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Variations in Plant Diversity and Carbon Storage among Subtype Communities in a Dry Dipterocarp Community Forest of Mae Tha Sub-district, Mae On District, Chiang Mai Province

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ABSTRACT

Variations in plant diversity and carbon storage among subtype communities in a dry dipterocarp forest were investigated in the Mae Tha sub-district community forest, Mae On district, Chiang Mai province, in 2014. Fifteen sample plots, each 40 x 40 m, were used for vegetation survey and arranged randomly over the forest. Plant data in these plots were collected by measuring stem girths at 1.3 m above ground and tree heights, and then used to calculate plant species diversity, biomass and carbon storage. The DDF could be divided into five subtype communities based on dominant tree species: Teng (*Shorea obtusa*) (DDF-1), Rang (*S. siamensis*) (DDF-2), Hiang (*Dipterocarpus obtusifolius*) (DDF-3), Pluang (*D. tuberculatus*) (DDF-4), and two-needle pine (*Pinus merkusii*, P-DDF). In total, 83 plant species (69 genera, 42 families) with an average tree density of 2,266 trees ha^{-1} were found. These five communities had different quantitative features: species richness, 181, 181, 219, 129 and 213; tree density, 2,723, 2,115, 2,544, 1,857 and 1,596 trees ha^{-1}; stem basal area, 23, 30, 26, 19 and 12 m^2 ha^{-1}; species diversity index (SWI), 3.25, 2.97, 3.55, 3.43 and 3.92; and forest condition index (FCI), 3.73, 4.80, 5.87, 6.23 and 3.28, respectively. The biomass amounts of these forest communities were estimated as 135, 159, 146, 109 and 62 Mg ha^{-1}, respectively, and were calculated to contain carbon at 67, 79, 72, 54 and 31 Mg ha^{-1}, respectively. The average values of plant biomass and stored carbon amounts were calculated as 125±55 and 62±31 Mg ha^{-1}, respectively. These data provide basic information for zoning community forest management by the Mae Tha Sub-district Administrative Organization to improve forest conditions as well as the carbon storage potential to mitigate global warming.

Keywords: Carbon Storage, Community Forest, Dry Dipterocarp Forest, Plant Diversity

INTRODUCTION

Community forest management in Thailand is considered an important approach through the participation of local communities in the management of natural forests with promotion by local forestry officers. The establishment of a village organization and regulations or rules for forest protection and utilization is needed. The community forest may be divided into conservation (CF) and utilization forest (UF) as for example in the Nong Tao community forest managed by a Karen tribe (Seeloy-ounkeaw, 2014a). According to village regulations, the CF is designed as a watershed forest, and cutting of trees and wildlife hunting are prohibited. The villagers can cut some trees in the UF for constructing accommodation and smaller trees for fuel wood and making fences. The collection of non-wood forest products is allowed only in the UF. The people outside the village are not allowed to utilize the community forest. Different management approaches for community forest were found for different locations and tribes (Nong-nuang, 2006, Pornleesangsuwan, 2006; Pornchalern, 2009; Seeloy-ounkeaw, 2014a). Differences in forest types, altitude and other physical factors are important in the different community forests. The non-wood forest products are normally used for household consumption and some income.

The Mae Tha community forest is different from other community forests in that it is united at the sub-district level and does not belong to a single village. Seven villages in Mae Tha sub-district have mutual forest management with the MTSAO. Two representatives from each village are members of the MTSAO for management of their community forest. From 1901 to 1969, forest concessions were taken by private companies for timber, especially teak, wood railway sleepers and fire wood supplied to a tobacco factory. These activities caused forest degradation and critical drought occurred in 1991 and 1992. The villagers in the Mae Tha sub-district have organized their members to work closely with the MTSAO. They set regulations and rules for the management of the community forest. Forests in the Mae Tha sub-district are divided into four types: dry dipterocarp forest (DDF), mixed deciduous forest (MDF), dry evergreen forest (DEF) and pine-dry dipterocarp forest (PF). Plant diversity differs among these forests. However this research focused only on the DDF, because it covers most of the community forest. The DDF covers dry areas including four dominant dipterocarp tree species: Teng, Rang, Hiang and Pluang. At higher altitude, the forest is composed of dipterocarp species and the two-needle pine in the so-called pine-DDF. The important foods from this forest are mainly wild mushrooms and ant eggs, which are used as food and income.

Carbon can be stored in different components of a forest ecosystem including forest biomass (plants, animals and microbes), organic layers on the forest floor and in the mineral soil. Carbon begins it cycle through the forest ecosystem when plants assimilate atmospheric CO_2 through photosynthesis to produce reduced sugars. Usually about half of the gross photosynthetic products produced are expended by plants in autotrophic respiration for the synthesis and maintenance of living cells, releasing CO_2 back into the atmosphere (Waring and Running, 2007). The remaining carbon products go into net primary production: foliage, branches, stems, roots and plant reproductive organs. As plants shed leaves and roots, or are killed, the dead organic matter forms detritus, a substrate that supports animals and microbes, which through their heterotrophic metabolism release CO_2 back into the atmosphere. Soil humus represents the major accumulation of carbon in most forest ecosystems. When the forest condition improves, not only will this enhance carbon stocks, it will improve biodiversity, water quality and provide other vital environmental services. This research assessed the present condition of the DDF, particularly variations in plant diversity and carbon storage potential among different subtype communities as the basis for management of this community forest.

MATERIALS AND METHODS

Study area

The research area was in the Mae Tha sub-district, Mea On district, Chiang Mai province. It is located at latitude 180° 32'10"- 180° 38' 45" N and longitude 99° 13'02"- 99021' 30" E with an altitudinal range between 480 and 1,200 meters above sea level.

Management of Mae Tha community forest

The data on community forest management were obtained from the documents of the MTSAO, interviews with local officers and representatives of farmers and from field observation.

Plant community study

Vegetation sampling

A method of plant community analysis was used for the vegetation study. Fifteen sample plots, each 40 x 40 m, were used and arranged randomly over the DDF. The stem girths at breast height (gbh, 1.3 m above ground) and tree heights of all tree species with height over 1.5 m were measured.

Ecological parameters

The ecological parameters of tree species were calculated consisting of: frequency, density, abundance, importance value index (IVI) and Shannon-Wiener Index (SWI) of species diversity as given by Krebs (1985).

$$H = -\sum_{i=1}^{S} (p_i)(\log_2 p_i)$$

Where H = index of species diversity (SWI)
S = number of species
pi = proportion of total sample belonging to the *i* species

$$E = \frac{H}{H_{max}}$$

Where E = equitability (range 0-1)
H = observed species diversity
H_{max} = maximum species diversity = $\log_2 S$

The forest condition index (FCI) was calculated using an equation of Seeloy-ounkeaw (2014a) for the 15 sample plots. For immature trees, the stem girth class of tree species was divided into 25 cm intervals for stem gbh up to 100 cm. The 100 cm interval was applied to mature trees, having gbh over 100 cm. This assumes that the increasing importance of the mature trees is due to their stem size (which produced merchantable timber for the concessionaire in the past for Thailand as well as having high ecological influence). A large number of big trees in the plot will result in a higher FCI value.

$$FCI = \sum n_1.10^{-4} + n_2.10^{-3} + n_3.10^{-2} + n_4.10^{-1} + 1(n_5) + 2(n_6) + 3(n_7) + \ldots$$

Where n_1 = number of tree individuals having gbh <25 cm

n_2 = number of individuals having gbh 25 to <50 cm

n_3 = number of individuals having gbh 50 to <75 cm

n_4 = number of individuals having gbh 75 to <100 cm

n_5 = number of individuals having gbh 100 to < 200 cm

n_6 = number of individuals having gbh 200 to < 300 cm

n_7 = number of individuals having gbh 300 to < 400 cm

Plant biomass and carbon storages

Plant biomass

The data on stem gbh and tree heights of tree species were used to calculate the biomass of the stem, branches, leaves and roots using allometric equations reported for deciduous forests in Thailand by Ogino *et al.* (1967).

$$w_S = 189\ (D^2H)^{0.902}$$

$$w_B = 0.125Ws^{1.204}$$

$$1/w_L = (11.4/ws^{0.90}) + 0.172$$

Where W_S = stem biomass in kilograms

W_B = branch biomass in kilograms

W_L = leaf biomass in kilograms

Tree diameter (D) and height (H) unit is meters.

The root biomass was calculated using an equation from Ogawa *et al.* (1965)

$$W_R = 0.026\ (D^2H)^{0.775}$$

Where root W_R is the biomass in kilograms, D is the diameter in centimeters and the H is the height in meters.

Carbon storage in plant biomass

The amounts of carbon stored in the plant biomass of each tree species were calculated by multiplying the biomass by the average carbon content in different plant tissues. The mean carbon contents in the stem, branch, leaf and root organs of 62 tree species in Thailand were calculated as 49.9%, 48.7%, 48.3% and 48.2%, respectively (Tsutsumi *et al.*, 1983).

RESULTS AND DISCUSSION

Management of Mae Tha community forest

The Mae Tha sub-district community forest was established in 1989 and has a forest committee which is responsible for forest management. The forest committee works co-operatively with the Sub-district Administrative Organization. In 1993, this local organization attended the movement of the Northern Farmer's Network to propose the community forest laws to the government. In 2000, the Mae Tha Sub-district communities strengthened the forest community management by themselves through improvements to organizational structures and functions based on their livelihood, and have made the specific plans for forest management in different locations in the sub-district areas. Moreover, they established "the Network of Mae Tha Sub-district Natural Resource Management" which consists of various groups as representatives from seven villages including sub-district administrative officers, housewives, youths, forest committee members and farmers of alternative agriculture. They have duties associated with the integrated natural management involving agricultural crops, soil, land use, water, forest, environment and their livelihood. The main income for villagers is from agriculture: baby corn, cows' milk, longan and laboring. They obtain food from the fields such as fish, crabs, frogs and insects, and also collect non-wood forest products for food or income such as bamboo shoots, bamboo worms, ant eggs and wild mushrooms.

The Mae Tha sub-district communities manage the community forest efficiently through cooperation between the forest committee and the MTSAO. They set rules and regulations to control forest utilization such as villagers who need wood for house construction have to request permission before taking any wood from the forest and they have to pay a fee. People who cut trees without permission will be fined 500 baht for every inch of stem diameter or be sent to the forestry officers to be punished according to the government laws. Through such management, the Mae Tha sub-district communities can protect and conserve the forest efficiently with no illegal tree cutting and forest clearing. Recently (April, 2015) the communities were the only ones in Northern Thailand to receive community land certificates from the government. As a result, the community forest has recovered as the watershed supplying water to perennial streams for agriculture and supporting food security with sufficient economic livelihoods for the villagers.

Variations of plant diversity and forest condition in the DDF

The plant diversity in the DDF was evaluated using species richness and the species diversity index. The forest condition was considered from the number of existing tree individuals of different stem-sized classes in each sample plot.

1) Plant species composition and richness

Within the 15 plots, 83 tree species (69 genera and 42 families) with an average density of 2,269 trees ha^{-1} were found. The DDF in the Mae Tha sub-district community forest could be divided into five subtype communities according to different dominant tree species: (1) Teng (*S. obtusa*), DDF-1 (2) Rang (*S. siamensis*), DDF-2 (3) Hiang (*D. obtusifolius*), DDF-3 (4) Pluang (*D. tuberculatus*), DDF-4 and (5) two-needle pine (*Pinus merkusii*, the so-called pine-dry dipterocarp forest), P-DDF. These communities had varying species composition, species richness, plant population and forest condition.

1.1) DDF with Teng (*S. obtusa*)

The forest in six plots was classified as DDF-1. It had a total of 59 species, varying from 21 to 39 species/plot. The tree densities varied between 1,538 and 3,388 trees ha^{-1} and stem basal areas ranged from 18 to 28 m^2 ha^{-1}.

Teng had different quantitative characteristics among the plots: density, 579 to 1,313 trees ha^{-1}, dominance, 3.44% to 55.04% for all species and important value index (IVI) variation, 27.29% to 46.29%. The highest IVI values of Teng occurred in five plots, and Rak *(Gluta usitata*) had the highest IVI in one plot because the Teng individuals in this plot were mainly small trees.

In DDF-1, Rang had different features: density, 19 to 1,313 trees ha^{-1}; dominance, 0.28% to 26.12% and IVI, 0.52% to 26.59%. For Hiang, variable values were observed: density, 19 to 456 trees ha^{-1}, dominance, 0.48% to 23.53% and IVI, 0.44% to 19.34%. The values also varied for Pluang: density, 25 to 413 trees ha^{-1}; dominance, 0.22% to 15.52% and IVI, 0.97% to 15.18%. Great variation in the density, dominance and IVI of these dipterocarps occurred among the sample plots.

1.2) DDF with Rang (*S. siamensis*)

DDF-2 was composed of three plots. A total of 48 species, with 26 to 33 species/plot, was found. Other parameters varied among plots: tree density, 1,914 to 2,412 trees ha^{-1} and stem basal area, 25 to 32 m^2 ha^{-1}. Rang had different features among the plots: density, 706 to 1,244 trees ha^{-1}, dominance, 52.98% to 68.98% and IVI, 28.24% to 54.10%.

In DDF-2, Teng had variable features: density, 19 to 106 trees ha^{-1}, dominance 1.12% to 2.90% and IVI, 1.29% to 3.66%. As for Hiang, variable values were observed: density, 0 to 6 trees ha^{-1}, dominance 0 % to 0.81% and IVI, 0% to 0.73%. The values were also different for Pluang: density, 19 to 194 trees ha^{-1}, dominance, 0.07% to 6.85% and IVI, 0.2% to 7.45%.

1.3) DDF with Hiang (*D. obtusifolius*)

DDF-3 was found only in one plot. It had a species richness of 35 species, 407 trees ha^{-1} and 26 m^2 ha^{-1} of stem basal area. Hiang had 550 trees ha^{-1} density, 64.13% dominance and 48.93% IVI. Teng in DDF-3 consisted of 213 trees ha^{-1}, 3.37% dominance and 5.87% IVI. For Rang, there were 19 trees ha^{-1}, 1.09% dominance and 0.92% IVI, and Pluang had 144 trees ha^{-1}, 6.70% dominance and 6.18% IVI. Many medium and big trees existed in DDF-3.

1.4) DDF with Pluang (*D. tuberculatus*)

DDF-4 was found in three plots. Its species richness was 31 species, with 17 to 28 species /plot. Tree density varied from 1,068 to 2,237 trees ha^{-1}, and stem basal area varied between 16 and 21 m^2 ha^{-1}. Pluang had different quantitative features among plots: density, 288 to 713 trees ha^{-1}, dominance, 28.29% to 46.86% and IVI, 21.71% to 42.80%.

In this subtype community, Teng had variable features: density, 238 to 375 trees ha^{-1}, dominance, 6.57% to 24.88% and IVI, 8.61% to 25.60%. The values were different for Rang: density, 6 to 19 trees ha^{-1}, dominance, 0.02% to 3.62% and IVI, 0.30% to 2.23%; and also for Hiang: density, 6 to 319 trees ha^{-1}, dominance, 1.43% to 16.58% and IVI, 1.01% to 15.43%. In DDF-4, Teng density varied from moderate to high, Rang was rare and Hiang varied from low to moderate densities.

1.5) DDF with two needle-pine (*P. merkusii*)

Two plots pine-dry dipterocarp forest (P-DDF) were located between 734 and 759 m m.s.l. Two-needle-pine existed as the dominant tree in the forest which consisted of 49 species, 247 to 264 trees ha^{-1} and a stem basal area between 10 and 14 m^2 ha^{-1}. Two-needle pine had 69 to 388 trees ha^{-1}, dominance, 21.38% to 26.82% and IVI, 15.67% to 22.57%.

The quantitative features of dipterocarps were different: (1) Teng: density, 194 to 306 trees ha^{-1}, dominance, 11.19% to 11.26% and IVI, 11.57% to 15.64%, (2) Rang: density, 13 to 25 trees ha^{-1}, dominance, 2.82% to 3.26% and IVI, 2.04% to 2.18%, and (3) Pluang: density, 81 to 388 trees ha^{-1}, dominance, 7.91% to 21.38% and IVI, 6.62% to 22.57%.

2) Species diversity and forest condition indices

Table 1 shows values of H_{max}, H (SWI) and E for the plant species diversity in the five subtype communities of the DDF. The average value for these communities was 3.35±0.46. The values varied among subtype communities: DDF-1, 2.62 to 3.84; DDF-2, 2.69 to 3.33; DDF-3, 3.55; DDF-4, 2.66 to 3.71 and P-DDF, 3.90 to 3.95. Some variations were observed among sample plots. However, DDF-4 had higher SWI values than the others. This might have been caused by the influence of the higher altitude and the appearance of some plant species.

Table 2 shows values for the forest condition index (FCI) in the five subtype communities of DDF. The average FCI for all communities was 4.53±3.35. The FCI values varied among subtype communities: DDF-1, 0.51 to 9.49; DDF-2, 2.11 to 8.20; DDF-3, 5.87; DDF-4, 1.97 to 10.46; and P-DDF, 0.62 to 5.93. Great variation occurred among sample plots.

Table 1 Shannon-Wiener index (SWI) of plant species diversity in the DDF.

Plot	Dominant tree	Tree density/ha	No. of species/plot	H_{max}	H (SWI)	E
	DDF-1					
1	*S. obtusa*	2,438	21	4.39	2.62	0.60
2	*S. obtusa*	2,781	31	4.95	3.84	0.78
3	*S. obtusa*	1,538	27	4.75	3.38	0.71
4	*S. obtusa*	3,200	29	4.86	3.15	0.65
5	*S. obtusa*	2,994	39	5.29	3.72	0.70
6	*S. obtusa*	3,388	27	4.75	2.91	0.61
Mean±S.D.		2,723±668	29±5.93	4.83±0.29	3.27±0.5	0.67±0.07
	DDF-2					
7	*S. siamensis*	1,913	33	5.04	3.33	0.66
8	*S. siamensis*	2,019	26	4.70	2.69	0.57
9	*S. siamensis*	2,413	28	4.81	2.88	0.60
Mean±S.D.		2,115±263	29±40	4.85±0.18	2.97±0.33	0.61±0.05
	DDF-3					
10	*D. obtusifolius*	2,544	35	3.55	3.55	0.69
Mean±S.D.		–	–	–	–	–
	DDF-4					
11	*D. tuberculatus*	1,069	17	4.09	3.15	0.77
12	*D. tuberculatus*	2,238	28	4.81	3.71	0.77
13	*D. tuberculatus*	2,263	17	4.09	2.66	0.65
Mean±S.D.		1,857±681	21±6.35	4.33±0.42	3.43±0.39	0.73±0.07
	P-DDF					
14	*P. merkusii*	1,544	34	5.09	3.90	0.77
15	*P. merkusii*	1,650	34	5.09	3.95	0.78
Mean		1,596	34	5.09	3.92	0.77
Mean (for 15 plots)		2,266	28.4	4.79	3.35	0.69
S.D.		638	6.39	0.36	0.46	0.07

Table 2 Forest condition index (FCI) in five subtype communities in the DDF.

Plot	Dominant tree species	Number of trees/ha with different stem gbh classes								FCI
		<25	26-50	51-75	76-100	101-200	201-300	301-400	Total	
	DDF-1									
1	*S. obtusa*	1,044	1,119	219	56	–	–	–	2,438	1.45
2	*S. obtusa*	1,588	894	200	63	31	–	6	2,781	9.49
3	*S. obtusa*	844	388	231	50	19	–	6	1,537	7.25
4	*S. obtusa*	1,781	1,275	106	25	13	–	–	3,200	2.80
5	*S. obtusa*	1,531	1,281	156	25	–	–	–	2,994	0.88
6	*S. obtusa*	1,994	1,281	106	6	–	–	–	3,388	0.51
Mean		1,463	1,039	170	38	21	–	–	2,723	3.73
S.D.		438	353	55	22	12			668	3.74
	DDF-2									
7	*S. siamensis*	813	538	375	156	31	–	–	1,913	8.20
8	*S. siamensis*	700	756	413	144	6	–	–	2,019	4.09
9	*S. siamensis*	969	1,150	256	31	6	–	–	2,413	2.11
Mean		827	814	348	110	15	–	–	2,115	4.80
S.D.		135	310	81	69	12			263	3.11
	DDF-3									
10	*D. obtusifolius*	1,538	619	219	150	19	–	–	2,544	5.87
Mean		–	–	–	–	–	–	–	–	–
	DDF-4									
11	*D. tuberculatus*	519	300	125	75	44	6	–	1,069	10.46
12	*D. tuberculatus*	1,150	831	188	50	13	–	6	2,237	6.25
13	*D. tuberculatus*	1,244	838	138	38	6	–	–	2,263	1.97
Mean		971	656	150	54	21	–	–	1,856	6.23
S.D.		394	308	33	19	19			682	4.25
	P-DDF									
14	*P. merkusii*	1,150	275	44	50	19	6	–	1,544	5.93
15	*P. merkusii*	1,169	369	88	25	–	–	–	1,650	0.62
Mean		1,159	322	66	38	–	–	–	1,597	3.28
Mean (15 plots)		1,202	794	191	63	14	0.92	1.38	2,266	4.53
S.D.		416	369	102	48	12	2.25	2.63	660	3.35

3) Assessment of plant biomass and carbon storages

1) Plant biomass

Table 3 shows the plant biomass in the five subtype communities in DDF using the 15 sample plots. The average amount of biomass for all communities was 125 ± 55 Mg ha^{-1}, divided into stem, branch, leaf and root biomass of 63%, 23%, 1% and 12% of the total biomass, respectively.

1.1) DDF with Teng (*S. obtusa*)

The biomass amount in DDF-1 was 135 Mg ha^{-1} on average. It was divided into stem, branch, leaf and root biomass of 84, 33, 2 and 16 Mg ha^{-1}, respectively. The biomass amounts of Teng, Rang, Hiang and Pluang were: 34, 11, 17 and 12 Mg ha^{-1}, respectively.

1.2) DDF with Rang (*S. siamensis*)

In DDF-2, the average amount of biomass was 159 Mg ha^{-1}.with amounts in the stem, branch, leaf and root biomass in the following order: 104, 34, 1 and 20 Mg ha^{-1}. Rang, Teng, Hiang and Pluang had biomass amounts of 100, 2, 1 and 4 Mg ha^{-1}, respectively.

1.3) DDF with Hiang (*D. obtusifolius*)

DDF-3 had biomass of 146 Mg ha^{-1}. The biomass amounts of Hiang, Teng, Rang and Pluang were 105, 3, 2 and 9 Mg ha^{-1}, respectively.

1.4) DDF with Pluang (*D. tuberculatus*)

DDF-4 had biomass of 109 Mg ha^{-1} on average, consisting of stem, branch, leaf and root biomass of 70, 26, 1 and 20 Mg ha^{-1}, respectively. The biomass amounts of Pluang, Teng, Rang and Hiang were: 41, 15, 3 and 9 Mg ha^{-1}, respectively.

1.5) DDF with two needle-pine (*P. merkusii*)

P-DDF had average biomass of 62 Mg ha^{-1} separated into stem, leaf, branch and root biomass of 39, 15, 1 and 7 Mg ha^{-1}, respectively. Koa (*Tristaniopsis burmanica*) was abundant in this forest and made the highest contribution to plant biomass. The biomass amounts of Teng, Rang and Pluang were estimated at 5, 2 and 8 Mg ha^{-1}, respectively. Hiang was not present in this subtype community.

Table 3 Biomass amounts of dipterocarps and other species in 15 plots of the DDF.

Plot	Dominant tree	Plant biomass (Mg ha^{-1})								
		Dominant species					%	Other species		Total
		Teng	Rung	Hiang	Pluang	Mg ha^{-1}		Mg ha^{-1}	%	
	DDF-1									
1	*S. obtusa*	41	1	22	16	80	66	42	34	122
2	*S. obtusa*	164	1	27	25	217	81	52	19	269
3	*S. obtusa*	55	5	1	14	75	79	20	21	95
4	*S. obtusa*	47	23	-	1	71	74	25	26	96
5	*S. obtusa*	41	14	32	9	96	69	43	31	139
6	*S. obtusa*	32	22	0.3	8	62	75	20	25	82
	Mean	63	11	14	12	100	-	34	-	135
	S.D.	50	9	15	8	82	-	14	-	68
	DDF-2									
7	*S. siamensis*	1.4	137	1.4	0.1	140	75	48	25	188
8	*S. siamensis*	2.8	97	-	3.8	103	60	68	40	171
9	*S. siamensis*	2.9	66	-	7.3	76	65	41	35	117
	Mean	2.36	100	-	3.7	106	-	52	-	159
	S.D.	0.23	52	-	4.11	30	-	20	-	47
	DDF-3									
10	*D. obtusifolius*	3	2	105	9	119	81	28	19	146
	Mean	-	-	-	-	-	-	-	-	-
	DDF-4									
11	*D. tuberculatus*	35	0.8	2	50	88	59	60	41	148
12	*D. tuberculatus*	5	6	19	34	64	64	36	36	100
13	*D. tuberculatus*	5.4	-	6	40	51	65	28	35	79
	Mean	15	-	9	41	68	-	41	-	109
	S.D.	15	-	43	20	34	-	16	-	50
	P-DDF									
14	*P. merkusii*	8	3	-	7	18	19	65	81	83
15	*P. merkusii*	4	1	-	10	15	36	28	64	43
	Mean	6	2	-	9	17	-	47	-	62

2) Carbon storage in plant biomass

Table 4 shows the amount of carbon stored in the plant biomass of the five subtype communities in the DDF in the 15 sample plots. The average carbon amount for all communities was 62±31 Mg ha^{-1}, divided into carbon storage in stem, branch, leaf and root organs of 40, 14, 0.8 and 7 Mg ha^{-1}, respectively.

2.1) DDF with Teng (*S. obtusa*)

The amount of carbon in the biomass of DDF-1 was 67 Mg ha^{-1} on average. The storage in stem, branch, leaf and root was: 42, 16, 1 and 8 Mg ha^{-1}. Teng, Rang, Hiang and Pluang could accumulate carbon at 29, 4, 8 and 6 Mg ha^{-1}, respectively. The biomass carbon of Teng varied from 66% to 81% of the total amount.

2.2) DDF with Rang (*S. siamensis*)

In DDF-2, the average carbon amount in biomass was 79 Mg ha^{-1} consisting of carbon storage in stem, branch, leaf and root organs of 52, 17, 1and 9 Mg ha^{-1}, respectively. Rang, Teng, Hiang and Pluang had carbon amounts of 49, 1, 1 and 2 Mg ha^{-1}, respectively. The biomass carbon of Rung varied from 60% to 75% of the total amount.

2.3) DDF with Hiang (*D. obtusifolius*)

DDF-3 had 72 Mg ha^{-1} carbon as biomass, which was divided into carbon amounts in the stem, branch, leaf and root organs of 47, 16, 1and 9 Mg ha^{-1}, respectively. Teng, Rang and Pluang had carbon amounts of: 2, 1 and 4 Mg ha^{-1}, respectively. The biomass carbon of Hiang was 81% of the total amount.

2.4) DDF with Pluang (*D. tuberculatus*)

An average amount of 54 Mg ha^{-1} biomass carbon was found in DDF-4. The carbon amounts in stem, branch, leaf and root organs were calculated at 35, 13, 1 and 6 Mg ha^{-1}, respectively. Pluang, Teng, Rang and Hiang accumulated carbon amounts of: 20, 8, 2 and 4 Mg ha^{-1}, respectively. The biomass carbon of Pluang varied from 59% to 65% of the total amount.

2.5) DDF with two needle-pines (*P. merkusii*)

The carbon stored in plant biomass of P-DDF was lower than in the others, being 31 Mg ha^{-1}, and partitioned into stem, branch, leaf and root organs at 20, 7, 0.4 and 3 Mg ha^{-1}, respectively. Two-needle pine contained carbon at 8 Mg ha^{-1} while Teng, Rang and Pluang had carbon amounts at 2, 1 and 4 Mg ha^{-1}, respectively. The biomass carbon of pine varied from 19% to 36% of the total amount.

Table 4 Amounts of biomass carbon of tree species in 15 plots of the DDF.

Plot	Dominant tree	Biomass Carbon (Mg ha^{-1})								
		Dominant species					%	Other species		Total
		Teng	Rung	Hiang	Pluang	Mg ha^{-1}		Mg ha^{-1}	%	
	DDF-1									
1	*S. obtusa*	20	0.6	11	8	40	66	21	34	61
2	*S. obtusa*	81	0.8	13	12	107	81	25	19	132
3	*S. obtusa*	27	3	0.7	8	39	79	10	21	49
4	*S. obtusa*	23	11	-	0.5	35	74	12	26	47
5	*S. obtusa*	20	7	16	5	48	69	21	31	69
6	*S. obtusa*	16	11	0.1	4	31	75	10	25	41
	Mean	31	6	7	6	50	-	17	-	67
	S.D.	24	5	7	4	7	-	29	-	7
	DDF-2									
7	*S. siamensis*	1	68	1	0.03	69	75	24	25	93
8	*S. siamensis*	1.4	48	-	2	51	60	34	40	85
9	*S. siamensis*	1.4	33	-	4	38	65	20	35	58
	Mean	1.2	50	0.2	2	53	-	26		79
	S.D.	0.4	18	-	2	4		16	-	7
	DDF-3									
10	*D. obtusifolius*	2	1	52	4	59	81	14	19	73
	Mean	-	-	-	-	-	-	-	-	-
	DDF-4									
11	*D. tuberculatus*	18	0.01	1	25	44	59	30	41	74
12	*D. tuberculatus*	3	3	9	17	32	64	18	36	50
13	*D. tuberculatus*	3	-	3	20	26	65	14	35	40
	Mean	8	-	4	21	34	-	21	-	55
	S.D.	9	-	4	4	2	-	9	-	8
	P-DDF									
14	*P. merkusii*	3	2	-	3	8	19	32	81	40
15	*P. merkusii*	2	1	-	5	8	36	14	65	22
	Mean	3	2	-	4	8	-	23	-	31

The DDF can be divided into subtype communities according to different dominant dipterocarp tree species: Teng (*S. obtusa*), Rang (*S. siamensis*), Hiang (*D. obtusifolius*), Pluang (*D. tuberculatus*) and mixed dominant species (Bunyavejchewin, 1983; Pampasit, 1995). Pampasit (1995) reported that species richness in four subtype communities at Doi Inthanon area varied between 17 and 31 species/plot. In our study area, the five subtype communities consisted of 21 to 34 species/plot which was nearly the same range with those at the Doi Inthanon area. He described soil characteristics including soil depth, soil type and physicochemical properties that were greatly different among sud-type communities.

The mean amounts of organic matter in soils dominated by Teng, Rang, Hiang and Pluang were 38.62, 36.06, 106.66 and 142.57 Mg ha^{-1}, respectively. For nitrogen, the values were in the following order: 2, 1.79, 5.42 and 7.58 Mg ha^{-1}. These indicated the different soil fertility levels, and further affected the growth and production of tree species which are important factors affecting the different rates of forest recovery of the DDF communities.

The tree densities in the five communities varied from 1,596 to 2,723 trees ha^{-1}. Different degrees of tree cutting for each species during forest concession harvesting in the past were one important factor. Some species might be preferable for making wooden railway sleepers and other species might be used for fire wood, especially Teng. Illegal selective cutting of some species such as Pluang by local people for making houses was relevant. Sprouting is also an important factor affecting tree densities in these communities. The distance of forest communities from the villages was also related to the remaining tree densities in these subtype communities.

Tree cutting in the past, succession, sprouting and increasing plant production during stand development have influenced the present amounts of plant biomass in the five forest communities. The amounts of plant biomass in Teng, Rang, Hiang, Pluang and two needle-pine were estimated at 21.57, 25.41, 23.37, 17.44 and 9.92 Mg ha^{-1}, respectively. The carbon amounts stored in biomass were calculated as: 10.65, 12.57, 11.55, 8.61 and 4.90 Mg ha^{-1}, respectively. The amounts were higher in the Teng, Rang and Hieng communities. The amounts of biomass carbon in the DDF varied with locations depending upon different forest conditions.

Wattanasuksakul *et al.* (2012) reported that the DDF with dominant Pluang having biomass of 106.6 Mg ha^{-1} could store 52.6 Mg ha^{-1} carbon. Phonchaluen (2009) studied DDF with dominant Hiang in the community forest, and reported that the forest had 119.83 Mg ha^{-1} biomass and 59.16 Mg ha^{-1} carbon, whereas the DDF, had 47.65 Mg ha^{-1} biomass and 23.50 Mg ha^{-1} carbon. Seramethakun (2012) found that the pine-DDF with dominant Hiang, Pluang and Teng had biomass of 139.2, 103.9 and 85.2 Mg ha^{-1}, respectively, and biomass carbon amounts of: 69.0, 51.5 and 42.1 Mg ha^{-1}, respectively. In our study, DDF with dominant Teng, Rang, Hiang and Pluang had greatly different amounts of biomass (62 to 135 Mg ha^{-1}, respectively) and carbon (55 to 79 Mg ha^{-1}, respectively). Seeloy-ounkeaw (2014b) reported higher amounts of plant biomass and carbon for lower, montane community forests (LMF) of Nong Tao, Huay Khaw Leeb, Huay Tong and Mae Ya Noy villages of: biomass: 252.36, 273.90, 287.11 and 393.15 Mg ha^{-1}, respectively, and carbon: 126.88, 135.31, 141.85 and 194.27 Mg ha^{-1}, respectively.

CONCLUSION

Conclusions for the assessment of the Mae Tha sub-district community forest were:

1. The DDF in Mae Tha sub-district was divided into five subtype communities based on different dominant tree species: Teng (*S. obtusa*), Rang (*S. siamensis*), Hiang (*D.

obtusifolius), Pluang (*D. tuberculatus*) and two-needle pine (*Pinus merkusii*, pine-DDF forest).

2. The forest had suffered from forest concession activity in the past where wood had been extracted for railway sleepers and for fire wood supplied to a tobacco factory, and by illegal tree cutting by villagers. These activities had caused forest degradation and severe flash flooding or drought, which had adversely affected the local people.

The community forest has been protected and managed by members of the seven villages of Mae Tha sub-district as their community forest since 1989, and has recovered during the past 26 years. The biomass amounts of the five subtype communities varied from 63 to 159 Mg ha^{-1} and could store carbon amounts from 31 to 79 Mg ha^{-1}. At present, the forest communities are recovering and have increasing potential for carbon storage.

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