CHAPTER 4

Carbon Stocks in Pine Forest Ecosystems

Abstract

The research on ecosystem carbon stocks of four subtype communities of the natural pine forest was carried out at Ban Chan sub-district, Kunlaya Ni Wattana district, Chiang Mai province. Three subtypes were the pine-dry dipterocarp forest of dominated *Dipterocarpus obtusifolius* (P-DDF1), *D. tuberculatus* (P-DDF2) and *Shorea obtusa* (P-DDF3), and the fourth subtype was pine-lower montane forest (P-LMF). The plant diversity in these subtype communities was described in Chapter 2. The investigation on soil type and physico-chemical properties was given in Chapter 3.

Forest biomass of the P-DDF1, P-DDF2, P-DDF3 and P-LMF were calculated as 139.2, 103.9, 85.2 and 79.5 Mg ha^{-1}, respectively. It was the highest for P-DDF1 and the lowest for P-LMF. The amounts of carbon storages in tree biomass of the P-DDF1, P-DDF2, P-DDF3 and P-LMF were in the order of 69.0, 51.5, 42.1 and 39.4 Mg ha^{-1}. As same as forest biomass, it was the highest for the P-DDF1 and the lowest for the P-LMF. The amounts of carbon in one-meter soils under these subtypes were 54.3, 52.1, 65.8 and 85.0 Mg ha^{-1}, respectively. The total carbon stocks in their ecosystems were 122.5, 103.6, 107.9 and 124.8 Mg ha^{-1}, respectively. The ecosystem carbon stocks were related to different forest conditions and soil fertility in these subtype communities of the natural pine forest.

4.1 Introduction

Carbon cycling affects on global warming through increasing CO_2 release from ecosystems to atmosphere. Various forests have different carbon cycling since these forests compose of variable plant species composition and diversity. The climate, topographical, parent rock and soil factors influence on existence and spatial distribution of tree species in the area. As described by Landsberg and Gower (1997) and Waring and Running (2007), carbon begins the cycling in forest ecosystem when plants assimilate CO_2 through photosynthesis into reduced sugar. About half of the gross primary production (GPP) is used by plants in respiration for the synthesis and maintenance of living cells, releasing CO_2 back into the atmosphere. The remaining primary products go into net primary production (NPP) or plant biomass including stem branch, root and reproductive organs. The above-ground and below-ground litter fall is substrate of decomposers, which through their heterotrophic metabolism release CO_2 back into the atmosphere. Grazing by herbivores and carnivores is the way of carbon cycling into secondary production, and lose of CO_2 into the atmosphere is occurred through heterotrophic respiration.

Forest plays an important role in contributing organic residues to the soil through above-ground and below-ground litter fall, and later become soil organic matter which is usually found in substantial amounts under evergreen broad-leaved

forests including moist, dry and montane evergreen forests. Fire has important role on carbon cycling in deciduous forests and pine forests. Some amounts of carbon in plants, forest floor and soil are lost through forest fire annually. Soil erosion is another process of carbon lose from the soil, and results in poor soil.

The aims of this research were to assess the carbon stocks in ecosystems of four subtypes of the natural pine forest including pine - *D. obtusifolius*, pine - *D. tuberculatus*, pine - *S. obtusa* and pine-lower montane forests.

4.2 Materials and Methods

4.2.1 Forest Biomass Estimation

The forest biomass in four subtypes of the pine forest was calculated using equations of previous researchers.

(1) For pine trees, they were calculated according to Kajornsrichon *et al*., (1989)

For Pinus merkusii:

$\log W_S = 1.1449 \log D^2H - 2.3890$ $(r = 0.994)$
$\log W_B = 1.3479 \log D^2H - 4.2661$ $(r = 0.996)$
$\log W_L = 0.6534 \log D^2H - 1.9424$ $(r = 0.789)$

For Pinus kasiya:

$\log W_S = 0.9814 \log D^2H - 1.6693$ $(r = 0.995)$
$\log W_B = 1.4561 \log D^2H - 4.8060$ $(r = 0.929)$
$\log W_L = 1.0138 \log D^2H - 3.5245$ $(r = 0.937)$

(2) Biomass of evergreen tree species was calculated by equations of Tsutsumi *et al*. (1983)

W_S (stem)	$= 0.0509 (D^2H)^{0.919}$	$(r^2 = 0.978)$
W_B (branch)	$= 0.00893 (D^2H)^{0.977}$	$(r^2 = 0.890)$
W_L (leaf)	$= 0.0140 (D^2H)^{0.669}$	$(r^2 = 0.714)$
W_R (root)	$= 0.0313 (D^2H)^{0.805}$	$(r^2 = 0.981)$

When biomass (W) unit was in kilogram, the diameter (D) unit was centimeter and the height (H) unit was meter.

(3) Biomass of other deciduous species were calculated by using equations of Ogino *et al.* (1967).

W_S	$= 189 (D^2H)^{0.902}$	(kg/tree)	: $D^2H = m^3$
W_B	$= 0.125 Ws^{1.204}$	(kg/tree)	
W_L	$= 1/(11.4/Ws^{0.90} + 0.172)$	(kg/tree)	

(4) Root biomass was calculated by using an equation of Ogawa *et al.* (1965).

$W_R = 0.026 (D^2H) 0.775$: $D^2H = (cm^2.m)$

4.2.2 Carbon Storages in Forest Biomass

The carbon amounts in biomass of stem, branch, leaf and root components were calculated. The nutrient contents in different organs of tree species were based

on average values studied by Tsutsumi *et al.* (1983). For trees with stem diameter >4.5 cm, average carbon contents in stem, branch, leaf and root are 49.90, 48.70, 48.30 and 48.10%, respectively, whereas those trees with stem diameter <4.5 cm, carbon contents in these organs were in the order of 48.80, 49.40, 46.60 and 48.10%.

4.2.3 Carbon Storages in Organic Layers and Soils

The amounts of organic matter in forest floor were determined using a sampling plot of 1 x 1 m in size (five replications/subtype). The sampling was taken at the end of the fall season. The amounts of nutrients accumulated in soils including total C and N, extractable P, K, Ca, and Mg were calculated from their contents and soil mass.

4.3 Results

4.3.1 Forest Biomass

Table 4-1 to **4-2** shows tree biomass in the four subtypes of pine forest. The amounts of forest biomass in P-DDF1, P-DDF2, P-DDF3 and P-LMF were in the order of 139.2, 103.9, 85.2 and 79.5 Mg ha^{-1} (**Figure 4-1**). The forest biomass was the highest in P-DDF1 and the lowest for P-LMF.

Table 4-1 Forest tree biomass in four subtypes of pine forest

Forest subtype	Trees biomass ($Mg.ha^{-1}$)				
	Stem	Branch	Leaf	Root	Total
P-DDF1	109.50	14.67	1.61	13.42	139.21
P-DDF1	80.93	10.99	1.26	10.72	103.89
P-DDF3	65.08	8.55	1.41	9.92	84.96
P-LMF	61.37	7.21	1.26	9.63	79.48

(1) P-DDF1 (Pine-*D. obtusifolius*)

In this forest subtype, the biomass in stem, branch, leaf and root organs were 109.50, 14.67, 1.61 and 13.42 Mg ha^{-1}, respectively. *Pinus merkusii* had the highest amount among 37 tree species (100,755.4 kg ha^{-1}, 72.41%). The other trees had the lower amounts; *Dipterocarpus obtusifolius* (24,539.2 kg ha^{-1}, 17.60%), *P. kesiya* (9,958.8 kg ha^{-1}, 7.15%), *Gluta usitata* (3,097.7 kg ha^{-1}, 2.22%) and *D. tuberculatus* (249.1 kg ha^{-1}, 0.18%).

(2) P-DDF2 (Pine-*D. tuberculatus*)

The biomass in stem, branch, leaf and root components were calculated as 80.93, 10.99, 1.26 and 10.72 Mg ha^{-1}, respectively. *P. merkusii* had the highest amount among 46 tree species (60,044.2 kg ha^{-1}, 57.84%). The remained tree species had the lower amounts of biomass including *D. tuberculatus* (23,242.6 kg ha^{-1}, 22.35%), *P.*

kesiya, (10,272.7 kg ha^{-1}, 9.88%), *Gluta usitata*, (4,903.2 kg ha^{-1}, 4.71%) and *D. obtusifolius*, (1,377.9 kg ha^{-1}, 1.32%).

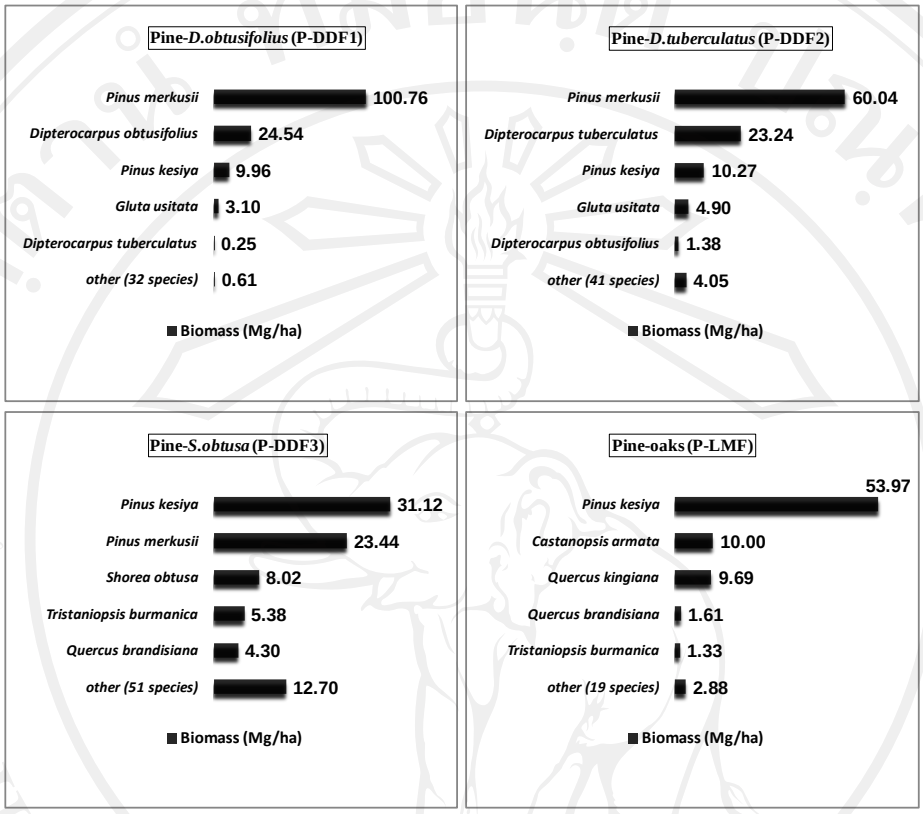

Figure 4.1 Biomass of tree species in four subtypes of natural pine forest

(3) P-DDF3 (Pine-*S. obtusa*)

The pine - *S. obtusa* forest had the biomass in stem, branch, leaf and root organs of 65.08, 8.55, 1.41, 9.92 and 84.96 Mg ha^{-1}, respectively. *Pinus kesiya* had the highest amount among 56 tree species (31,122.6 kg ha^{-1}, 36.65%). The other tree species had the lower biomass including *P. merkusii*, (23,436.0 kg ha^{-1}, 27.62%), *Shorea obtusa* (8,017.3 kg ha^{-1},9.42%), *Tristaniopsis burmanica*, (5,377 kg ha^{-1},6.32%) and *Quercus brandisiana* (4,304.5 kg ha^{-1}, 5.06%).

(4) P-LMF (Pine-oaks)

The pine-oak forest had the biomass in stem, branch, leaf and root of 61.37, 7.21, 1.26, 9.63 and 79.48 Mg ha^{-1}, respectively. Among 24 tree species, *P. kesiya* had the highest amount of biomass (53,968.0 kg ha^{-1},67.94%). The other trees had the lower biomass; *Castanopsis acuminatissima* (10,002.1 kg ha^{-1}, 12.57%), *Quercus kingiana* (9,685.6 kg ha^{-1}, 12.19%), *Q. brandisiana* (1,610.8 kg ha^{-1}, 2.02%) and *Tristaniopsis burmanica*, (1,325.2 kg ha^{-1}, 1.66%).

According to forest condition index (FCI), P-DDF1, P-DDF2, P-DDF3 and P-LMF had the mean values of 25.06, 20.33, 18.74 and 19.02, respectively. Thus, the

amounts of forest biomass in these subtypes were related to the forest conditions. It was high in the relatively good forest, and low in the poor forest.

Table 4-2 Biomass of stem, branch, leaf and root in four subtypes of pine forest

Forest subtype	No	Species	Trees biomass (kg.ha^{-1})					Total (%)
			Stem	Branch	Leaf	Root	total	
P-DDF1	1	*Pinus merkusii*	80,614.9	10,367.2	1,028.5	8,744.8	100,755.	72.41
	2	*Dipterocarpus obtusifolius*	18,323.3	2,757.7	336.7	3,121.6	24,539.2	17.60
	3	*Pinus kesiya*	7,704.9	1,115.9	153.9	984.1	9,958.8	7.15
	4	*Gluta usitata*	2,247.0	338.2	71.5	441.0	3,097.7	2.22
	5	*Dipterocarpus tuberculatus*	188.2	28.3	2.7	29.9	249.1	0.18
	6	*Castanopsis tribuloides*	72.5	10.9	3.8	17.6	104.8	0.07
	7	*Lithocarpus glandifolius*	72.6	10.9	3.0	15.5	102.0	0.07
	8	*Semecarpus anacardium*	62.7	9.4	2.7	13.7	88.5	0.06
	9	*Wendlandia tinctoria*	33.3	5.0	1.3	7.1	46.8	0.03
	10	*Anneslea fragrans*	29.2	4.4	1.3	6.5	41.4	0.03
	11	*Lithocarpus sootepensis*	26.8	4.0	1.3	6.1	38.2	0.03
	12	*Tristaniopsis burmanica*	23.0	3.5	0.9	4.7	32.0	0.02
	13	*Ziziphus oenoplia*	12.7	1.9	0.8	3.3	18.7	0.01
	14	*Quercus kingiana*	13.4	2.0	0.5	2.8	18.7	0.01
	15	*Craibiodendron stellatum*	12.7	1.9	0.7	3.1	18.4	0.01
	16	*Phyllanthus emblica*	11.2	1.7	0.7	3.1	16.7	0.01
	17	*Vangueria pubescens*	10.0	1.5	0.5	2.3	14.3	0.01
	18	*Castanopsis*	8.3	1.0	0.3	1.5	9.6	0.01
	19	*Vaccinium sprengelii*	7.7	1.2	0.5	2.0	11.3	0.01
	20	*Engelhardtia spicata*	5.3	0.8	0.3	1.2	7.6	0.01
	21	*Quercus brandisiana*	4.5	0.7	0.2	1.0	6.5	0.00
	22	*Shorea obtusa*	3.8	0.6	0.3	1.1	5.7	0.00
	23	*Glochidion sphaerogynum*	3.1	0.5	0.2	1.0	4.9	0.00
	24	*Buchanania lanzan*	2.0	0.3	0.1	0.5	3.0	0.00
	25	*Aporosa villosa*	1.8	0.3	0.1	0.6	2.7	0.00
	26	*Terminalia chebula*	1.5	0.2	0.1	0.5	2.4	0.00
	27	*Catunaregam tomentosa*	1.5	0.2	0.1	0.4	2.2	0.00
	28	*Glochidion hirsutum Voigt*	1.1	0.2	0.1	0.3	1.6	0.00
	29	*Dalbergia cultrata*	1.0	0.2	0.1	0.3	1.6	0.00
	30	*Symplocos recemosa*	1.0	0.1	0.1	0.3	1.5	0.00
	31	*Quercus kerrii*	0.9	0.1	0.1	0.3	1.4	0.00
	32	*Antidesma acidum*	0.7	0.1	0.1	0.2	1.1	0.00
	33	*Colona flagrocarpa*	0.5	0.1	0.0	0.2	0.8	0.00
	34	*Lithocarpus lindleyanus*	0.5	0.1	0.0	0.1	0.7	0.00
	35	*Lithocarpus truncatus*	0.1	0.0	0.0	0.1	0.2	0.00
	36	*Flacourtia indica*	0.1	0.0	0.0	0.0	0.2	0.00
	37	*Dillenia obovata*	0.0	0.0	0.0	0.0	0.1	0.00
		total	**109,503.**	**14,671.0**	**1,613.4**	**13,419.0**	**139,205.**	**100.00**
P-DDF2	1	*Pinus merkusii*	48,010.8	6,157.9	622.6	5,252.8	60,044.2	57.84
	2	*Dipterocarpus tuberculatus*	17,474.8	2,630.0	271.2	2,866.6	23,242.6	22.35
	3	*Pinus kesiya*	7,895.4	1,067.3	156.1	1,153.9	10,272.7	9.88
	4	*Gluta usitata*	3,654.0	549.9	71.8	627.5	4,903.2	4.71
	5	*Dipterocarpus obtusifolius*	1,022.4	153.9	21.4	180.1	1,377.9	1.32
	6	*Quercus brandisiana*	704.6	106.0	25.5	147.5	983.6	0.94
	7	*Tristaniopsis burmanica*	383.0	57.6	21.4	100.6	562.5	0.54
	8	*Wendlandia tinctoria*	253.3	38.1	10.2	56.8	358.4	0.34
	9	*Vaccinium sprengelii*	222.9	33.5	13.1	60.3	329.8	0.32
	10	*Shorea obtusa*	214.5	32.3	7.0	42.7	296.4	0.28
	11	*Castanopsis tribuloides*	179.2	27.0	6.4	37.0	249.6	0.24
	12	*Quercus kingiana*	159.1	23.9	2.9	27.1	213.0	0.20
	13	*Quercus kerrii*	135.1	20.3	4.1	26.6	186.2	0.18
	14	*Semecarpus anacardium*	126.3	19.0	3.4	23.6	172.3	0.17
	15	*Syzygium albiflorum*	88.7	13.4	1.3	14.5	117.8	0.11
	16	*Aporosa villosa*	73.5	11.1	3.2	17.1	104.9	0.10
	17	*Craibiodendron stellatum*	53.7	8.1	3.1	13.7	78.5	0.08
	18	*Ziziphus oenoplia*	40.9	6.2	2.4	10.5	60.0	0.06
	19	*Anneslea fragrans*	33.5	5.0	2.2	9.4	50.1	0.05

Table 4-2 (continued)

Forest subtype	No	Species	Trees biomass (kg.ha^{-1})					Total (%)
			Stem	Branch	Leaf	Root	total	
	20	*Quercus helferiana*	34.1	5.1	1.3	7.2	47.7	0.05
	21	*Phyllanthus emblica*	30.1	4.5	1.7	7.6	43.9	0.04
	22	*Dalbergia cultrata*	31.3	4.7	1.0	6.2	43.2	0.04
	23	*Syzygium cumini*	28.0	4.2	0.8	5.4	38.5	0.04
	24	*Semecarpus albescens*	19.5	2.9	0.9	4.3	27.6	0.03
	25	*Albizia odoratissima*	13.4	2.0	0.7	3.2	19.3	0.02
	26	*Schima wallichii*	11.3	1.7	0.7	3.1	16.8	0.02
	27	*Glochidion hirsutum Voigt*	10.2	1.5	0.6	2.5	14.8	0.01
	28	*Buchanania lanzan*	8.1	1.2	0.4	1.8	11.5	0.01
	29	*Lithocarpus lindleyanus*	3.5	0.5	0.2	1.0	5.3	0.01
	30	*Symplocos recemosa*	2.5	0.4	0.2	0.8	3.8	0.00
	31	*Vangueria pubescens*	1.7	0.3	0.1	0.6	2.7	0.00
	32	*Glochidion sphaerogynum*	1.3	0.2	0.1	0.5	2.1	0.00
	33	*Antidesma acidum*	1.3	0.2	0.1	0.4	2.1	0.00
	34	*Cratoxylum formosum*	1.3	0.2	0.1	0.5	2.1	0.00
	35	*Castanopsis purpurea*	0.8	0.1	0.1	0.3	1.2	0.00
	36	*Colona flagrocarpa*	0.7	0.1	0.1	0.2	1.1	0.00
	37	*Gardenia coronaria*	0.6	0.1	0.1	0.2	1.0	0.00
	38	*Terminalia chebula*	0.6	0.1	0.1	0.2	1.0	0.00
	39	*Castanopsis acuminatissima*	0.5	0.1	0.0	0.2	0.8	0.00
	40	*Lithocarpus truncatus*	0.4	0.1	0.0	0.2	0.7	0.00
	41	*Catunaregam tomentosa*	0.4	0.1	0.0	0.2	0.7	0.00
	42	*Dillenia obovata*	0.4	0.1	0.0	0.1	0.6	0.00
	43	*Castanopsis diversifolia*	0.2	0.0	0.0	0.1	0.4	0.00
	44	*Lithocarpus glandifolius*	0.2	0.0	0.0	0.1	0.4	0.00
	45	*Engelhardtia spicata*	0.1	0.0	0.0	0.1	0.2	0.00
	46	*Pavetta tomentosa*	0.1	0.0	0.0	0.0	0.1	0.00
		total	**80,928.**	**10,991.0**	**1,258.7**	**10,715.3**	**103,893.3**	**100.00**
P-DDF3	1	*Pinus kesiya*	24,289.	2,816.9	476.9	3,539.6	31,122.6	36.65
	2	*Pinus merkusii*	18,765.	2,414.8	236.9	2,019.2	23,436.0	27.62
	3	*Shorea obtusa*	5,772.9	868.8	203.1	1,172.5	8,017.3	9.42
	4	*Tristaniopsis burmanica*	3,902.0	587.2	121.0	767.6	5,377.8	6.32
	5	*Quercus brandisiana*	3,185.5	479.4	71.0	568.6	4,304.5	5.06
	6	*Gluta usitata*	1,946.1	292.9	51.9	365.4	2,656.3	3.12
	7	*Quercus kerrii*	1,798.7	270.7	55.9	353.1	2,478.4	2.91
	8	*Quercus kingiana*	1,533.4	230.8	20.8	243.7	2,028.7	2.39
	9	*Wendlandia tinctoria*	844.7	127.1	51.8	224.8	1,248.3	1.46
	10	*Vaccinium sprengelii*	636.1	95.7	31.9	155.3	918.9	1.08
	11	*Shorea siamensis*	381.7	57.5	14.0	78.5	531.7	0.62
	12	*Semecarpus anacardium*	323.9	48.7	9.1	61.3	443.0	0.52
	13	*Castanopsis acuminatissima*	279.9	42.1	8.9	55.0	386.0	0.45
	14	*Semecarpus albescens*	250.5	37.7	8.5	50.3	347.0	0.41
	15	*Dalbergia cultrata*	151.1	22.7	3.5	27.5	205.0	0.24
	16	*Terminalia chebula*	133.1	20.0	2.3	22.6	178.1	0.21
	17	*Craibiodendron stellatum*	110.8	16.7	6.0	27.5	160.9	0.19
	18	*Xantoris burmanica*	91.4	13.8	1.9	16.0	123.0	0.14
	19	*Aporosa villosa*	79.1	11.9	5.1	22.0	118.1	0.14
	20	*Lithocarpus garrettianus*	79.3	11.9	4.3	19.3	114.9	0.13
	21	*Phyllanthus emblica*	61.6	9.3	4.6	19.0	94.4	0.11
	22	*Schima wallichii*	61.7	9.3	1.8	11.9	84.8	0.10
	23	*Gardenia coronaria*	56.7	8.5	2.9	13.4	81.5	0.10
	24	*Castanopsis tribuloides*	51.9	7.8	2.3	11.5	73.4	0.09
	25	*Stereospermum neuranthum*	50.1	7.5	2.1	10.8	70.6	0.08
	26	*Lithocarpus sootepensis*	48.3	7.3	2.3	10.8	68.6	0.08
	27	*Glochidion hirsutum Voigt*	33.0	5.0	2.3	9.5	49.7	0.06
	28	*Ziziphus oenoplia*	29.2	4.4	1.9	8.1	43.6	0.05
	29	*Castanopsis calathiformis*	22.0	3.3	1.1	5.2	31.6	0.04
	30	*Shorea roxburghii*	16.6	2.5	0.8	3.7	23.6	0.03
	31	*Stereospermum colais*	15.8	2.4	0.7	3.5	22.4	0.03
	32	*Anneslea fragrans*	13.0	1.9	0.9	3.8	19.6	0.02

Table 4-2 (continued)

Forest subtype	No	Species	Trees biomass (kg.ha^{-1})					Total (%)
			Stem	Branch	Leaf	Root	total	
	33	*Glochidion sphaerogynum*	12.3	1.9	0.9	3.7	18.8	0.02
	34	*Symplocos recemosa*	8.9	1.3	0.7	2.8	13.7	0.02
	35	*Catunaregam tomentosa*	7.9	1.2	0.6	2.5	12.2	0.01
	36	*Castanopsis purpurea*	8.2	1.2	0.5	2.0	11.8	0.01
	37	*Syzygium albiflorum*	5.7	0.9	0.4	1.5	8.4	0.01
	38	*Dipterocarpus tuberculatus*	5.0	0.8	0.3	1.3	7.4	0.01
	39	*Antidesma ghaesembilla*	3.4	0.5	0.3	1.1	5.3	0.01
	40	*Lithocarpus sootepensis*	2.5	0.4	0.2	0.7	3.8	0.00
	41	*Dillenia indica*	1.7	0.3	0.1	0.6	2.7	0.00
	42	*Colona flagrocarpa*	1.2	0.2	0.1	0.4	2.0	0.00
	43	*Strychnos nux-vomica*	1.2	0.2	0.1	0.4	1.9	0.00
	44	*Markhamia stipulata*	1.1	0.2	0.1	0.4	1.7	0.00
	45	*Engelhardtia spicata*	1.0	0.1	0.1	0.3	1.5	0.00
	46	*Holarrhena pubescens*	0.9	0.1	0.1	0.3	1.5	0.00
	47	*Cratoxylum formosum*	0.9	0.1	0.1	0.3	1.4	0.00
	48	*Quercus semiserrata*	0.8	0.1	0.1	0.3	1.3	0.00
	49	*Protium serratum*	0.8	0.1	0.1	0.3	1.3	0.00
	50	*Schoepfia fragrans*	0.7	0.1	0.1	0.3	1.2	0.00
	51	*Lithocarpus truncatus*	0.7	0.1	0.1	0.2	1.1	0.00
	52	*Dillenia obovata*	0.6	0.1	0.1	0.3	1.0	0.00
	53	*Celastrus paniculata*	0.6	0.1	0.0	0.2	0.9	0.00
	54	*Quercus helferiana*	0.3	0.0	0.0	0.1	0.5	0.00
	55	*Pavetta tomentosa*	0.3	0.0	0.0	0.1	0.5	0.00
	56	*Syzygium cumini*	0.2	0.0	0.0	0.1	0.3	0.00
		total	**65,081.1**	**8,546.8**	**1,413.4**	**9,921.1**	**84,962.4**	**100.00**
P-LMF	1	*Pinus kesiya*	42,505.6	4,373.5	832.4	6,256.5	53,968.0	67.94
	2	*Castanopsis*	7,361.2	1,107.9	183.9	1,349.3	10,002.1	12.57
	3	*Quercus kingiana*	7,367.8	1,108.8	79.9	1,129.1	9,685.6	12.19
	4	*Quercus brandisiana*	1,180.4	177.7	30.0	222.7	1,610.8	2.02
	5	*Tristaniopsis burmanica*	964.2	145.1	27.4	188.6	1,325.2	1.66
	6	*Gluta usitata*	580.7	87.4	24.5	125.8	818.4	1.03
	7	*Vaccinium sprengelii*	514.2	77.4	28.9	128.5	749.1	0.94
	8	*Wendlandia tinctoria*	187.2	28.2	13.8	57.4	286.6	0.36
	9	*Lithocarpus glandifolius*	205.1	30.9	7.2	41.3	284.4	0.36
	10	*Terminalia chebula*	171.3	25.8	6.8	36.4	240.3	0.30
	11	*Anneslea fragrans*	62.2	9.4	4.0	16.7	92.3	0.12
	12	*Craibiodendron stellatum*	60.8	9.1	3.3	14.8	88.1	0.11
	13	*Aporosa villosa*	52.9	8.0	4.3	17.9	83.1	0.10
	14	*Phyllanthus emblica*	47.3	7.1	3.6	14.8	72.8	0.09
	15	*Lithocarpus garrettianus*	33.9	5.1	2.2	9.1	50.3	0.06
	16	*Dalbergia cultrata*	15.1	2.3	1.3	5.4	24.1	0.03
	17	*Quercus kerrii*	14.5	2.2	1.1	4.6	22.4	0.03
	18	*Quercus helferiana*	13.2	2.0	1.0	4.3	20.6	0.03
	19	*Colona flagrocarpa*	10.6	1.6	0.8	3.2	16.3	0.02
	20	*Glochidion hirsutum Voigt*	8.2	1.2	0.6	2.6	12.7	0.02
	21	*Gardenia coronaria*	6.9	1.0	0.6	2.4	10.9	0.01
	22	*Ziziphus oenoplia*	3.2	0.5	0.3	1.1	5.1	0.01
	23	*Dillenia indica*	2.6	0.4	0.2	1.0	4.2	0.01
	24	*Antidesma ghaesembilla*	1.3	0.2	0.1	0.6	2.2	0.00
		total	**61,370.5**	**7,212.6**	**1,258.2**	**9,634.2**	**79,475.5**	**100.00**

4.3.2 Carbon Storages in Forest Biomass

Table 4-3 to **4-4** shows amounts of carbon storages in tree biomass in the four subtypes of pine forest. The amounts of biomass carbon in P-DDF1, P-DDF2, P-DDF3 and P-LMF were in the order of 69.0, 51.5, 42.1 and 39.4 Mg ha^{-1}. As same as the forest biomass, it was the highest in P-DDF1 and the lowest for P-LMF.

(1) P-DDF1 (*Pine-D. obtusifolius*)

Among 37 tree species in this subtype forest, *P. merkushii* had the highest biomass carbon (50.0 Mg ha^{-1}, 72.41%). The lower carbon amounts were found for *D. obtusifolius* (12.2 Mg ha^{-1}, 17.60%), *P. kesiya* (4.9 Mg ha^{-1}, 7.15%), *G. usitata* (1.5 Mg ha^{-1}, 2.22%) and *D. tuberculatus* (0.1 Mg ha^{-1}, 0.18%).

(2) P-DDF2 (*Pine-D. tuberculatus*)

Among 46 tree species in this forest (Table 4-2), *P. merkushii* had the highest biomass carbon (29.80 Mg ha^{-1}, 57.84%). The trees having the lower carbon storages were *D. tuberculatus* (11.5 Mg ha^{-1} 22.35%), *P. kesiya* (5.1 Mg ha^{-1}, 9.88%), *G. usitata* (2.4 Mg ha^{-1}, 4.71% and *D. obtusifolius* (0.7 Mg ha^{-1}, 1.32%).

(3) P-DDF3 (*Pine-S. obtusa*)

Among 56 tree species in this subtype (Table 4-3), *P. kesiya* had the highest carbon storage in biomass (15.40 Mg ha^{-1}, 36.65%). The lower amounts of stored carbon were found for *P. merkusii* (11.6 Mg ha^{-1}, 27.62%), *S. obtusa* (4.0 Mg ha^{-1}, 9.42%), *T. burmanica* (2.7 Mg ha^{-1}, 6.32%) and *Q. brandisiana* (2.1 Mg ha^{-1}, 5.06%).

(4) P-LMF (*Pine-oaks*)

Among 24 tree species in the forest, *P. kesiya* had the highest amount of biomass carbon (26.80 Mg ha^{-1}, 67.94%). The tree species having lower storages were *C. accuminatissima* (5.0 Mg ha^{-1}, 12.57%), *Q. kingiana* (4.8 Mg ha^{-1}, 12.19%), *Q. brandisiana* (0.8 Mg ha^{-1}, 2.02 %) and *T. burmanica*, 0.7 Mg ha^{-1}, 1.66%).

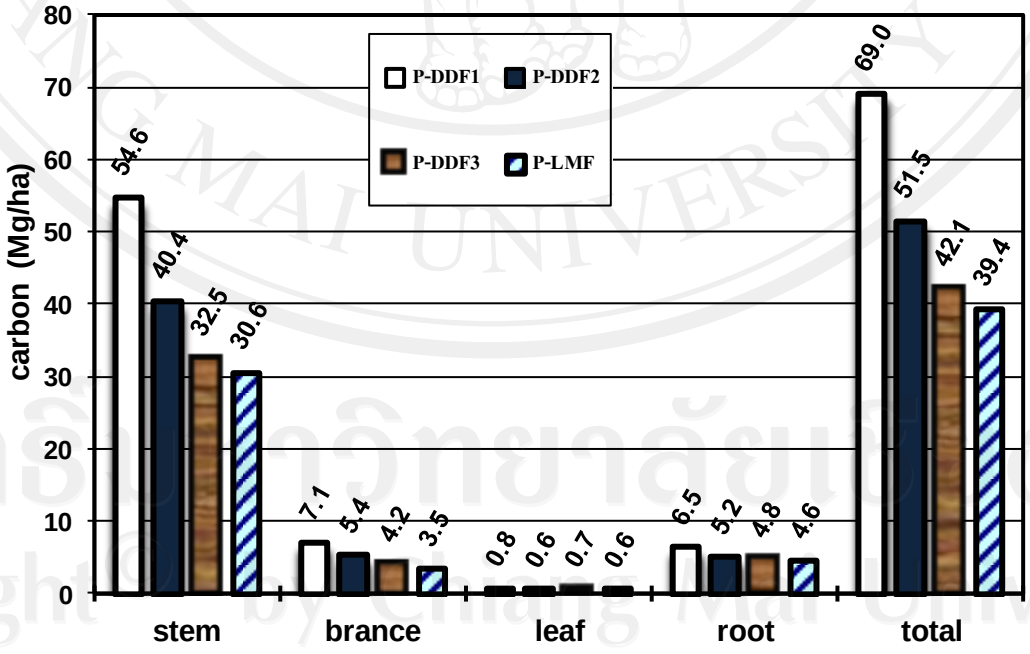

Figure 4-2 Amounts of carbon storage in forest biomass of four-subtype pine forest

Table 4-3 Amounts of carbon storages in biomass of trees species in P-DDF1

No	Tree Species	Organic Carbon in Trees Biomass (kg.ha^{-1})					Total (%)
		Stem	Branch	Leaf	Root	Total	
1	*Pinus merkusii*	40,226.8	5,048.8	496.8	4,215.0	49,987.4	72.41
2	*Dipterocarpus obtusifolius*	9,143.2	1,343.0	162.6	1,504.6	12,153.4	17.60
3	*Pinus kesiya*	3,844.7	543.4	74.3	474.3	4,936.8	7.15
4	*Gluta usitata*	1,121.2	164.7	34.6	212.6	1,533.0	2.22
5	*Dipterocarpus tuberculatus*	93.9	13.8	1.3	14.4	123.4	0.18
6	*Castanopsis tribuloides*	36.2	5.3	1.8	8.5	51.8	0.07
7	*Lithocarpus glandifolius*	36.2	5.3	1.4	7.5	50.4	0.07
8	*Semecarpus anacardium*	31.3	4.6	1.3	6.6	43.8	0.06
9	*Wendlandia tinctoria*	16.6	2.4	0.6	3.4	23.1	0.03
10	*Anneslea fragrans*	14.6	2.1	0.6	3.1	20.5	0.03
11	*Lithocarpus sootepensis*	13.4	2.0	0.6	2.9	18.9	0.03
12	*Tristaniopsis burmanica*	11.5	1.7	0.4	2.3	15.8	0.02
13	*Ziziphus oenoplia*	6.4	0.9	0.4	1.6	9.2	0.01
14	*Quercus kingiana*	6.7	1.0	0.2	1.4	9.3	0.01
15	*Craibiodendron stellatum*	6.3	0.9	0.3	1.5	9.1	0.01
16	*Phyllanthus emblica*	5.6	0.8	0.3	1.5	8.2	0.01
17	*Vangueria pubescens*	5.0	0.7	0.2	1.1	7.0	0.01
18	*Castanopsis acuminatissima*	4.1	0.6	0.2	0.9	5.8	0.01
19	*Vaccinium sprengelii*	3.8	0.6	0.2	1.0	5.6	0.01
20	*Engelhardtia spicata*	2.6	0.4	0.1	0.6	3.7	0.01
21	*Quercus brandisiana*	2.3	0.3	0.1	0.5	3.2	0.00
22	*Shorea obtusa*	1.9	0.3	0.1	0.5	2.8	0.00
23	*Glochidion sphaerogynum*	1.6	0.2	0.1	0.5	2.4	0.00
24	*Buchanania lanzan*	1.0	0.1	0.1	0.3	1.5	0.00
25	*Aporosa villosa*	0.9	0.1	0.1	0.3	1.3	0.00
26	*Terminalia chebula*	0.7	0.1	0.1	0.2	1.2	0.00
27	*Catunaregam tomentosa*	0.7	0.1	0.0	0.2	1.1	0.00
28	*Glochidion hirsutum*	0.5	0.1	0.0	0.1	0.8	0.00
29	*Dalbergia cultrata*	0.5	0.1	0.0	0.2	0.8	0.00
30	*Symplocos recemosa*	0.5	0.1	0.0	0.2	0.7	0.00
31	*Quercus kerrii*	0.4	0.1	0.0	0.1	0.7	0.00
32	*Antidesma acidum*	0.4	0.1	0.0	0.1	0.6	0.00
33	*Colona flagrocarpa*	0.2	0.0	0.0	0.1	0.4	0.00
34	*Lithocarpus lindleyanus*	0.2	0.0	0.0	0.1	0.3	0.00
35	*Lithocarpus truncatus*	0.1	0.0	0.0	0.0	0.1	0.00
36	*Flacourtia indica*	0.1	0.0	0.0	0.0	0.1	0.00
37	*Dillenia obovata*	0.0	0.0	0.0	0.0	0.0	0.00
	total	**54,642.0**	**7,144.9**	**779.2**	**6,468.1**	**69,034.3**	**100.00**

Table 4-4 Amounts of carbon stocks in biomass of trees species in P-DDF2

No	Tree Species	Organic Carbon in Trees Biomass (kg.ha^{-1})					Total (%)
		Stem	Branch	Leaf	Root	Total	
1	*Pinus merkusii*	23,957.3	2,998.9	300.7	2,531.9	29,788.7	57.84
2	*Dipterocarpus tuberculatus*	8,719.8	1,280.8	131.0	1,381.7	11,513.3	22.35
3	*Pinus kesiya*	3,939.7	519.8	75.4	556.2	5,091.1	9.88
4	*Gluta usitata*	1,823.3	267.8	34.7	302.5	2,428.3	4.71
5	*Dipterocarpus obtusifolius*	510.2	74.9	10.4	86.8	682.3	1.32
6	*Quercus brandisiana*	351.3	51.7	12.3	71.1	486.4	0.94
7	*Tristaniopsis burmanica*	190.2	28.2	10.2	48.5	277.0	0.54
8	*Wendlandia tinctoria*	126.1	18.6	4.9	27.4	177.0	0.34
9	*Vaccinium sprengelii*	110.7	16.4	6.2	29.1	162.4	0.32
10	*Shorea obtusa*	107.0	15.7	3.4	20.6	146.7	0.28
11	*Castanopsis tribuloides*	89.4	13.1	3.1	17.8	123.4	0.24
12	*Quercus kingiana*	79.4	11.7	1.4	13.1	105.5	0.20
13	*Quercus kerrii*	67.4	9.9	2.0	12.8	92.1	0.18
14	*Semecarpus anacardium*	63.0	9.3	1.6	11.4	85.3	0.17
15	*Syzygium albiflorum*	44.3	6.5	0.6	7.0	58.4	0.11
16	*Aporosa villosa*	36.6	5.4	1.5	8.3	51.8	0.10
17	*Craibiodendron stellatum*	26.8	3.9	1.5	6.6	38.8	0.08
18	*Ziziphus oenoplia*	20.4	3.0	1.2	5.1	29.6	0.06
19	*Anneslea fragrans*	16.7	2.5	1.1	4.5	24.7	0.05
20	*Quercus helferiana*	17.0	2.5	0.6	3.5	23.6	0.05
21	*Phyllanthus emblica*	15.0	2.2	0.8	3.7	21.6	0.04
22	*Dalbergia cultrata*	15.6	2.3	0.5	3.0	21.4	0.04
23	*Syzygium cumini*	14.0	2.1	0.4	2.6	19.1	0.04
24	*Semecarpus albescens*	9.7	1.4	0.4	2.1	13.6	0.03
25	*Albizia odoratissima*	6.7	1.0	0.3	1.5	9.5	0.02
26	*Schima wallichii*	5.6	0.8	0.3	1.5	8.3	0.02
27	*Glochidion hirsutum Voigt*	5.1	0.7	0.3	1.2	7.3	0.01
28	*Buchanania lanzan*	4.0	0.6	0.2	0.9	5.7	0.01
29	*Lithocarpus lindleyanus*	1.7	0.3	0.1	0.5	2.6	0.01
30	*Symplocos recemosa*	1.2	0.2	0.1	0.4	1.9	0.00
31	*Vangueria pubescens*	0.8	0.1	0.1	0.3	1.3	0.00
32	*Glochidion sphaerogynum*	0.6	0.1	0.1	0.2	1.0	0.00
33	*Antidesma acidum*	0.7	0.1	0.0	0.2	1.0	0.00
34	*Cratoxylum formosum*	0.6	0.1	0.1	0.2	1.0	0.00
35	*Castanopsis purpurea*	0.4	0.1	0.0	0.1	0.6	0.00
36	*Colona flagrocarpa*	0.3	0.1	0.0	0.1	0.5	0.00
37	*Gardenia coronaria*	0.3	0.0	0.0	0.1	0.5	0.00
38	*Terminalia chebula*	0.3	0.0	0.0	0.1	0.5	0.00
39	*Castanopsis acuminatissima*	0.2	0.0	0.0	0.1	0.4	0.00
40	*Lithocarpus truncatus*	0.2	0.0	0.0	0.1	0.3	0.00
41	*Catunaregam tomentosa*	0.2	0.0	0.0	0.1	0.3	0.00
42	*Dillenia obovata*	0.2	0.0	0.0	0.1	0.3	0.00
43	*Castanopsis diversifolia*	0.1	0.0	0.0	0.0	0.2	0.00
44	*Lithocarpus glandifolius*	0.1	0.0	0.0	0.0	0.2	0.00
45	*Engelhardtia spicata*	0.1	0.0	0.0	0.0	0.1	0.00
46	*Pavetta tomentosa*	0.0	0.0	0.0	0.0	0.1	0.00
	total	**40,380.5**	**5,352.9**	**607.6**	**5,164.8**	**51,505.7**	**100.00**

Table 4-5 Amounts of carbon stocks in biomass of trees species in P-DDF3

No	Tree Species	Organic Carbon in Trees Biomass (kg.ha^{-1})					Total (%)
		Stem	Branch	Leaf	Root	Total	
1	*Pinus kesiya*	12,120.1	1,371.9	230.3	1,706.1	15,428.4	36.65
2	*Pinus merkusii*	9,363.8	1,176.0	114.4	973.3	11,627.5	27.62
3	*Shorea obtusa*	2,880.4	423.1	98.1	565.1	3,966.8	9.42
4	*Tristaniopsis burmanica*	1,946.3	286.1	58.3	370.0	2,660.7	6.32
5	*Quercus brandisiana*	1,589.3	233.5	34.3	274.0	2,131.2	5.06
6	*Gluta usitata*	970.9	142.6	25.1	176.1	1,314.8	3.12
7	*Quercus kerrii*	897.5	131.8	27.0	170.2	1,226.5	2.91
8	*Quercus kingiana*	765.1	112.4	10.0	117.4	1,005.0	2.39
9	*Wendlandia tinctoria*	420.6	62.0	24.9	108.4	615.8	1.46
10	*Vaccinium sprengelii*	316.8	46.7	15.3	74.8	453.6	1.08
11	*Shorea siamensis*	190.5	28.0	6.8	37.8	263.1	0.62
12	*Semecarpus anacardium*	161.6	23.7	4.4	29.6	219.3	0.52
13	*Castanopsis acuminatissima*	139.7	20.5	4.3	26.5	191.0	0.45
14	*Semecarpus albescens*	125.0	18.4	4.1	24.2	171.7	0.41
15	*Dalbergia cultrata*	75.4	11.1	1.7	13.3	101.4	0.24
16	*Terminalia chebula*	66.4	9.8	1.1	10.9	88.2	0.21
17	*Craibiodendron stellatum*	55.2	8.1	2.9	13.2	79.4	0.19
18	*Xantoris burmanica*	45.6	6.7	0.9	7.7	60.9	0.14
19	*Aporosa villosa*	39.3	5.8	2.5	10.6	58.2	0.14
20	*Lithocarpus garrettianus*	39.5	5.8	2.1	9.3	56.8	0.13
21	*Phyllanthus emblica*	30.6	4.5	2.2	9.1	46.5	0.11
22	*Schima wallichii*	30.8	4.5	0.9	5.8	41.9	0.10
23	*Gardenia coronaria*	28.3	4.2	1.4	6.5	40.3	0.10
24	*Castanopsis tribuloides*	25.9	3.8	1.1	5.5	36.3	0.09
25	*Stereospermum neuranthum*	25.0	3.7	1.0	5.2	34.9	0.08
26	*Lithocarpus sootepensis*	24.1	3.5	1.1	5.2	33.9	0.08
27	*Glochidion hirsutum Voigt*	16.3	2.4	1.1	4.6	24.4	0.06
28	*Ziziphus oenoplia*	14.5	2.1	0.9	3.9	21.5	0.05
29	*Castanopsis calathiformis*	11.0	1.6	0.5	2.5	15.6	0.04
30	*Shorea roxburghii*	8.3	1.2	0.4	1.8	11.7	0.03
31	*Stereospermum colais*	7.9	1.2	0.4	1.7	11.1	0.03
32	*Anneslea fragrans*	6.5	1.0	0.4	1.8	9.7	0.02
33	*Glochidion sphaerogynum*	6.1	0.9	0.4	1.8	9.2	0.02
34	*Symplocos recemosa*	4.4	0.7	0.3	1.3	6.7	0.02
35	*Catunaregam tomentosa*	4.0	0.6	0.3	1.2	6.0	0.01
36	*Castanopsis purpurea*	4.1	0.6	0.2	1.0	5.9	0.01
37	*Syzygium albiflorum*	2.8	0.4	0.2	0.7	4.2	0.01
38	*Dipterocarpus tuberculatus*	2.5	0.4	0.2	0.6	3.7	0.01
39	*Antidesma ghaesembilla*	1.7	0.3	0.1	0.5	2.6	0.01
40	*Lithocarpus sootepensis*	1.3	0.2	0.1	0.4	1.9	0.00
41	*Dillenia indica*	0.8	0.1	0.1	0.3	1.3	0.00
42	*Colona flagrocarpa*	0.6	0.1	0.0	0.2	0.9	0.00
43	*Strychnos nux-vomica*	0.6	0.1	0.0	0.2	0.9	0.00
44	*Markhamia stipulata*	0.5	0.1	0.0	0.2	0.8	0.00
45	*Engelhardtia spicata*	0.5	0.1	0.0	0.2	0.7	0.00
46	*Holarrhena pubescens*	0.5	0.1	0.0	0.2	0.7	0.00
47	*Cratoxylum formosum*	0.4	0.1	0.0	0.1	0.7	0.00

Table 4-5 (continue)

No	Tree Species	Organic Carbon in Trees Biomass (kg.ha^{-1})					Total (%)
		Stem	Branch	Leaf	Root	Total	
48	*Quercus semiserrata*	0.4	0.1	0.0	0.1	0.6	0.00
49	*Protium serratum*	0.4	0.1	0.0	0.1	0.6	0.00
50	*Schoepfia fragrans*	0.4	0.1	0.0	0.1	0.6	0.00
51	*Lithocarpus truncatus*	0.3	0.0	0.0	0.1	0.5	0.00
52	*Dillenia obovata*	0.3	0.0	0.0	0.1	0.5	0.00
53	*Celastrus paniculata*	0.3	0.0	0.0	0.1	0.4	0.00
54	*Quercus helferiana*	0.2	0.0	0.0	0.1	0.3	0.00
55	*Pavetta tomentosa*	0.1	0.0	0.0	0.1	0.2	0.00
56	*Syzygium cumini*	0.1	0.0	0.0	0.0	0.1	0.00
	total	**32,471.3**	**4,162.7**	**682.1**	**4,782.0**	**42,098.1**	**100.00**

Table 4-6 Amounts of carbon stocks in biomass of trees species in P-LMF

No	Tree Species	Organic Carbon in Trees Biomass (kg.ha^{-1})					Total (%)
		Stem	Branch	Leaf	Root	Total	
1	*Pinus kesiya*	21,209.9	2,129.9	402.0	3,015.7	26,757.4	67.94
2	*Castanopsis acuminatissima*	3,673.2	539.5	88.8	650.3	4,951.9	12.57
3	*Quercus kingiana*	3,676.3	540.0	38.6	544.2	4,799.1	12.19
4	*Quercus brandisiana*	588.7	86.6	14.4	107.4	797.0	2.02
5	*Tristaniopsis burmanica*	480.5	70.7	13.1	90.9	655.2	1.66
6	*Gluta usitata*	289.7	42.6	11.8	60.6	404.7	1.03
7	*Vaccinium sprengelii*	256.4	37.7	14.0	62.0	370.1	0.94
8	*Wendlandia tinctoria*	92.8	13.8	6.6	27.7	140.8	0.36
9	*Lithocarpus glandifolius*	102.4	15.0	3.5	19.9	140.7	0.36
10	*Terminalia chebula*	85.4	12.6	3.3	17.5	118.8	0.30
11	*Anneslea fragrans*	31.0	4.6	1.9	8.0	45.5	0.12
12	*Craibiodendron stellatum*	30.3	4.5	1.6	7.2	43.5	0.11
13	*Aporosa villosa*	26.1	3.9	2.0	8.6	40.7	0.10
14	*Phyllanthus emblica*	23.4	3.5	1.7	7.1	35.8	0.09
15	*Lithocarpus garrettianus*	16.9	2.5	1.0	4.4	24.8	0.06
16	*Dalbergia cultrata*	7.4	1.1	0.6	2.6	11.7	0.03
17	*Quercus kerrii*	7.2	1.1	0.5	2.2	11.0	0.03
18	*Quercus helferiana*	6.5	1.0	0.5	2.1	10.1	0.03
19	*Colona flagrocarpa*	5.3	0.8	0.4	1.6	8.0	0.02
20	*Glochidion hirsutum Voigt*	4.1	0.6	0.3	1.3	6.3	0.02
21	*Gardenia coronaria*	3.4	0.5	0.3	1.1	5.3	0.01
22	*Ziziphus oenoplia*	1.5	0.2	0.1	0.6	2.5	0.01
23	*Dillenia indica*	1.3	0.2	0.1	0.5	2.0	0.01
24	*Antidesma ghaesembilla*	0.6	0.1	0.1	0.3	1.1	0.00
	total	**30,620.4**	**3,512.9**	**607.2**	**4,643.7**	**39,384.2**	**100.00**

4.3.3 Carbon Storages in Soils

Table 4-7 shows amounts of carbon and nutrient storages in soils under the four subtype communities of pine forest.

(1) P-DDF1 (*Pine-D. obtusifolius*)

Amounts of organic matter, carbon and nitrogen in this forest were 92.0, 53.4 and 3.40 Mg ha^{-1}, respectively. The amounts of extractable P, K, Ca and Mg in the soil were in the order of 29.1, 906.9, 1210.1 and 1287.5 kg ha^{-1}.

(2) P-DDF2 (*Pine-D. tuberculatus*)

The amounts of organic matter, carbon and nitrogen in this forest were 108.9, 52.1 and 4.30 Mg ha^{-1}, respectively. The amounts of extractable P, K, Ca and Mg in the soil were in the order of 7.1, 1119.4, 372.4 and 514.9 kg ha^{-1}.

(3) P-DDF3 (*Pine-S. obtusa*)

The amounts of organic matter, carbon and nitrogen in this forest were 113.4, 65.8 and 4.87 Mg ha^{-1}, respectively. The amounts of extractable P, K, Ca and Mg in the soil were in the order of 4.9, 1328.9, 1027.3 and 1137.2 kg ha^{-1}.

.

(4) P-LMF (*Pine-oaks*)

The amounts of organic matter, carbon and nitrogen in this forest were 146.5, 85.0 and 5.11 Mg ha^{-1}, respectively. The amounts of extractable P, K, Ca and Mg in the soil were in the order of 7.9, 363.5, 741.7 and 375.1 kg ha^{-1}.

4.3.4 Carbon Storages in Forest Ecosystems

As already described, the amounts of carbon storages in forest biomass of the P-DDF1, P-DDF2, P-DDF3 and P-LMF were 69.0 (56.33%), 51.5 (49.71%), 42.1 (39.02%) and 39.4 (31.57%) Mg ha^{-1}, respectively. The amounts of organic carbon in one-meter soils under these subtypes were in the order of 53.5 (43.67%), 52.1 (50.29%), 65.8 (60.98%) and 85.0 (68.51%) Mg ha^{-1}. Therefore, the total carbon storages in ecosystems of these subtypes were 122.5, 103.6, 107.9 and 124.8 Mg ha^{-1}, respectively.

The amounts of biomass carbon indicated to the forest condition that it was the best for the P-DDF1 and the poorest for P-LMF. The soil was more fertile in P-LMF and poor for P-DDF1. The soil fertility was related to the carbon storages. Thus, the ecosystem carbon storage was the highest in P-LMF, and followed by P-DDF1, P-DDF2 and P-DDF3, respectively.

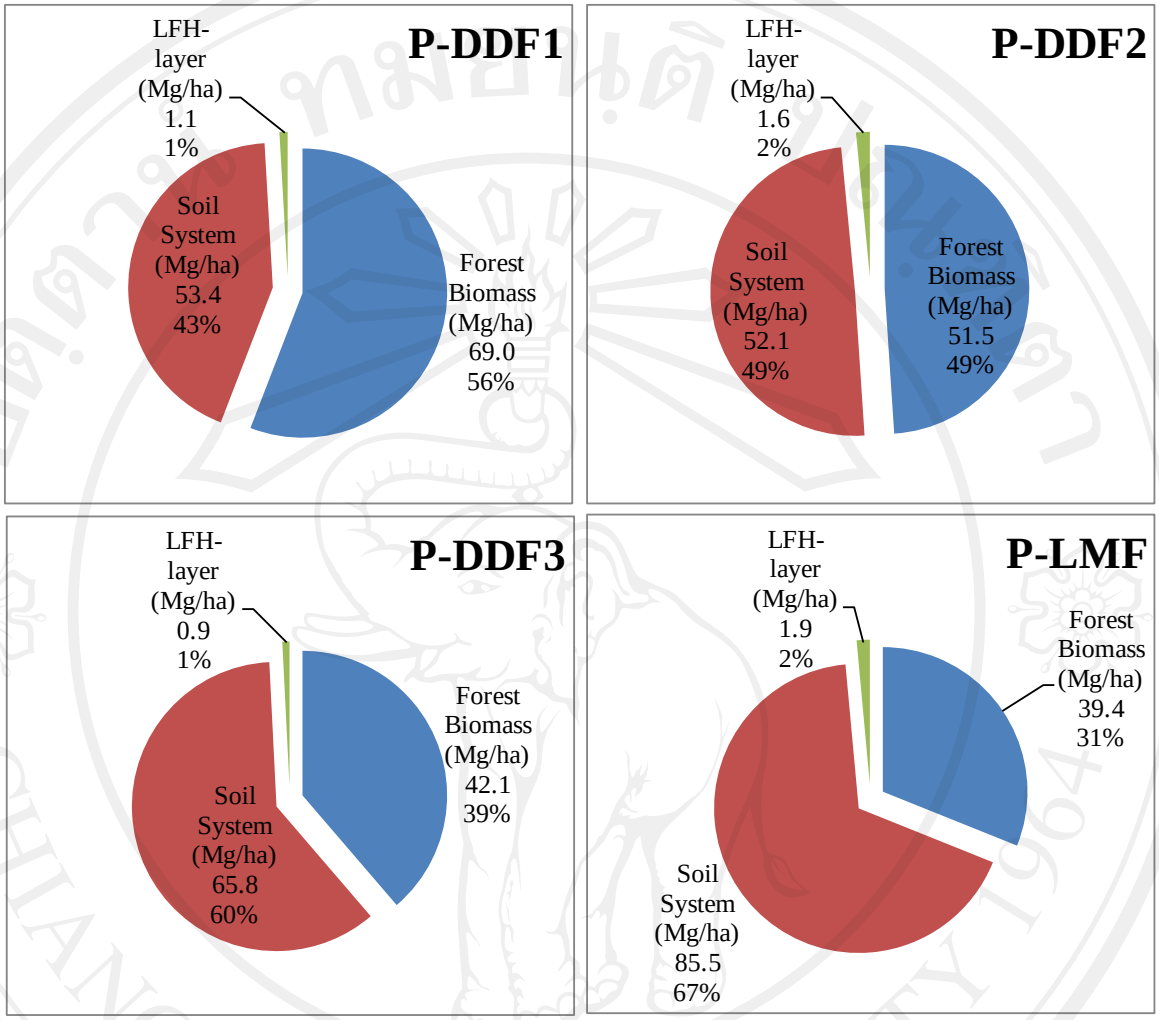

Figure 4-3 Amounts of carbon storage in forest biomass, soil and LFH layer of four-subtype pine forest

Table 4-7 Amounts of total carbon and nitrogen, and extractable P, K, Ca and Mg in one-meter soil profiles under four subtypes of pine forest

Forest type	Soil depth	Soil	SOM	SOC	Total-N	Avai. P	Avai. K	Extr. Ca	Extr. Mg
	(cm)	($Mg.ha^{-1}$)			($kg.ha^{-1}$)				
P-DDF1	0-5	696.7	18.5	10.7	557.4	9.8	57.1	209.0	78.5
	5-10	695.3	8.4	4.9	278.1	13.2	50.4	118.2	75.2
	10-20	1,367.7	18.2	10.6	547.1	5.7	138.1	194.2	202.9
	20-30	1,227.5	8.5	4.9	245.5	0.1	98.2	93.3	144.0
	30-40	1,291.6	5.8	3.4	258.3	-	102.7	72.3	52.0
	40-60	2,505.4	11.8	6.8	501.1	-	181.6	160.3	259.3
	60-80	2,558.1	5.6	3.3	511.6	-	147.1	173.9	250.1
	80-100	2,483.4	4.5	2.6	496.7	-	131.6	188.7	225.6
	0-100	12,825.7	81.3	47.1	3,395.8	29.1	906.9	1,210.1	1,287.5
P-DDF2	0-5	560.7	19.3	11.2	616.8	3.7	63.1	54.9	56.7
	5-10	642.9	16.2	9.4	321.4	2.2	67.5	25.7	41.4
	10-20	1,337.8	22.1	12.8	668.9	1.2	125.1	42.8	73.8
	20-30	1,347.3	15.6	9.1	538.9	-	154.3	26.9	54.2
	30-40	1,329.6	8.2	4.8	531.9	-	144.9	16.0	44.3
	40-60	2,352.1	7.8	4.5	705.6	-	208.2	32.9	70.3
	60-80	2,391.2	12.2	7.1	478.2	-	187.7	71.7	85.2
	80-100	2,204.4	7.5	4.3	440.9	-	168.6	101.4	88.7
	0-100	12,166.0	108.9	63.2	4,302.6	7.1	1,119.4	372.4	514.9
P-DDF3	0-5	596.0	31.9	18.5	715.2	4.9	111.8	401.7	155.6
	5-10	600.1	21.4	12.4	480.1	-	94.8	46.8	41.4
	10-20	1,159.6	23.4	13.6	695.7	-	231.3	62.6	81.3
	20-30	1,300.2	16.8	9.7	650.1	-	200.9	59.8	140.6
	30-40	1,290.2	7.6	4.4	516.1	-	169.7	77.4	139.5
	40-60	2,551.2	4.1	2.4	765.4	-	187.5	132.7	208.3
	60-80	2,580.0	6.7	3.9	516.0	-	158.7	123.8	186.9
	80-100	2,661.1	1.6	0.9	532.2	-	174.3	122.4	183.6
	0-100	12,738.5	113.4	65.8	4,870.8	4.9	1,328.9	1,027.3	1,137.2
P-LMF	0-5	603.9	35.3	20.5	785.1	3.5	27.5	198.1	57.6
	5-10	622.8	17.5	10.2	373.7	3.1	16.5	27.4	17.9
	10-20	1,354.7	28.4	16.5	677.3	1.2	24.4	43.3	28.0
	20-30	1,457.1	19.5	11.3	582.8	-	19.7	52.5	31.8
	30-40	1,473.6	11.1	6.4	442.1	-	23.6	79.6	40.7
	40-60	2,989.3	16.7	9.7	896.8	-	40.4	215.2	103.1
	60-80	2,911.8	11.1	6.4	873.5	-	200.9	64.1	46.9
	80-100	2,369.1	6.9	4.0	473.8	-	10.7	61.6	49.0
	0-100	13,782.2	146.5	85.0	5,105.1	7.9	363.5	741.7	375.1

Table 4-8 The ecosystem carbon storages in four subtypes of pine forest

	Carbon							
Forest Subtypes	Forest Biomass		Soil System		LFH-layer		Ecosystem	
	Mg.ha-1	%	Mg.ha-1	%	Mg.ha-1	%	Mg.ha-1	%
1. P-DDF1	69.0	55.86	53.4	43.23	1.1	0.91	123.5	100
2. P-DDF2	51.5	48.95	52.1	49.52	1.6	1.53	105.2	100
3. P-DDF3	42.1	38.71	65.8	60.50	0.9	0.80	108.8	100
4. P-LMF	39.4	31.08	85.5	67.45	1.9	1.46	126.8	100

4.4 Discussion

In all subtypes of the pine forest at Ban Wat Chan area, forest fire was occurred during dry season, and had a little accumulation of organic layers on forest floor. The forest biomass was mainly plant species, and biomass of animals was assumed to very small. Thus, two compartments of carbon storages in the pine ecosystem were determined as plant biomass and soil system.

Though the illegal cutting of trees as occurred in all subtypes, more trees in the P-DDF3 were cut since *S. obtusa* was good for making house and fuel wood. Another tree species used for fuel wood was *Tristaniopsis burmanica*. For the P-LMF, this subtype was recovered from rotation agriculture and many oaks were cut for fuel wood. The soil fertility was rather high and the farmer used this subtype forest for rotation agriculture.

Seanchanthong (2005) studied the carbon accumulations in different forest soils. He found that the pine-DDF at Pangmapaa district, Mae Hong Son province, had 36.79-49.67 Mg ha^{-1}. It was higher in soil under the pine-LMF, 94.02 Mg ha^{-1}.

Phonchaluen (2009) reported that DDF with the poor forest condition had forest biomass of 119.83 Mg ha^{-1}, and it was very low as 47.65 Mg ha^{-1} in very poor newly preserved community forest in Lamphun. In the Doi Suthep-Pui national park, Khamyong (2009) reported that the amounts of forest biomass in DDF, MDF, DEF, PF and MF were in the order of 119.69, 162.62, 478.31, 233.39 and 301.03 Mg ha^{-1}. The forest biomass in pine forest of this national park was higher than Bann Chun sub-district according to the better forest condition. Seeloy-ounkeaw (2011) found that two community (pine-LMF) forests for utilization and conservation had the biomass amounts of 139.74 and 252.36 Mg.ha^{-1}, respectively. This implied that tree harvesting in utilization forest caused the forest degrade and lower amount of forest biomass. For carbon storages in forest biomass, Phonchaluen (2009) reported that DDF with the poor forest condition had biomass carbon of 59.16 Mg ha^{-1}, and it was very low as 23.50 Mg ha^{-1} in very poor newly preserved community forest in Lamphun. In the Doi Suthep-Pui national park, Khamyong (2009) reported that the amounts of biomass carbon in DDF, MDF, DEF, PF and MF were in the order of 127.07, 216.89, 375.36, 233.56 and 281.77 Mg ha^{-1}. The stored carbon in pine forest of this national park was higher than Bann Chun sub-district according to the better

forest condition. Seeloy-ounkeaw (2011) found that the two community (pine-LMF) forests for utilization and conservation had the biomass carbon of 69.01 and 124.68 Mg ha^{-1}, respectively. This implied that tree harvesting in utilization forest caused forest degrade and decreased in the biomass carbon storage.