ i = \left(\frac{Number\ of\ plants\ species\ i\ in\ sampling\ plot}{Number\ of\ sampling\ plot\ found\ species\ i}\right) \quad \text{Equation 3.2}$$

c) Plant density

Total number of each plant species in the total sampling plots studied. The bamboo species will obtain the number of clumps as well as the individuals. The equation to estimate plant density is as follows.

$$Density\ of\ Species\ i = \left(\frac{Total\ number\ of\ plants\ species\ i}{Total\ number\ of\ all\ sampling\ plot}\right) \quad \text{Equation 3.3}$$

d) Plant dominance

Plant dominant of each specie was estimated from the area of section of stem at DBH position. The equation for quantify is as follows.

$$Dominance\ Species\ i = \left(\frac{Total\ basal\ area\ of\ species\ i}{Total\ basal\ area\ of\ all\ species}\right) \quad \text{Equation 3.4}$$

e) Ecological importance value index (IVI)

The vegetation structure was quantitatively characterized by investigating the Ecological Important Value Index (IVI) of the plant species. The parameters quantified in relative IVI are relative density, frequency, and dominance, of plant species. The important value index (IVI) of vegetation structure was obtained based on the equation of Curtis (Curtis, 1959) as follows:

$$IVI = relative\ density + relative\ frequency + relative\ dominance \quad \text{Equation 3.5}$$

where

$$Relative\ Density = \frac{Number\ of\ indivirual\ of\ the\ species\ i}{Number\ of\ individual\ of\ all\ the\ species} \times 100 \quad \text{Equation 3.6}$$

$$Relatvie\ Frequency = \frac{Number\ of\ occurrence\ of\ the\ species\ i}{Number\ of\ occurrence\ of\ all\ the\ species} \times 100 \quad \text{Equation 3.7}$$

$$Relative\ Dominace = \frac{Total\ basal\ area\ of\ the\ species\ i}{Total\ basal\ area\ of\ all\ the\ species} \times 100 \quad \text{Equation 3.8}$$

3.1.3 Aboveground Biomass and Carbon Stock Estimation

The vegetation plant stage in the tropical forest was defined as 3 stages (Viriyabancha, 2003) are following,

1) Pole stage: woody plants in pole stage have a DBH ≥4.5cm DBH, and Ht ≥130cm.
2) Sapling stage: trees in sapling stage have a DBH as ≤4.5cm and Ht ≥130cm.
3) Seedling stage: plant in seedling stage means the baby trees that have a DBH ≤4.5cm and Ht ≤ 130cm.

However, the biomass fuel is one of the categories to estimate the aboveground biomass in the study site. The biomass fuel means undergrowth without seedling stage and dead product. The understory consists climbers, herb, grass which are Ht ≤ 130cm and ≤4.5cm DBH and dead products on the ground such as litter, twig and wooden log. The summary of number of plot set up to collect the DBH and Ht of vegetation for aboveground and carbon stock estimation is illustrated in Table 3.1

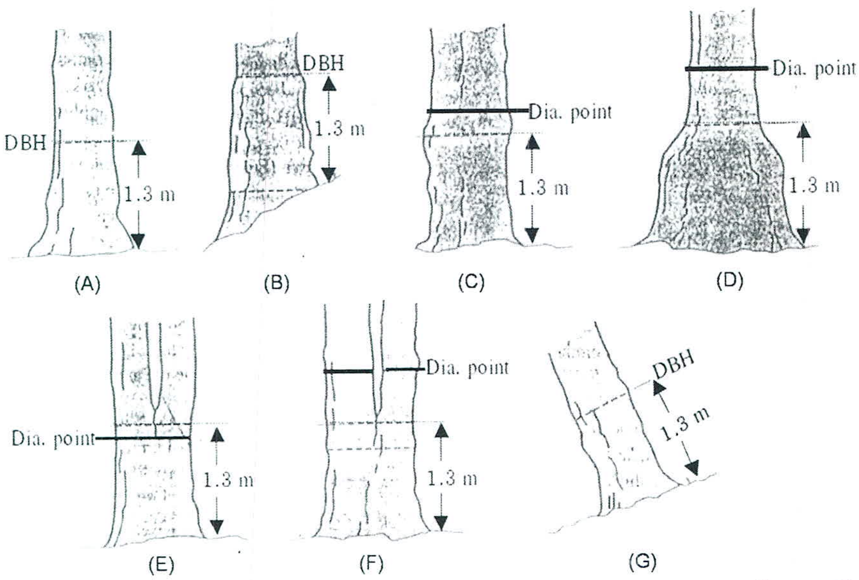
Table 3.1 Summary of number of plots setup for estimation of aboveground biomass of four category in tropical deciduous forest; DDF and MDF

Category	Diameter at breath height (DBH) and height (Ht)	plot size (m^2)	Number of subplot in tropical deciduous forest (plots)							
			DDF				MDF			
			I	II	III	IV	I	II	III	IV
Pole stage	DBH ≥ 4.5cm, Ht ≥ 130cm	20×20	1	1	1	1	1	1	1	1
Sapling stage	DBH ≤ 4.5cm, Ht ≥ 130cm	10×10	4	4	4	4	4	4	4	4
Seedling stage	DBH ≤ 4.5cm, Ht ≤ 130cm	1×1	4	4	4	4	4	4	4	4
Biomass fuel	Climbers, herb, grass, litter, and twig.	1×1	4	4	4	4	4	4	4	4

A. Diameter at Breath Height (DBH) Measurement

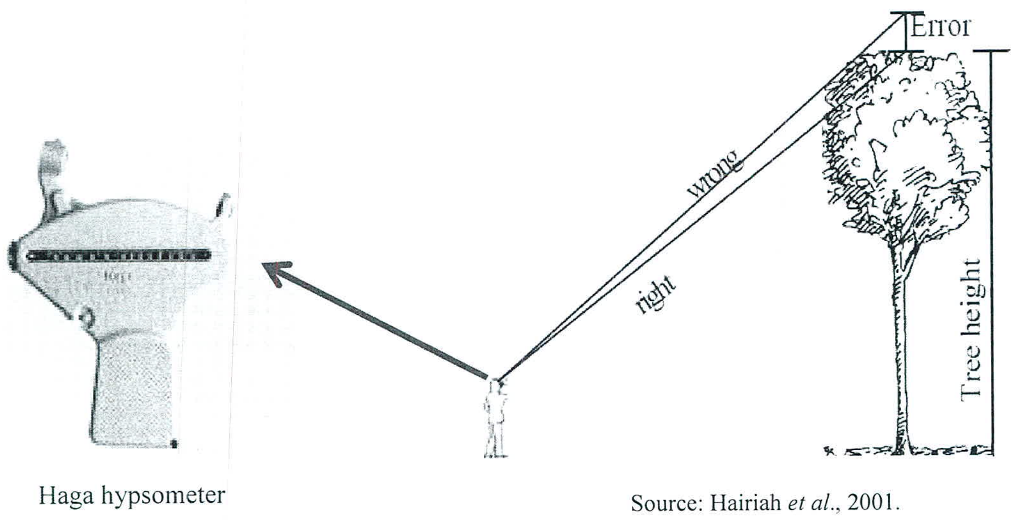
The method to define DBH and obtain the height of trees is based on Ogawa's methodology (Ogawa *et al.*, 1965). Fiber tape is applied to measure a diameter of trees in pole stage and sapling stage. In Figure 2.3 showed the variety shapes of tree to measure DBH for estimate aboveground biomass.

Four 40m × 40m plots were set up in DDF and MDF (Figure 3.1). Determination of biomass loads related carbon stock, the aboveground estimation of tree (DBH >4.5cm) and bamboo were collected in one square 20m × 20m plot located at the left corner of the main 40m × 40m areas, while saplings (DBH< 4.5cm and Ht> 1.3m) were estimated from four square 10m × 10m subplots. The seedlings (total Ht <1.3m), other understory (grass, herb, shrub, climber) and litters (both leaf and small twig) were collected from four square 1m × 1m subplots (Figure 3.1) during 2010 to 2011 at Mae Nam Phachi Wildlife Sanctuary, Ratchaburi, Thailand.



Source: Hairiah *et al.*, 2001.

Figure 3.2 Position to measure DBH of living trees in pole stage and sapling stage which have variables of standing shape and standing slope (A), (B), (C), (D),(E), (F) and (G)



Source: Hairiah *et al.*, 2001.

Figure 3.3 Tree height measured by Haga hypsometer

B. Tree height measurement

The height of trees in pole stage and sapling stage was measured by the use of Haga hypsometer (Figure 3.3). The operator fixed a baseline position standing distance from tree 15m or 20m. The heights of plants will be simulate in the pole stage in the left corner of 20m x 20m placed in 40m x 40m of DDF and MDF.

DBH and Ht were recorded for all pole stage, sapling stage and bamboo in subplot 20m ×20m (Figure 3.1). The aboveground tree biomass was estimated using the allometric equation of Ogawa et al. (Ogawa *et al.*, 1965). The estimation of aboveground sapling biomass and aboveground bamboo biomass (*T. siamensis*) were obtained from the allometric equation of Issaree (Issaree, 1982) and Suwannapinunt (Suwannapinunt, 1983), which illustrated in Chaiyo et al. (Chaiyo *et al.*, 2011). The carbon content in aboveground biomass of pole stage and sapling stage was calculated by multiplying the 0.47 of the total aboveground biomass (McGroddy *et al.*, 2004) that was illustrated in the IPCC Guidelines 2006. The conversion factor for biomass to carbon stock of bamboo of the other research studies are ranged 0.45-0.50 (Lin *et al.*, 1998b, Zhou and Jiang, 2004, Li *et al.*, 2006, Chen *et al.*, 2009 and Yen and Lee 2011) that this study was used the mean value (0.47) of conversion factor to estimate carbon stock of *T. siamensis*.

C. Estimation of aboveground biomass of trees and sapling

The aboveground tree biomass was estimated using the allometric equation of Ogawa (1965), and defined in Equation 3.9. The estimation of aboveground sapling biomass and above-ground bamboo biomass (*T. siamensis*) were obtained from the allometric equations of Issaree (Issaree, 1982) and Suwannapinunt (Suwannapinunt, 1983), and indicated in Equations 3.10 and 3.11, respectively.

$$W_s = 0.0396\ D^2H^{0.9326}$$
$$W_b = 0.003487\ D^2H^{1.0270}$$
$$W_l = \left(\frac{28.0}{W_{tc}} + 0.025\right)^{-1}$$

Equation 3.9

$$W_s = 0.0893059\ D^2H^{0.66513}$$
$$W_b = 0.0153063\ D^2H^{0.58255}$$
$$W_l = 0.0000140\ D^2H^{0.44363}$$

Equation 3.10

where: D is the diameter at breast height [cm], H is the height of tree stand [m], W_s is the mass of stem [kg], W_b is the mass of branch [kg], W_l is the mass of leaf [kg] and W_{tc} is the total mass of stem and branch [kg],

$$W_c = 0.0691512\ D^2 H^{0.7930}$$
$$W_t = 0.0883689\ D^2 H^{0.7703} \qquad \text{Equation 3.11}$$
$$W_{b+l} = W_t - W_c$$

where: D is the diameter at breast height (cm), H is the height of culm (m), W_c is the mass of culm (kg), W_t is the total mass of culm, branch and leaf (kg) and W_{b+l} is the total mass of branch and leaf (kg).

D. Mass of biomass fuels

The biomass fuel is defined as leaf litter, twig, seedling, and understory (i.e. grass, climbers and herb). The systemic random sampling method was used to sample biomass fuel sample from field experiments. Four sampling of biomass fuel sample was collected from four a square 1m × 1m area in the left corner of each a square 20m × 20m areas of the main plot (Figure 3.1). The next sampling time, biomass fuel will be collected every 1 m next to the previous subplot from previous a 1m × 1m area of the diagonal of the lower left corner to the upper right. In a 1m × 1m area, biomass fuel was observed and estimated the percentage of coverage and measured a fuel height of each type prior cutting and directly sampling. Each of sampling plots in a square 1m × 1m area, samples were separated for each category or fuel type such leave litter, twig, seedling, and understory and then weighed in the field. Finally, all of samples were carried to oven-dried at 70-80 °C for 24 h or until weight constant. All fuel types were sampled to obtain the dry mass and percentage of moisture content on July, September, November, December in year 2010 and January, February and March in year 2011, respectively.

Moisture content of biomass fuels of each category was obtained by Equation 3.12 then the quantity of dry fuel mass was calculated by Equation 3.13 as follows:

$$MC_{db} = \frac{FW - DW}{DW} \times 100 \qquad \text{Equation 3.12}$$

$$DW_{db} = \frac{FW}{(100+\%MC_{db})} \times 100 \qquad \text{Equation 3.13}$$

where: MC_{wb} and MC_{db} is the percent of wet basis and dry basis moisture content in biomass, *FW* is the fresh weight of biomass (g) *DW* is the weight after dry-oven at 70-80 for 24 h or until weight constant (g) and DW_{db} is dry weight of biomass of dry basis (g).

3.2 Results and Discussion

3.2.1 Vegetation in Tropical Deciduous Forests

In DDFs, the vegetation of trees is composed of 15 families, 27 genus, 30 species and one unknown. Trees species types of *Shorea. obtusa*, *S. siamensis*, *Diperocarpus obtusifolias*, *Lannea coromandelica*, *Xylia xylocarpa* and *Carnarium subulatum* are the top of 5 abundance and also higher basal area, respectively. The species *S. obtusa* is the highest IVI in the DDF site. The vegetation species dominant in DDF is the same order magnitude with the other regions of Thailand. Boonrodklab and Teejuntuk (Boonrodklab and Teejuntuk 2008) found that the top three dominant are *D. tuberculatus*, *S. obtusa*, and *S. siamensis* in DDFs located in Doi Inthanon National Park, Chiangmai, northern Thailand.

Table 3.2 Structure (abundance, basal area (BA), relative frequency (RF), relative density (Rden), relative dominance (Rdo) and ecologiacl important value index (IVI) of tree stands in DDF plots located in the Mae Nam Phachi Wildlife Sanctuary Ratchaburi Province, Thailand

Species	Abundance (indiv./ha)	BA ($cm^2 ha^{-1}$)	RF	Rden	Rdo	IVI
Shorea obtusa	813	92,925	9.30	45.296	20.990	75.588
Shorea siamensis	713	106,497	4.65	19.861	24.055	48.567
Dipterocarpus obtucifolius	375	50,923	2.33	5.226	11.502	19.054
Lannea coromandelica	225	22,239	4.65	6.272	5.023	15.946
Xylia xylocarpa	125	14,927	6.98	5.226	3.372	15.575
Canarium subulatum	125	36,020	2.33	1.742	8.136	12.204
Sohleichera oleosa	25	22,353	2.33	0.348	5.049	7.723
Vitex peduncularis	63	4,104	4.65	1.742	0.927	7.320
Aporosa villosa	38	3,856	4.65	1.045	0.871	6.567
Dalbergia oliveri	50	1,833	4.65	1.394	0.414	6.459
Gluta usitata	25	15,058	2.33	0.348	3.401	6.075
Pterocarpus macrocarpus	38	1,377	4.65	1.045	0.311	6.007
Antidesma ghaesembilla	75	10,169	2.33	1.045	2.297	5.668
Grewia eriocarpa	50	11,691	2.33	0.697	2.641	5.663
Buchanania kanzan	25	718	4.65	0.697	0.162	5.510
Vangueria catunare	50	9,266	2.33	0.697	2.093	5.115
unknown	75	4,339	2.33	1.045	0.980	4.351
Careya spharica	75	3,857	2.33	1.045	0.871	4.242
Bridelia retusa	50	5,341	2.33	0.697	1.206	4.229
Artocarpus lakoocha	25	6,464	2.33	0.348	1.460	4.134
Terminalia chebula	25	4,718	2.33	0.348	1.066	3.740
Sindora siamensis	25	4,210	2.33	0.348	0.951	3.625
Anacardia ocidentale	50	1,401	2.33	0.697	0.317	3.339
Ochna integerrima	25	2,076	2.33	0.348	0.469	3.143
Croton oblongifolius	25	1,720	2.33	0.348	0.388	3.062
Mammea siamensis	25	1,194	2.33	0.348	0.270	2.944
Pavetta tomentisa	25	1,043	2.33	0.348	0.236	2.910
Gardenia sootepensis	25	963	2.33	0.348	0.217	2.892
Mammea harmandii	25	877	2.33	0.348	0.198	2.872
Dillenia spp.	25	542	2.33	0.348	0.122	2.796
Dalbergia assamia	25	21	2.33	0.348	0.005	2.679
Total	3,340	442,720	100	100	100	300

Table 3.3 Structure (abundance, basal area (BA), relative rrequency (RF), relative density (Rden), relative dominance (Rdo) and ecologiacl important value index (IVI) of tree stands in MDF plots located in the Mae Nam Phachi Wildlife Sanctuary Ratchaburi Province, Thailand

Species	Abundance (indiv./ha)	BA (cm^2 ha^{-1})	RF	Rden	Rdo	IVI
Thyrsostachys siamensis	14,613	95,609	8.33	96.892	32.424	161.877
Xylia xylocarpa	38	25,132	4.17	0.124	8.523	11.737
Millettia brandisiana	58	7,137	6.25	0.290	2.420	9.712
Vitex peduncularis	50	7,076	6.25	0.249	2.400	9.643
Lagerstroemia calyxcolata	50	15,844	4.17	0.166	5.373	9.026
Bauhinia saccocalyx	50	8,504	4.17	0.166	2.884	6.852
Lannea coromandelica	38	6,888	4.17	0.124	2.336	6.332
Albezia lebbeck	75	25,208	2.08	0.124	8.549	5.942
Bombax anceps	25	3,919	4.17	0.083	1.329	5.411
Dalbergia cultrata	25	3,869	4.17	0.083	1.312	5.396
Schleichera oleosa	50	16,631	2.08	0.083	5.640	4.630
Grewia eriocarpa	150	15,215	2.08	0.249	5.160	4.586
Stereospermum neuranthum	25	784	4.17	0.083	0.266	4.482
Terminalia pierrei	50	7,922	2.08	0.083	2.687	3.340
Canarium subulatum	50	7,851	2.08	0.083	2.662	3.329
Gratoxylum formosum	25	6,707	2.08	0.041	2.274	3.118
Dalbergia oliveri	50	5,015	2.08	0.083	1.701	2.909
Heterophragma adenophyllum	25	5,013	2.08	0.041	1.700	2.867
Xanthophyllum lanceatum	75	4,232	2.08	0.124	1.435	2.835
Atalantia monophylla	25	4,210	2.08	0.041	1.428	2.748
Bauhinia variegata	25	3,887	2.08	0.041	1.318	2.701
Vitex canescens	75	2,952	2.08	0.124	1.001	2.645
Pterocarpus macrocarpus	75	2,349	2.08	0.124	0.797	2.556
Diospyros castanea	25	2,437	2.08	0.041	0.826	2.486
Bauhinia glauca	50	1,823	2.08	0.083	0.618	2.436
Syzygium cumini	25	1,560	2.08	0.041	0.529	2.356
Croton oblongifolius	25	1,408	2.08	0.041	0.477	2.333
Terminaria triptera	25	1,165	2.08	0.041	0.395	2.297
Lagerstroemia loudonii	25	1,052	2.08	0.041	0.357	2.281
Bridelia tomentosa	25	894	2.08	0.041	0.303	2.257
Shorea obtusa	25	733	2.08	0.041	0.249	2.233
Phyllantus emblica	25	659	2.08	0.041	0.223	2.222
Arfeuilea arborescens	25	645	2.08	0.041	0.219	2.220
Buchanania latifolia	25	535	2.08	0.041	0.181	2.204
Total	16,021	294,867	100	100	100	300

The vegetation in MDFs is composed of 17 families, 28 genus and 34 species. The top 5 tree stand abundance species are *Xylia xylocarpa*, *Grewia eriocarpa*, *Albezia lebbeck*, *Xanthophyllum lanceatum*, *Vitex canescens* , and *Pterocarpus macrocarpus*. We found the most abundant vegetation species to be *T. siamensis*, which is a bamboo species. The species of this bamboo is the only one that we found in this site. The basal area of this bamboo is 32.42% as compared with the total basal area of all species. Tree species *Albezia lebbeck* constituted 12.65% of the total basal area of trees, which is the highest and followed by *X. xylocarpa* that constituted 12.61%.

In MDF, we found that the vegetation was composed of a mixture of bamboo and tree. Related to the other research found that the vegetation family dominant in MDF in the western region is composed of Fabaceae and Gramineae (McGroddy *et al.*, 2004). Bamboo of Gramineae is one of the dominant families in MDF located in the western region. However, the bamboo *Bambusa tulda, Gigantochloa albaciliata, G. hasskaliana* and *Cephalostachyum pergracile* were also dominant in this province (McGroddy *et al.*, 2004; Nuanurai, 2005).

The important value of five leading species in both DDF and MDF is illustrated in Tables 3.2 and 3.3. The IVI values less than 12 of family dominant in DDF are including the families of Dipterocarpaceae, Anacardeaceae, and Fabaceae. In MDF, the family of bamboo (*T. siamensis*) is Gramineae which the one of species growing in this site. Tree families in MDF are Vitigaceae and Lythraceae and also similar with DDF such Fabaceae. The IVI for top five families in MDF are >9.

3.2.2 Plant Structure in Tropical Deciduous Forest

The average of individual tree and sapling stage in DDF plots are 1,788±682 and 819±282 individuals/ha. The mean DBH of tree and sapling were 9.50 and 2.82 cm. According to the mean Ht of tree and sapling were 9.33 and 2.50 m, respectively (Table 3.4). Tree density and sapling in MDF plots are 481±189 and 383± 225 individuals/ha. Both of tree and sapling density in MDF are lower than in DDF plots. However, the DBH of trees had similar values in both DDF and MDF. On the contrary, the Ht mean value of trees in MDF is larger than tree in DDF plots (Table 3.4). Although the DBH size classes (4.5-10 cm) of both DDF and MDF is the highest density and distribute than other size (Figure 3.4). Figure 3.4 represents the density of trees as a function of DBH for tropical deciduous forest. This obtained graph is of L-shape, indicating that the DDF and MDF in this study are secondary forests. The DBH size classes in the study site have been a high variation due to the natural forest. The density, DBH, Ht and the habitat of vegetation are also high variation. However, the DBH of tree stands in ranged 20-40 cm are the highest capacity to sink carbon via photo synthesis process (Terakunpisut *et al.*, 2000).

Table 3.4 Plant structure (density, diameter at breast height, DBH and height, Ht) in DDF and MDF Plots

Forest type	Vegetation Category	Density (tree/ha)	DBH (cm)		Ht (m)	
			mean	range	mean	range
DDF	Tree	1,788±682	9.50	4.77-43.29	9.33	2.50-20.50
	Sapling	819±282	2.86	1.02-4.39	2.50	1.50-4.80
MDF	Tree	481±189	10.92	4.62-67.48	10.03	3.00-24.30
	Sapling	383±225	3.02	0.57-4.20	4.23	1.30-7.80
	Bamboo [a]	13,931±3,319	2.62	1.29-5.87	7.73	2.00-21.70
	Bamboo [b]	1,438±651	36.90	10.67-106.88	7.73	2.00-21.70

[a]The individual number of bamboo in unit culm/ha and [b]clump/ha.

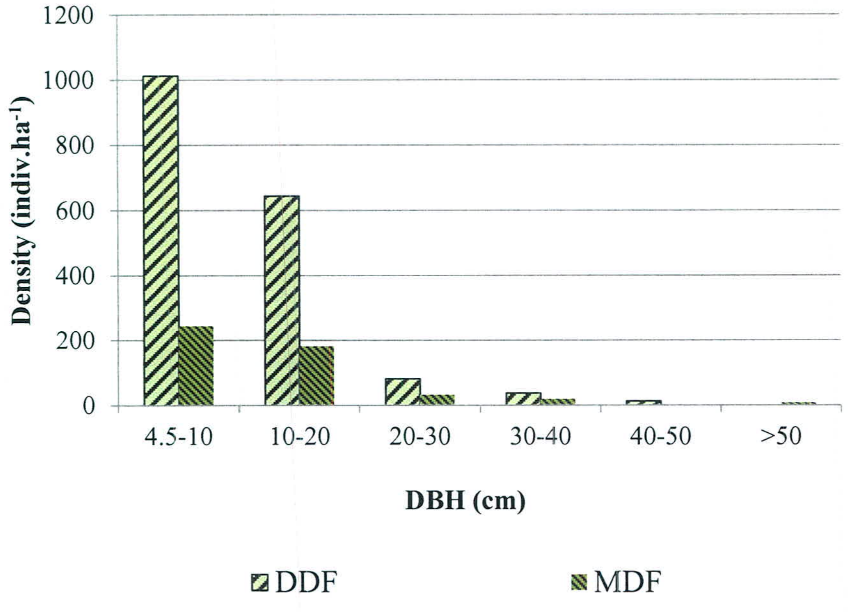


Figure 3.4 Tree diameter distributions in DDF and MDF

In the study site, MDF usually consists of tree species that with many bamboo species. Bamboo species of *T. siamensis* is the main bamboo in MDF plots. The density of *T. siamensis* is 13,931±3,319 culms/ha or 1,438±651 clumps/ha. The DBH and Ht ranged of bamboo species are 1.29-5.87 cm and 2.00-21.70 m, respectively (Table 3.4). The number of bamboo clump in MDF is 1,438± 651 clumps/ha and also of each clump was composed of 5-50 culms.

Table 3.5 Biomass Fuel Height in DDF and MDF Plots

Forest type	Biomass fuel height (cm)			
	Living part		Dead part	
	seedling	grass, herb, climber, etc.	litter	twig
DDF	10-55	7-25	5-10	2-6
MDF	12-50	25-30	4-6	1-4

Figure 3.5 Biomass fuel sampling in DDF plots (with slope <20%)

The height of the understory varied among site and depends on the structure and composition of live and dead vegetation type. The biomass of understory vegetation usually changes with the season, which its peak in rainy season. The height of seedling at the terrain in DDF site is the highest among other. The height of litter at the steep slope DDF, terrain DDF and terrain MDF are 5-10, 0-3 and 4-6 cm, respectively (Table 3.5). The good agreement was found when compared with the other research in western region of Thailand, Huay Kha Khaeng Wildlife Sanctuary, Uthai-thani Province, which the average of litter height in DDF was 5.27 cm and litter was highest in dry season (7-10 cm) (Akaakara *et al.*, 2003). However, the litter height at the terrain DDF is the lowest and the fuel arrangement was discontinuously (Table 3.5 and Figure 3.5) which can be attributed to the low density of vegetation plant. This low fuel height and fuel discontinuity, therefore, may affect rate of fire spread, and hence fire intensity of this plot.

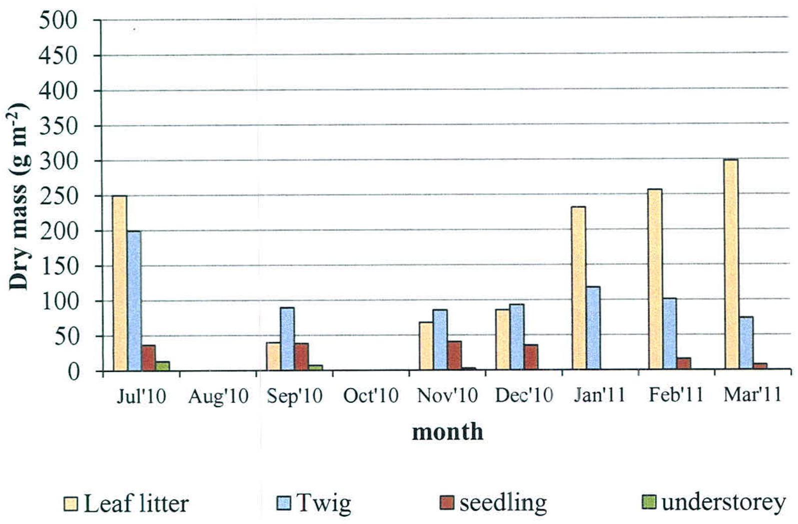


Figure 3.6 Dry mass of biomass fuel as leaf litter, twig, seedling, and understory in DDF plots during 2010 - 2011

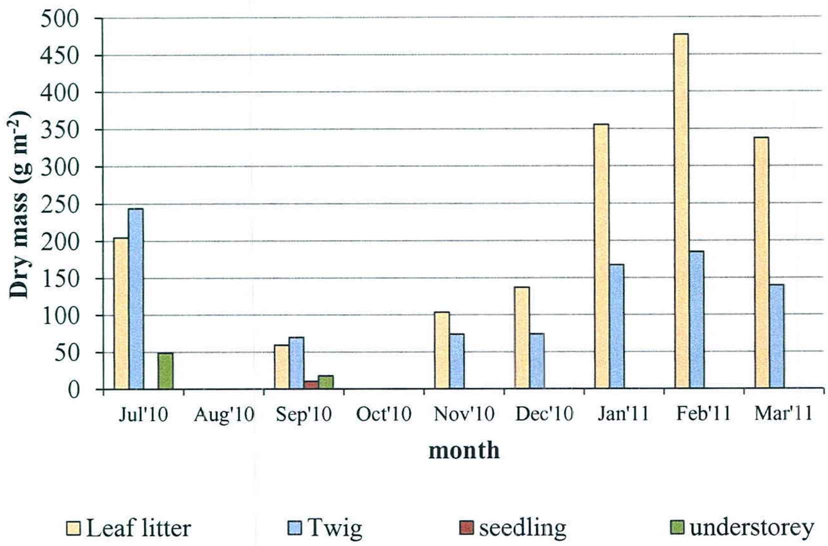


Figure 3.7 Dry mass of biomass fuel as leaf litter, twig, seedling, and understory in MDF plots during 2010 - 2011

In both forest types, the amount of leaf litter was increased and also the highest during dry season (from November to April) due to the dead leaves shaded (Figures 3.6 and 3.7). In addition, the ground was predominantly covered with leaf litter. The moisture content of leaf litter and twig were the lower than 20% in the same period time (Figures 3.8 and 3.9).

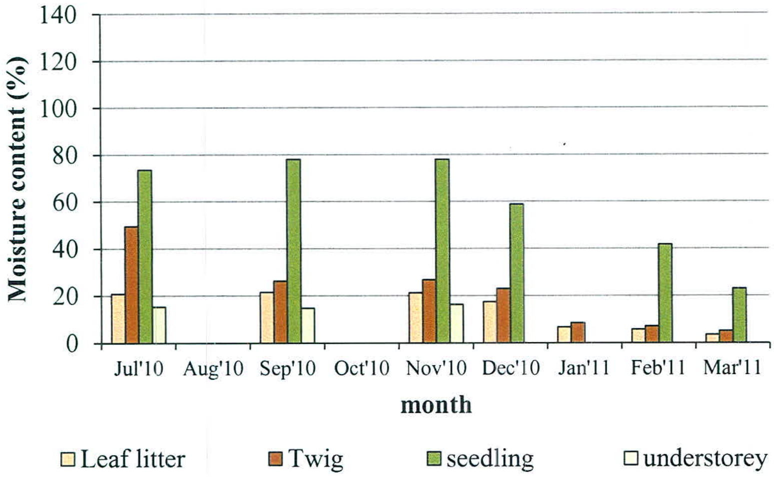


Figure 3.8 Percentage of moisture content in biomass fuel as leaf litter, twig, seedling, and understory in DDF plots during 2010 – 2011

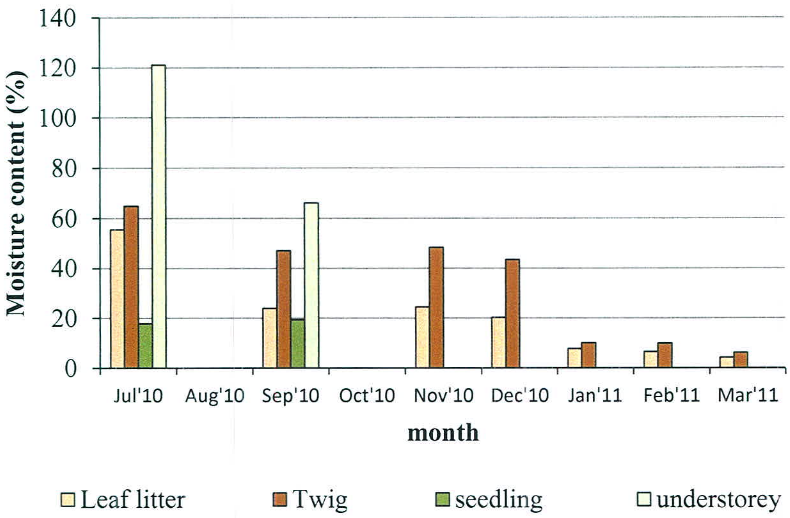


Figure 3.9 Percentage of moisture content in biomass fuel as leaf litter, twig, seedling, and understory in MDF plots during 2010 - 2011

The overall of 95% coverage of biomass fuel was leaf litter, followed by twig and undergrowth. In the dry season, a little mass of undergrowth such climber, herb and grass were dead and mixed in the duff and litter.

Table 3.6 Aboveground biomass of DDF and MDF plots

Category	Biomass section	AGB (ton/ha)		
		DDF		MDF
		Slope 20-40%	Slope <20%	Slope <20%
tree	Stem	68.40	19.90	16.83
	Branch	7.43	2.08	1.84
	Leaf	6.08	1.84	0.26
Sapling	Stem	1.51	1.10	0.66
	Branch	0.23	0.18	0.98
	Leaf	0.0002	0.66	0.0001
bamboo	Culm	-	-	26.98
	Branch and leaf	-	-	4.22
Biomass fuel	understory	-	0.26	1.13
	Litter	7.83	3.29	4.96
	Twig	0.48	1.64	1.58
Total AGB, ton/ha		91.96	30.95	59.44

3.2.3 Aboveground Biomass and Carbon Stock

The aboveground biomass of the stand composed of trees and saplings, which were estimated from 3 parts, i.e. stems, branches, and leaves. The aboveground biomass of tree in DDF at the steep slope, terrain and in MDF are 81.91, 23.82 and 18.93 tons/ha, respectively (Table 3.6). While aboveground biomass for sapling of each plot was equal among the forest (i.e. 1.74, 1.94 and 1.64 tons/ha for the DDF at steep slope, terrain, and MDF, respectively). The highest of aboveground biomass of tree in DDF at steep slope is related to the stand density. Based on the DBH mean values and density of tree stand in tropical deciduous forest, we estimate that the above-ground biomass in this area will slightly increase in the further.

In MDF, the aboveground biomass was present in the pole stage and the bamboo, especially the bamboo species influenced the amount of aboveground biomass in this site. According the aboveground biomass presents 76% from bamboo species. The aboveground biomass of the culm and branch (with leaf) of *T. siamensis* are 26.98 and 4.22 tons/ha (Table 3.6). The information of aboveground biomass and carbon stored in this forest will be used to quantify and estimation of carbon pools and fluxed that is important for understanding the contribution of the forest to net carbon emissions and their potential for carbon sequestration (Chhabra and Dadhwal, 2004).

Table 3.7 Aboveground biomass and carbon stock of tropical deciduous forest in western region, Thailand

Forest type	AGB (ton/ha)	C-stock (ton C/ha)	Ref.
DDF slope20-40%	91.96	43.22	this study
DDF slope <20%	30.95	14.55	this study
DDF	58.62 ± 19.42	29.31 ± 9.71	Nuanurai, 2005
MDF slope <20%	59.44	27.94	this study
MDF	68.52 ± 48.36	34.26 ± 24.18	Nuanurai, 2005
MDF	141.06	66.30	Terakulpisut et al., 2007
MDF	96.28 ± 33.44	45.28 ± 15.72	
MDF	158.68	74.58	Jampanin et al., 2007

Biomass carbon storage at the steep slope DDF, terrain DDF and terrain MDF are 43.22, 14.55 and 27.94 tons·C/ha, respectively. The comparison of carbon storage with the other research is based on the IPCC 2006 conversion of aboveground biomass by factor value. We found that the variation values of carbon storage in the tropical deciduous forests in the western region were in the range of 10-66 tons·C/ha. The aboveground biomass in the study was estimated by means of the allometry correlation between mean value of DBH, Ht, and biomass. Obviously, the result of our study is comparable with other studies. Moreover, the variation of carbon stock in aboveground dependent on many factors such as the stand structure and composition, topography, altitude, and disturbance, forest fire in particular. However, carbon stocks in aboveground biomass in DDF and MDF are the same order of magnitude with the secondary forest that was present the carbon stock lower than 51.90 tons·C /ha (Kaeskrom *et al.*, 2011).

3.3 Summary of Findings

- The vegetation species in this site is less than those found in the other areas.
- In DDF, tree species of *Shorea obtusa*, *S. siamensis*, and *Diperocarpus obtusifolias* are family of Dipterocarpaceae that is the one of three deciduous family in the world.
- The species *Shorea obtusa* is the highest of IVI that it was show that this site was covered with this species.
- *T. siamensis* is the bamboo species dominant in MDF and influenced the amount of aboveground biomass.

- The aboveground biomass and carbon stock at the steep slope DDF was the highest, followed by the terrain MDF and they were lowest at the terrain DDF.
- Biomass fuel loads are composed mainly of leaf litter, which is varied based on the tree density and tree species. However, the understory as grass, climb and herb will die and not be found in both DDF and MDF during the dry season.
- In MDF, not only the leaf litter of the tree but also bamboo leaf litter that is the major composition in biomass fuel.
- The moisture content of leaf litter in both DDF and MDF has the same order of magnitude.