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Original article

Carbon and Macronutrient Storages in a Dry Dipterocarp Forest with Enriched Three Needle Pine (*Pinus kesiya* Royle ex Gordon), Northern Thailand

Thananiti Thichan[1*] **Soontorn Khamyong**[2]

Niwat Anongrak[1] **Panida Kachina**[3]

[1]Plant and Soil Sciences Department, Faculty of Agriculture, Chiang Mai University
[2]Makok Village Community, Pasang District, Lamphun Province
[3]Highland Agriculture and Natural Resources Department, Faculty of Agriculture, Chiang Mai University
[*]Corresponding author, E-mail: Thananiti61@gmail.com

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ABSTRACT

Storages of carbon and micronutrient in the ecosystem of dry dipterocarp forest (DDF) with 34-year-old enrich pine (*Pinus kesiya* Royle ex Gordon) were investigated at the Huai Hong Khrai Royal Development Study Center (HHKRDSC). This study used a method of plant community analysis for studying plant species diversity and biomass production. Ten sampling plots, 40x40 m^2 in size, were arranged using a random technique over the forest from about 226 m to 518 m above mean sea level. Forest biomass of 86 plant species was calculated using allometric equations. The total plant biomass was estimated to be 101.62 Mg/ha. The total amounts of stored carbon (C), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in the biomass were calculated to be 50.18 Mg/ha, 463.75 kg/ha, 53.38 kg/ha, 229.54 kg/ha, 899.23 kg/ha, and 134.98 kg/ha, respectively. *Pinus kesiya* had the highest amount of nutrient storage, followed by *Dipterocarpus tubercula*, *Dipterocarpus obtusifolius, Shorea obtusa*, etc. The total amounts of C, N, extractable P, extractable K, extractable Ca and extractable Mg in a one-meter soil profile were evaluated to be as follows: 13.51 Mg/ha, 804.95 kg/ha, 50.95 kg/ha, 3,523.94 kg/ha, 1,752.54 kg/ha and 2,337.48 kg/ha, respectively. Thus, the total ecosystem storages of carbon and nitrogen were in the following order: 63.69 Mg/ha and 1,268.70 kg/ha. The planted pine could increase carbon and nitrogen stored in forest biomass as 36.19% and 35.88% of the total, respectively.

Keywords: carbon, dry dipterocarp forest, macronutrients, plant biomass, plant diversity

INTRODUCTION

Most remaining dry dipterocarp forest (DDF) in Thailand has been disturbed by selective tree cutting and results in the secondary forest with different forest conditions. The DDF varies from degraded to relative abundant forest depending on disturbing levels. Enrichment planting of selective fast-growing tree species in the degraded forests is considered as an alternative method of forest restoration within a more shot period (Thomas *et al*., 2021). Other methods of forest restoration have been practiced such as fire protection, increasing site moisture by making check dams and water reservoirs for promoting tree growth and natural regeneration. In general, the degraded forests have more opened canopy with big gaps, high light intensity, fluctuated site temperature and poorer soil due to erosion as compare to the undisturbed forest (Romell *et al*., 2009: Zhang *et al*., 2018). The tree species selected to enrichment planting should be light demanding, fast growing, drought tolerant and lesser nutrient requirement (Santos *et al*., 2020). The enrichment planting in poor natural forests has been practiced in Thailand, but very few data are published. Homchan (2014) studied influences of three planted bamboo species including *Dendrocalamus menbranaceus* Munro, *Bambusa nutans* Wall. ex Munro and *Thrysostachys siamensis* Gamble on changing ecosystem of a secondary DDF. Asanok *et al*. (2013) investigated functional traits and the ability of tree species to grow in 15-year-old enriched secondary montane forest in the highlands of northern Thailand. The planted trees were five native species including *Castanopsis acuminatissima* (Blume) A. DC., *Betula alnoides* Buch. Ham. ex G. Don, *Cinnamomum iners* Reinw. ex Blume, *Diospyros glandulosa* Lace, and *Ternstroemia gymnanthera* (Wight & Arn.) Bedd. It is concluded that *Betula alnoides* could grow the best with 12 cm stem DBH and 8.3 m height. In other counties, enrichment planting of native species in plantation forest of exotic species may be taken as replacing the stand to avoid invasion of exotic species into nearby natural forest. The enriched planting of native tree species in a 16-year-old Eucalyptus plantation in South China showed significantly reducing surface water flow, soil erosion and nutrient losses (Chu *et al*., 2019).

The biological production (biomass) of the DDF in Thailand is different with locations according to variable subtypes and forest conditions. The forest nearby villages without conservation is tending to be degrading forest in contrast to inside national park, protection forest and conservation community forest which are the recovering forest. Standing biomass of the DDF on sandstone including four stands of *Shorea obtusa*, *Shorea siamensis*, *Dipterocarpus obtusifolius* and *Dipterocarpus tuberculatus* at HHKRDSC, Chiang Mai province was estimated to 90.65 Mg/ha on average (Khamyong *et al*., 2016: Suttawan *et al*., 2016). The amounts in these stands were in the following order: 87.86, 80.33, 95.25, and 77.22 Mg/ha. The Mae Tha community forest in Chiang Mai including five subtypes based on the most dominant tree species: *Shorea obtusa*, *Shorea siamensis*, *Dipterocarpus obtusifolius*, *Dipterocarpus tuberculatus*, and two-needle pine (*Pinus merkusii*). The average biomass amount of all stands was estimated to be 125.49 Mg/ha. The total amount of biomass in these stands were 134.81, 158.81, 146.08, 118.26 and 61.99 Mg/ha, respectively (Phongkhamphanh *et al*., 2018).

Soils under the DDF have different nature of depth, physicochemical properties and carbon-nutrient accumulations. It covers on xeric sites in the northern, northeastern and central regions of Thailand. The forest can be found on rocky area (without soil) and various soil types having different parent rocks (Sutthawan *et al*., 2016: Thichan *et al*., 2020). The difference of soil types influences plant growth and production. Other factors such as the amount of rainfall, topography, altitude, microclimate, etc. are also influenced on the variation since this forest covers on extensive areas from a peneplain of about 150 m altitude to slopes and rides of up to 1,300 m (Smithinand *et al*., 1980). Pampasit (1995) found that soils under the DDF of four subtype communities in the Doi Inthanon National Park, varied from Order Entisols (very shallow) to Inceptisols (moderately deep) and Ultisols (deep). The DDF dominated by *Dipterocarpus tuberculatus* on the flat area derived from granitic rocks had a deep soil with high clay accumulation in subsoil, Order Ultisols (Wattanasuksakul, 2012). The soil on the sloping and ridge sites is usually shallow containing fragmented rocks. The parent rocks vary from sedimentary rocks (sandstone, limestone) to igneous rocks (granite, andesite) and have influenced on soil physicochemical and biological properties (Fisher and Binkly, 2000). Carbon sequestration by forests through photosynthesis and accumulation of carbon as carbohydrate in plant tissues of different organs including stem, branch, leaf and root are considered as the carbon sink (Landsberg and Gower, 1997; Waring and Running, 1998). A part of carbon is moved to forest floor and accumulated in the soil system. The carbon sink in forest ecosystems is an important process of reducing atmospheric carbon dioxide and global warming (Soepadmo, 1993). However, different forests have the different potentials of carbon sink due to sub-type communities, the stages of forest succession caused by human disturbance particularly timber harvesting and influences of the environmental factors.

This research aims to investigate the role of 34-year-old enriched planting pine (*Pinus kesiya* Royle ex Gordon) on carbon and macronutrient storages in plant biomass and soil of a secondary DDF in Chiang Mai province, northern Thailand. The data are useful information for forest management and reforestation program.

MATERIALS AND METHODS

Study area

This research was conducted in the HHKRDS Center established in 1982, Doi Saket district, Chiang Mai province. It is about 27 km to the north of Chiang Mai city on the road to Chiang Rai province. The Center covers an area of about 1,360 ha with an altitude range between 350 and 591 meters above mean sea level. The meteorological data recorded between the year 1985 and 2011 using instruments in the Center could be reported: average annual rainfall, 1,328.9 mm, average maximum and minimum air temperatures, 32.2^{o}C and 18.9^{o}C, and average water evaporation, 1,222.6 mm per year. Before 1982, the two forests, mixed deciduous forest and dry dipterocarp forest, in this area were devastated to be extremely poor. Most medium and big trees were cut for timber whereas many small trees used for fuel woods and remained only the small trees of 5 to 10 m heights with the scattered distribution (Khamyong *et al*., 2016).

Plant community study

Vegetation sampling

A method of plant community analysis was used for vegetation study. Ten sampling plots, each of size 40 x 40 m^2, were used in enriched pine planted DDF, and arranged randomly over the forest having an altitude range of 403-564 m m.s.l. The sequent number of all trees in each plot was made on the stem. 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. All plots were located using the GPS. Growth forms of these plant species were given according to their nature and field observation experience of researchers as big tree, medium-sized trees, small trees and shrub. The maximum heights of them were approximately about >25 m, 20-25 m, 5 to-,20 m and <5m, respectively.

Ecological parameters

The recorded field data of tree species were calculated for ecological parameters: plant frequency, abundance, density, dominance, importance value index (IVI) and Shannon-Wiener Index (SWI) of species diversity using equations given by Krebs (1985). Forest condition index (FCI) was based on an equation of Seeloy-ounkeaw *et al.* (2014) used for the plot of 40 × 40 m^2 in size. For immature trees, the stem girth class of tree species was divided into 25 cm intervals for the gbh up to 100 cm, and the 100 cm interval was applied for mature trees having the gbh over 100 cm. This equation was assumed that the greater importance of the mature trees due to the stem sizes (which gave merchantable timber for concession in the past in Thailand as well as their high ecological influence). Thus, the increasing number of big trees in the plot will result in the higher FCI value.

Plant biomass estimation

The data of stem-gbh and tree heights of all tree species were also used for calculation of biomass amounts in the stem, branch, leaf and root using allometry equations studied in deciduous forests in Thailand by Ogino *et al.* (1967).

$$W_S = 189\,(D^2H)^{0.902}$$
$$W_B = 0.125 Ws^{1.204}$$
$$1/W_L = (11.4/Ws^{0.90}) + 0.172$$

When W_S = stem biomass in kilogram
W_B = branch biomass in kilogram
W_L = leaf biomass in kilogram

The unit of stem diameter (D) and tree height (H) was in meter. The root biomass was calculated using an equation of Ogawa *et al.* (1965)

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

The units used here were in kilogram for root biomass (W_R), centimeter for stem diameter (D) and meter for tree height (H).

All standing individuals of pine in sampling plots were calculated for standing biomass. The amounts of pine biomass allocated in stem, branch and leaf components in the plantation were calculated using the allometric equations of the pine plantations at Boa Kaew Watershed Management Station, Sa Moeng district, Chiang Mai province (Nongnuang *et al*., 2012) as follow:

$$W_S = 0.0503\ (D^2H)^{0.8775}$$
$$W_B = 0.0012\ (D^2H)^{1.0996}$$
$$W_L = 0.4536\ (WB)^{0.7933}$$

The root biomass of pine was not investigated in this study. However, the root biomass of pine and biomass of successional tree species were calculated using the equations investigated by Tsutsumi *et al*. (1983). $W_R = 0.0313\ (D^2H)^{0.805}$

Carbon and macronutrient storages in plant biomass

According to Tsutsumi *et al*. (1983), the average nutrient contents in the stem, branch, leaf, and root organs of 62 tree species in Thailand are used for the calculating nutrient storages in plant biomass: carbon (C): 49.90%, 48.70%, 48.30% and 48.12%, nitrogen (N): 0.34%, 0.64, 1.83% and 0.53%, phosphorus (P): 0.05%, 0.08%, 0.13% and 0.02%, potassium (K): 0.16%, 0.34%, 0.91% and 0.27%, calcium (Ca): 0.74%, 1.26%, 2.12% and 0.88%, and magnesium (Mg): 0.08%, 0.27%, 0.92% and O.08%, respectively.

Carbon and macronutrient storages in soil

This study selected three plots of vegetation study for soil investigating soil characteristics in the forest. Soil sampling was carried out by making three pits in these plots, 1.5 m width × 1 m long × 1 m depth in size, and soil samples were collected along the depth using a 100 cm^3 corer from eight soil depths with three replications: 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm. Each sample was analyzed for physical properties including bulk density (B.D.), particle-size distribution and texture, and for chemical properties such as pH, organic matter (O.M.), C, N and extractable forms of P, K, Ca and Mg, The amounts of carbon and macronutrients (N, P, K, Ca, Mg) in soils were evaluated.

RESULTS AND DISCUSSION

Plant species composition and diversity in the DDF

Using 10 sampling plots of area 40x40 m^2, a total of 86 species (69 genera and 36 families) was existed in the forest. These included 20 big trees, 18 medium-sized trees, 23 small trees, 16 shrubs and 9 climber species are given in Appendix Table 1.

According to data within 10 plots (Table 1), the most dominant tree species was observed: seven plots of *Dipterocarpus tuberculatus*, two plots of *Dipterocarpus obtusifolius* and one plot of *Shorea obtusa*. The species richness of these stands varied between 22 and 45 species per plot and tree densities varied from 1,688 to 3,606 trees/ha. The pine density contributed to only 5.53% of the total density.

The quantitative characteristics of plant species in the forest were investigated. Twelve species had the highest frequency value (100%); *Pinus kesiya*, *Dipterocarpus tuberculatus*, *Shorea obtusa*, *Aporosa villosa*, *Wendlandia tinctoria*, *Pterocarpus macrocarpus*, *Strychnos nux-vomica*, *Canarium subulatum*, *Syzygium cumini*, *Dalbergia oliverli*, *Bridelia retusa* and *Quercus kerrii*. The dipterocarps species of *Dipterocarpus obtusifolius* and *Shorea siamensis* had the values as 70% and 10%, respectively.

Average density of all species was 2,729 trees/ha. The species with the highest density was *Dipterocarpus tuberculatus* (473 trees/ha), followed by *Shorea obtusa* (291), *Aporosa villosa* (266), *Dipterocarpus obtusifolius* (201), *Wendlandia tinctoria* (151), *Pinus kesiya* (146), *Gluta usitata* (143), *Symplocos recemosa* (76), *Strychnos nux-vomica* (71), *Canarium subulatum* (60), *Dalbergia cultrata* (54) and *Pterocarpus macrocarpus* (52). These 12 species accounted for 72.70% of the total density.

The dominance of tree species was calculated from the stem basal area by measurement of stem girths at the breast height. *Pinus kesiya* had the highest dominance (31.81%), followed by *Dipterocarpus tuberculatus* (16.79), *Shorea obtusa* (12.06), *Dipterocarpus obtusifolius* (11.87), *Gluta usitata* (6.34), *Aporosa villosa* (3.52), *Pterocarpus macrocarpus* (2.03), *Semecarpus* *ancardium* (1.78), *Dalbergia cultrata* (1.54), *Strychnos nux-vomica* (1.27), and *Wendlandia tinctoria* (1.22). These 11 species accounted for 90.23% of the total dominance.

The ecological IVI combines three factors of the relative frequency, relative density and relative dominance into a measure that can be used to imply the ecological influence of each species in the DDF. The species with the highest IVI was *Pinus kesiya* (13.32% of all species), followed by *Dipterocarpus tuberculatus* (12.31%), *Shorea obtusa* (8.51%), *Dipterocarpus obtusifolius* (7.07%), *Aporosa villosa* (5.36%), *Gluta usitata* (4.70%), *Wendlandia tinctoria* (3.19%), *Pterocarpus macrocarpus* (2.25%), *Strychnos nux-vomica* (2.23%), *Symplocos recemosa* (2.03%), *Dalbergia cultrata* (1.93%) and *Canarium subulatum* (1.79%). These 12 species accounted for 64.69% of the total value.

The SWI as indicating plant species diversity were different among plots, 3.49 to 4.31 (3.87$\pm$0.24 on average), while the forest condition index values were measured to be a range of 1.03 to 10.98 (6.18$\pm$3.24 on average). If the pine were not planted in the forest, the values would decrease to 3.79$\pm$0.25 for the SWI, and 2.70$\pm$2.24 for the FCI.

Table 1. Plant communities within 10 sampling plots in the DDF

Plot no.	Dominant species	Species richness	Density (ha)	Pine density (ha)	Pine density %	SWI	FCI
1	*D. tuberculatus*	45	3,356	175	5.21	4.31	7.72
2	*D. tuberculatus*	34	3,606	106	2.94	3.66	10.98
3	*D. tuberculatus*	30	1,788	56	3.14	3.90	6.74
4	*D. tuberculatus*	22	1,688	69	4.07	3.49	3.23
5	*S. obtusa*	40	3,594	219	6.08	4.04	9.53
6	*D. obtusifolius*	40	3,231	163	5.02	3.71	9.49
7	*D. tuberculatus*	31	1,856	263	14.14	3.86	5.12
8	*D. obtusifolius*	37	2,813	69	2.44	3.89	1.03
9	*D. tuberculatus*	38	2,817	256	9.09	4.12	3.56
10	*D. tuberculatus*	38	2,538	81	3.20	3.77	4.39
Mean		36	2,729	146	5.53	3.87	6.18
S.D.		7	741	80	3.61	0.24	3.24

The enrichment planting of this pine in the degraded DDF could increase number of species (species richness), species composition, species diversity (SWI) and forest condition caused by big, planted pine trees. The detail of the species composition and diversity in the DDF have already been also give in a previous study by Thichan *et al*. (2021). These data implied that the enrichment planting could increase species diversity and improve forest condition of the forest after planting for 34 years. A total of 233 individuals of pine was found within 10 plots (146 tree/ha on average). Most pine individuals were big trees because it is a fast-growing species (Pornleesangsuwan, 2012). The biggest tree had the stem-gbh of 129.5 cm with 25.5 m height while the smallest one had the value of 10.9 cm and 4.1 m. The average values of gbh and height were 72$\pm$22 cm and 15.1$\pm$4.0 m, respectively. The variable growth might be caused by competition with other tree species and the influences of site factors (Pornleesangsuwan, 2012). The species richness and diversity in the DDF on other locations (Phongkhamphanh, 2015; Khamyoung *et al*, 2016) may be higher than this DDF but the FCI value was a little higher caused by the higher number of bigger planted pine.

Amounts of plant biomass

The biomass amounts in this DDF within 10 plots varied between 58,730.31 kg/ha to 148,426.88 kg/ha, 101,622.73 kg/ha on average. The biomass in stem, branch, leaf and root were calculated in the following order: 38,378.95 to 95,771.34 kg/ha, 9,221.41 to 27,796.45 kg/ha, 1,588.28 to 3,071.92 kg/ha and 9,541.67 to 21,787.17 kg/ha. Among 10 plots, the pine biomass varied between 12,341.02 and 54,207.72 kg/ha. The percentage contribution of this pine was in a range of 17.32-51.36% of the total biomass (Table 2).

Table 2 Plant biomass within 10 plots and contribution of pine to biomass in each plot of the DDF

No.	Biomass (kg/ha)					Contribution of pine	
	Stem	Branch	Leaf	Root	Total	Biomass (kg/ha)	%
1	76,164.34	20,944.33	2,666.43	17,998.62	117,773.71	42,782.96	36.33
2	65,739.97	16,877.81	2,576.49	16,326.56	101,520.82	46,820.04	46.12
3	60,578.44	19,871.46	1,931.10	13,105.68	95,486.67	28,745.89	30.10
4	38,378.95	9,221.41	1,588.28	9,541.67	58,730.31	21,920.46	37.32
5	95,771.34	27,796.45	3,071.92	21,787.17	148,426.88	48,144.46	32.44
6	88,682.75	26,453.03	2,698.91	19,853.49	137,688.18	44,548.64	32.35
7	68,925.74	16,308.99	2,582.23	17,725.98	105,542.94	54,207.72	51.36
8	46,428.51	12,323.41	1,809.38	10,702.61	71,263.90	12,341.02	17.32
9	59,485.53	13,570.53	2,374.81	15,446.83	90,877.71	42,329.17	46.58
10	57,756.41	15,567.37	2,137.10	13,455.26	88,916.14	26,028.12	29.27
Total	657,911.99	178,934.78	23,436.64	155,943.85	1,016,227.26	367,868.47	36.20
Mean	65,791.20	17,893.48	2,343.66	15,594.38	101,622.73	36,786.85	
S.D.	17,632.35	5,948.17	464.49	3,925.79	27,575.27	13,577.26	

Pinus kesiya contained the highest biomass amount (36,786.85 kg/ha or 36.79 Mg/ha), followed by *Dipterocarpus tuberculatus* (15,972.05 kg/ha), *Dipterocarpus obtusifolius* (12,474.08 kg/ha), *Shorea obtusa* (12,194.71 kg/ha), *Gluta usitata* (6,590.47 kg/ha), *Pterocarpus macrocarpus* (2,445.90 kg/ha), *Aporosa villosa* (1,889.74 kg/ha), *Semecarpus anacardium* (1,505.87 kg/ha), *Dalbergia cana* (1,395.63 kg/ha) and *Irvingia malayana* (1,076.07 kg/ha). The remainders had values less than 1,000 kg/ha are given in Table 3.

Table 3 Amounts of plant biomass in 10 plots and contribution of tree species in the DDF

No.	Name	Biomass (kg/ha)				
		Stem	Branch	Leaf	Root	Total
1	*P. kesiya*	24,136.99	4,502.90	947.83	7,199.13	36,786.85
2	*D. tuberculatus*	10,201.07	3,398.81	341.96	2,030.21	15,972.05
3	*D. obtusifolius*	8,034.41	2,688.82	226.33	1,524.52	12,474.08
4	*S. obtusa*	7,827.59	2,600.52	240.62	1,525.98	12,194.71
5	*G. usitata*	4,191.88	1,541.85	97.55	759.19	6,590.47
6	*P. macrocarpus*	1,552.15	579.10	36.21	278.45	2,445.90
7	*A. villosa*	1,231.55	272.04	69.63	316.51	1,889.74
8	*S. anacardium*	973.10	298.34	34.88	199.55	1,505.87
9	*D. cana*	904.85	266.58	33.91	190.29	1,395.63
10	*I. malayana*	690.88	233.39	19.18	132.62	1,076.07
11	*S. nux-vomica*	625.03	144.45	33.28	152.74	955.50
12	*D. oliveri*	559.09	163.24	20.47	115.93	858.73
13	*W. tinctoria*	509.73	95.91	33.70	143.43	782.77
14	*S. parviflorus*	509.23	136.56	21.73	111.86	779.37
15	S. cumini	457.11	122.12	19.91	102.18	701.32
16	*D. obovata*	371.61	129.59	10.58	72.83	584.61
17	*S. recemosa*	363.61	78.59	21.00	93.72	556.93
18	*S. siamensis*	342.71	83.48	17.09	81.50	524.77
19	*Q. kerrii*	269.88	73.36	11.23	58.61	413.08
20	*A. odoratissima*	262.64	79.70	9.09	54.11	405.54
21	*Species 21-86*	1,776.09	404.14	97.50	451.02	2,728.76
	Total	65,791.20	17,893.48	2,343.66	15,594.38	101,622.73

Most DDF in Thailand was disturbed by forest concession and illegal tree cutting which results in mainly secondary forests. The enrichment planting of three needle pine in the degraded DDF could increase also plant biomass, carbon and macronutrient storages. Sutthawan *et al.* (2016) found that the DDF in adjacent area had the annual increment of plant biomass as 1.38 Mg/ha. It means that this DDF in the past 34 years had the biomass of 17.91 Mg/ha. The planted pine could increase the more biomass at the rate of 1.08 Mg/ha/yr. Tree species require different amounts of nutrients: C > N > Ca > K > Mg > P (Brady and Weil, 2010), and reflect to the different amounts of their storage in plant biomass.

Soil system

Soil characteristics have had an influence on storages of the carbon and macronutrients in the forest soil. The data regarding physical and chemical soil properties in the DDF are given in Table 4 and Table 5.

The physical properties include bulk density, gravel, particle size distribution and texture. The bulk densities were moderately high to high throughout soil depth. Sand particles in the soil pedon. 1, 2, and 3 were varied: 29.6-65.4%, 13.2-25.5% and 30.5-60.6%, respective. The gravel in soil was low (28.53-38.38%) because of high development soil. Their silt particles were in the following order: 5.2-12.0%, 20.1-40.2% and 5.0-23.2%, whereas the clay particles varied between the following ranges: 22.6-64.4%, 35.6-65.5% and 24.5-64.5%, respective. As a result, textures of the topsoils varied as sandy clay loam, sandy clay and clay loam, while those of subsoils were clay and sandy clay, and the soil type was classified into Order Oxisols.

The average soil chemical properties in pedon 1-3 show in Table 5, the soil reaction was moderately acid (pH=5.71-5.85) at the depth of 0-20 cm, slightly acid at 20-30 cm and 40-80 cm depth (pH=6.65-6.92), neutral (pH=6.56) at 30-40 cm and 80-100 cm depth. The organic matter was high only at the soil surface and decreased to low and very low to subsoil. The low to very low organic matter content in the soil of this forest was accompanied by the low to very low nitrogen content. The content proportion of extractable K was low only at the soil surface (0-5 cm) and very low in the subsoils whereas the content proportions of extractable P, Ca and Mg were very low throughout the soil profiles. These extractable macronutrients had a low content in such the acidic soil.

Table 4. Some physical properties in three soil profiles under the DDF with enriched pine

Dept (cm)	B.D. Mg/m³			Gravel %			Particle distribution (%)									Texture		
							Sand			Silt			Clay					
Pedon	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
0-5	1.6	1.6	1.6	33.6	36.4	32.2	65.	24.	60.	12.	40.	14.	22.	35.	24.	SC	C	SC
5-10	1.6	1.8	1.6	31.9	35.7	31.3	46.	25.	40.	9.0	36.	23.	44.	38.	36.	SC	C	CL
10-20	1.6	1.8	1.7	32.0	32.6	28.5	33.	15.	48.	6.0	30.	5.0	60.	54.	46.	C	C	SC
20-30	1.6	1.8	1.6	35.2	34.8	31.1	48.	16.	33.	8.0	26.	7.5	44.	56.	59.	SC	C	C
30-40	1.7	1.7	1.6	29.2	32.9	33.4	34.	17.	33.	6.5	24.	6.3	59.	58.	60.	C	C	C
40-60	1.6	1.7	1.7	28.9	28.5	33.9	32.	13.	30.	5.2	24.	5.2	62.	62.	64.	C	C	C
60-80	1.7	1.8	1.7	30.4	32.3	38.3	34.	15.	30.	6.0	20.	5.0	59.	64.	64.	C	C	C
80-	1.7	1.7	1.6	30.9	29.5	34.9	29.	14.	30.	6.0	20.	6.0	64.	65.	63.	C	C	C

Amounts of carbon and macronutrient stored in the DDF ecosystem

In this study, the storages of carbon and macronutrients in the DDF ecosystem involved two compartments: plant biomass and soil (Table 6). This research does not study the storages in animal and ground-covered species. The ecosystem storages of P, K, Ca and Mg could not be given since the total amounts in soil were not measured, and only the available forms were studied.

Amounts of carbon, nitrogen and macronutrients in plant biomass

Carbon: The amounts of carbon storage in the standing biomass of 86 woody species in the DDF are given in **Table 6**. The total amount in the forest was calculated to be 50,179.94 kg/ha or 50.18 Mg/ha. With the same trend as biomass, *Pinus kesiya* had the highest biomass carbon (18,159.29 kg/ha), followed by *Dipterocarpus tuberculatus* (7,887.66 kg/ha), *Dipterocarpus obtusifolius* (6,161.54 kg/ha), *Shorea obtusa* (6,022.94 kg/ha), *Gluta usitata* (3,255.07 kg/ha) and *Pterocarpus macrocarpus* (1,208.02 kg/ha). These 6 species accounted for 85.05% of the total. The remainders had values less than 1,000 kg/ha**.**

Table 5. Chemical properties in three soil profiles under the DDF with enriched pine

Depth (cm)	pH	O.M. %	C	N	Extractable nutrient (mg/kg)			
			g/kg		P	K	Ca	Mg
0-5	5.76	4.34	25.19	1.30	0.65	50.75	41.22	4.13
5-10	5.71	2.06	11.93	0.60	0.54	9.62	5.95	5.66
10-20	5.85	1.24	7.21	0.40	0.21	18.47	3.66	4.09
20-30	6.65	0.84	4.87	0.30	0.18	16.04	3.21	6.12
30-40	6.56	0.61	3.51	0.30	0.22	10.26	3.66	11.31
40-60	6.70	0.46	2.66	0.20	0.14	9.18	4.12	4.4
60-80	6.92	0.44	2.53	0.15	0.12	8.41	6.87	13.04
80-100	6.56	0.44	2.53	0.15	0.07	9.29	4.12	11.58

Table 6 Carbon, nitrogen and macronutrient amounts stored in plant biomass (10 plots) of the DDF

No.	Name	Nutrient (kg/ha)					
		Carbon	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
1	*P. kesiya*	18,159.29	166.38	18.34	81.99	318.80	45.95
2	*D. tuberculatus*	7,887.66	73.45	8.67	36.47	143.43	22.11
3	*D. obtusifolius*	6,161.54	56.75	6.77	28.17	111.55	16.99
4	*S. obtusa*	6,022.94	55.75	6.61	27.68	109.22	16.72
5	*G. usitata*	3,255.07	29.93	3.61	14.89	59.20	9.02
6	*P. macrocarpus*	1,208.02	11.12	1.34	5.53	22.00	3.36
7	*A. villosa*	932.97	8.88	0.99	4.38	16.80	2.61
8	*S. anacardium*	743.74	6.91	0.81	3.43	13.46	2.06
9	*D. cana*	689.29	6.41	0.75	3.18	12.45	1.91
10	*I. malayana*	531.49	4.90	0.58	2.43	9.63	1.47
11	*S. nux-vomica*	471.81	4.47	0.50	2.21	8.49	1.32
12	*D. oliveri*	424.15	3.93	0.46	1.95	7.65	1.17
13	*W. tinctoria*	386.36	3.72	0.40	1.84	6.96	1.09
14	*S. parviflorus*	384.93	3.60	0.41	1.78	6.93	1.07
15	S. cumini	346.35	3.24	0.37	1.60	6.24	0.96
16	*D. obovata*	288.70	2.67	0.32	1.33	5.25	0.80
17	*S. recemosa*	274.96	2.62	0.29	1.29	4.95	0.77
18	*S. siamensis*	259.14	2.44	0.28	1.21	4.67	0.72
19	*Q. kerrii*	204.02	1.90	0.22	0.94	3.68	0.56
20	*A. odoratissima*	200.30	1.86	0.22	0.92	3.62	0.55

21	*Species 21-86*	1,347.21	12.80	1.43	6.32	24.27	3.77
	Total	**50,179.94**	**463.75**	**53.38**	**229.54**	**899.23**	**134.98**

Nitrogen: The total amount of biomass nitrogen was 463.75 kg/ha. *Pinus kesiya* had the highest biomass nitrogen (166.38 kg/ha), as well, followed by *Dipterocarpus tuberculatus* (73.45 kg/ha), *Dipterocarpus obtusifolius* (56.75 kg/ha), *Shorea obtusa* (55.75 kg/ha), *Gluta usitata* (29.93 kg/ha) and *Pterocarpus macrocarpus* (11.12 kg/ha). These 6 species accounted for 84.83% of the total. The remainders had values less than 10 kg/ha**.** The amount of nitrogen storage of the rest of the species is given in Table 6.

Phosphorus: The amount of stored phosphorus in the biomass was 53.38 kg/ha. *Pinus kesiya* had the highest amount (18.34 kg/ha) of phosphorus, as well, followed by *Dipterocarpus tuberculatus* (8.67 kg/ha), *Dipterocarpus obtusifolius* (6.77 kg/ha), *Shorea obtusa* (6.61 kg/ha), *Gluta usitata* (3.61 kg/ha) and *Pterocarpus macrocarpus* (1.34 kg/ha). These 6 species accounted for 84.95% of the total. The remainders had values less than 1 kg/ha**.** The amount of phosphorus storage of the rest of the species is given in Table 6.

Potassium: The total amount of biomass potassium was 229.54 kg/ha. Again, *Pinus kesiya* had the highest amount (81.99 kg/ha), followed by *Dipterocarpus tuberculatus* (36.47 kg/ha), *Dipterocarpus obtusifolius* (28.17 kg/ha), *Shorea obtusa* (27.68 kg/ha), *Gluta usitata* (14.89 kg/ha) and *Pterocarpus macrocarpus* (5.53 kg/ha). These 6 species accounted for 84.84% of the total. The remainders had values less than 5 kg/ha**.** The amount of potassium storage of the rest of the species is given in Table 6.

Calcium: The total amount of biomass calcium was 899.23 kg/ha. Here, too, *Pinus kesiya* had the highest amount (318.80 kg/ha), followed by *Dipterocarpus tuberculatus* (143.43 kg/ha), *Dipterocarpus obtusifolius* (111.55 kg/ha), *Shorea obtusa* (109.22 kg/ha), *Gluta usitata* (59.20 kg/ha) and *Pterocarpus macrocarpus* (22.00 kg/ha). These 6 species accounted for 84.98% of the total. The remainders had values less than 20 kg/ha**.** The amount of calcium storage of the rest of the species is given in Table 6.

Magnesium: The total amount of magnesium stored in biomass was 134.98 kg/ha. *Pinus kesiy*a had also the highest amount (45.95 kg/ha), as well. followed by *Dipterocarpus tuberculatus* (22.11 kg/ha), *Dipterocarpus obtusifolius* (16.99 kg/ha), *Shorea obtusa* (16.72 kg/ha) and *Gluta usitata* (9.02 kg/ha. These 5 species accounted for 82.07% of the total. The remainders had values less than 5 kg/ha**.** The amount of magnesium storage of the rest of the species is given in Table 6.

Amounts of carbon, nitrogen and macro-nutrients in soil

In Table 7**,** the amounts of organic matter in one-meter soil profiles varied between 14,359.58 kg/ha and 14,959.88 kg/ha (14,591.02 kg/ha on average), and the amounts of carbon were calculated to be between 13,293.77 kg/ha and 13,849.34 kg/ha (13,508.22 kg/ha on average). The total amount of nitrogen, phosphorus, potassium, calcium and magnesium of three soil profiles varied along the pedons: 792.40 kg/ha to 826.20 kg/ha (804.95 kg/ha on average), 50.14 kg/ha to 52.34 kg/ha (50.95 kg/ha on average), 3,467.58 kg/ha to 3,626.67 kg/ha (3,523.94 kg/ha on average), 1,732.51 kg/ha to 1,789.61 kg/ha (1,752.54 kg/ha on average) and 2,286.91 kg/ha to 2,423.50 kg/ha (2,337.48 kg/ha on average), respectively.

Ecosystem storages of carbon and macro-nutrients

The carbon and macronutrient stocks in the DDF ecosystem are composed of two main source compartments: carbon in the standing plant biomass, and carbon in the soil. In Table 8, the total carbon stock in the ecosystem was measured at 63,688.16 kg/ha or 63.67 Mg/ha: the carbon stock in the biomass was 50,179.94 kg/ha (78.79%) and in the soil was 13,508.22 kg/ha (21.21%). The total nitrogen stock was low, 1,268.70 kg/ha: 463.75 kg/ha (36.55%) in the biomass, 804.95 kg/ha (63.45%), respectively. The total amounts of phosphorus, potassium, calcium and magnesium were in the following order: 104.32, 3,753.47, 2,651.77 and 2,472.46 kg/ha. Since the total amounts in soil of P, K Ca and Mg were not measured, the percentages in plant biomass and soil could not calculate.

Table 7 Amounts of organic matter, carbon and nutrients in three soil pits under the DDF

Depth (cm.)	O.M.	C	N	Extractable nutrients (kg/ha)			
	kg/ha			P	K	Ca	Mg
Pedon 1							
0-5	3,564.81	3,310.51	170.85	8.54	666.96	541.72	54.28
5-10	1,699.29	1,574.57	79.19	7.13	126.97	78.53	74.70
10-20	2,064.64	1,920.79	106.56	5.59	492.05	97.50	108.96
20-30	1,394.21	1,293.29	79.67	4.78	425.96	85.25	162.52
30-40	1,033.06	951.09	81.29	5.96	278.01	99.17	306.46
40-60	1,580.12	1,461.95	109.92	7.69	504.54	226.44	241.83
60-80	1,509.28	1,388.54	82.32	6.59	461.57	377.05	715.67
80-100	1,514.17	1,393.03	82.59	3.85	511.51	226.85	637.60
Total	**14,359.58**	**13,293.77**	**792.40**	**50.14**	**3,467.58**	**1,732.51**	**2,302.03**
Pedon 2							
0-5	3,523.01	3,271.69	168.84	8.44	659.14	535.37	53.64
5-10	1,776.59	1,646.19	82.79	7.45	132.74	82.10	78.10
10-20	2,254.07	2,097.01	116.34	6.11	537.20	106.45	118.96
20-30	1,523.54	1,413.27	87.06	5.22	465.48	93.15	177.60
30-40	1,079.35	993.71	84.93	6.23	290.47	103.62	320.20
40-60	1,613.40	1,492.75	112.24	7.86	515.17	231.21	246.92
60-80	1,598.02	1,470.18	87.16	6.97	488.70	399.21	757.75
80-100	1,591.89	1,464.54	86.83	4.05	537.77	238.49	670.33
Total	**14,959.88**	**13,849.34**	**826.20**	**52.34**	**3,626.67**	**1,789.61**	**2,423.50**
Pedon 3							
0-5	3,623.49	3,365.00	173.66	8.68	677.94	550.64	55.17
5-10	1,732.18	1,605.05	80.72	7.27	129.43	80.05	76.15
10-20	2,109.19	1,962.23	108.86	5.72	502.67	99.61	111.31
20-30	1,426.87	1,323.59	81.54	4.89	435.94	87.24	166.33
30-40	1,027.06	945.57	80.82	5.93	276.40	98.60	304.68
40-60	1,551.90	1,435.84	107.96	7.56	495.53	222.39	237.51
60-80	1,500.79	1,380.73	81.86	6.55	458.97	374.92	711.65
80-100	1,482.12	1,363.55	80.84	3.77	500.69	222.05	624.11
Total	**14,453.59**	**13,381.55**	**796.26**	**50.36**	**3,477.56**	**1,735.50**	**2,286.91**
Average (three pits)	**14,591.02**	**13,508.22**	**804.95**	**50.95**	**3,523.94**	**1,752.54**	**2,337.48**

Table 8 Amounts of organic carbon and macronutrients under the DDF

Nutrient compartments	C	%	N	%	P	K	Ca	Mg
	kg/ha							
Plant Biomass	50,179.94	78.79	463.75	36.55	53.38	229.54	899.23	134.98
Soil	13,508.22	21.21	804.95	63.45	50.95	3,523.94	1,752.54	2,337.48
Total	63,688.16	100	1,268.70	100	104.32	3,753.47	2,651.77	2,472.46

No data are available for the role of enrichment planting of pine species on the storages of carbon and macronutrients in the DDF. However, the data of previous research are available and used for comparation.

Carbon: As for the natural pine-DDF, Seramethakun (2012) reported that the pine-DDF dominated by three dipterocarp species (*Dipterocarpus obtusifolious*, *Dipterocarpus tuberculatus and Shorea obtusa*) at Kanlaya Ni Wattana district in Chiang Mai could produce the amount of biomass at 139.21, 103.89 and 84.96 Mg/ha, respectively. Amount of carbon in biomass storage at 69.03, 51.51 and 42.10 Mg/ha, respectively. The pine contribution to the biomass at following order: 49.98, 29.79 and 15.43 Mg/ha (72.41%, 57.84% and 36.65% of the total).

Nitrogen: In the non-pine DDF, Wong-in (2011) reported that the DDF dominated by *Shorea siamensis* on granitic rock at Petrified Wood national park, Ban Tak District, Tak could produce the amount of biomass at 48.13 Mg/ha and stored N of 267.43 kg/ha. Naimphulthong (2011) studied the DDF on sedimentary rock in the same park and found that the amount of biomass was 55.29 Mg/ha and stored nitrogen of 306.80 kg/ha. Sutthawan (2016) studied the DDF on sandstone area at HHKRDS Center, Chiang Mai province had the biomass and stored N at 90.63 Mg/ha and 419.69 kg/ha, respectively. Phongkhamphanh (2015) investigated the DDF in community forest of Mae Tha Sub-district, Chiang Mai province, and found that the biomass and stored N were higher than this study as the following order: 125.5 Mg/ha and 656.25 kg/ha.

Phosphorus: In the non-pine DDF, Wong-in (2011) reported that the DDF had the amount of biomass P at 37.01 kg/ha whereas Naimphulthong (2011) found that the amount of stored P was 40.19 kg/ha. Sutthawan (2016) reported that the DDF had the stored P at 49.31 kg/ha. Phongkhamphanh (2015) found that the stored P was higher than this study, 81.25 kg/ha.

Potassium: In the non-pine DDF, Wong-in (2011) reported that the DDF had the amount of biomass K at 182.81 kg/ha while Naimphulthong (2011) found that the amount of stored K was 205.91 kg/ha. Sutthawan (2016) reported that the DDF had the stored K at 207.94 kg/ha. The stored amount was higher in the DDF studied by Phongkhamphanh (2015), 325 kg/ha.

Calcium: In the non-pine DDF, Wong-in (2011) reported that the DDF had the amount of biomass Ca at 385.87 kg/ha. Naimphulthong (2011) found that the amount of stored Ca was 446.88 kg/ha. Sutthawan (2016) reported that the DDF had the stored Ca at 818.81 kg/ha. The stored amount was higher in the DDF studied by Phongkhamphanh (2015), 1,300 kg/ha.

Magnesium: In the non-pine DDF, Wong-in (2011) reported that the DDF the amount of biomass Mg at 81.82 kg/ha. Naimphulthong (2011) found that the amount of stored Mg was 98.63 kg/ha. Sutthawan (2016) reported that the DDF had the stored Mg at 124.44 kg/ha. The stored amount was higher in the DDF studied by Phongkhamphanh (2015), 193.75 kg/ha.

CONCLUSION

After 34 years, pine enrichment planting in the degraded DDF of northern Thailand could increase forest biomass at 36.79 Mg/ha. The non-planted pine forest should have the biomass of 64.83 Mg/ha instead of 101.62 Mg/ha in this pine-planted forest. As well as the storage of carbon and macronutrients (nitrogen, phosphorus, potassium, calcium and magnesium), the increasing amounts of percentages contribution by this planted pine were in the following order: 36.19, 35.88, 34.36, 35.72, 35.45 and 34.09 of the totals. Usually, tree species such as this pine provides above- and below-ground litter into soil and consequent decomposition, and later change to be organic matter containing carbon and macronutrients stored in soil with some losses from the forest. The biomass amounts of stem, branch, needle leaf and root of the pine were estimated at 24.14, 4.50, 0.95 and 7.20 Mg/ha, respectively. The litter from these organs particularly needle leaves is important to increasing soil carbon and macronutrients.

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Appendix Table 1 Species list, growth form and number of trees in DDF (based on Smitinand, 2014)

Family	No	Scientific name	Growth form	Number of trees
1. Anacardiaceae	1	*Buchanania lanzan* Spreng.	Big tree	20
	2	*Gluta usitata* (Wall.) Ding Hou.	Big tree	228
	3	*Lennea coromandelica* (Houtt.) Merr.	Big tree	2
	4	*Semecarpus anacardium* Linn.f.	Medium tree	60
2. Apocynaceae	5	*Aganosma 35ultrate35* (Roxb.) G.Don.	climber	3
3. Bignoniaceae	6	*Heterophragma sulfureum* Kurz.	Small tree	7
	7	*Markhamia 35ultrate35* (Wall.) Seem.	Medium tree	4
	8	*Stereospermum cylindricum* Pierre ex Dop.	Tree	3
	9	*Stereospermum neuranthum* Kurz.	Big tree	7
4. Burseraceae	10	*Canarium subulatum* Guillaumin.	Big tree	96
5. Celastraceae	11	*Celastrus 35ultrate35e* Willd.	Woody	3
6.	12	*Parinari anamensis* Hance.	Medium tree	10
7. Clusiaceae	13	*Garcinia cowa* Roxb. Ex Choisy.	Small tree	23
8. Combretaceae	14	*Terminalia alata* Heyne ex Roth.	Big tree	4
	15	*Terminalia chebula* Retz. Var. *chebula.*	Tree	5
9. Dilleniaceae	16	*Dillenia 35ultrat* (Blume) Hoogland.	Small tree	70
10.	17	*Dipterocarpus tuberculatus* Roxb.	Big tree	756
	18	*Dipterocarpus obtusifolius* Teijsm. Ex Miq.	Big tree	322
	19	*Shorea 35ultra* Wall. ex Blume.	Big tree	465
	20	*Shorea siamensis* Miq.	Big tree	67
11. Ebenaceae	21	*Diospiros ehretioides* Wall. ex G. Don.	Small tree	11
12. Ericaceae	22	*Craibiodendron stellatum* (Pierre) W. W. Sm.	Small tree	24
13. Fabaceae	23	*Acacia catechu* (L.f.) Willd.	Small tree	2
	24	*Albizia chinensis* (Osbeck) Merr.	Big tree	4
	25	*Albizia odoratissima* (L.f.) Benth.	Small tree	36
	26	*Butea superba* Rocb.	Climber	1
	27	*Dalbergia cana* Graham ex Kurz.	Tree	1
	28	*Dalbergia 35ultrate* Graham ex Benth.	Big tree	87
	29	*Dalbergia dongnaiensis* Pierre.	Medium tree	4
	30	*Dalbergia oliveri* Gamble.	Medium tree	37
	31	*Dalbergia velutina* Benth.	Climber	3
	32	*Indigofera sootepensis* Craib.	Shrub	1
	33	*Leucaena leucocephala* (Lam.) de Wit.	Small tree	1
	34	*Millettia extensa* (Benth.) Baker.	Climber	2
	35	*Peltophorum pterocarpum* (DC.) Backer ex K.	Medium tree	21
	36	*Pterocarpus macrocarpus* Kurz.	Big tree	83
	37	*Spatholobus parviflorus* (DC.) Kuntze.	Woody	50
	38	*Xylia xylocarpa* Taub. Var. *kerrii* Nielsen.	Big tree	23
14. Fagaceae	39	*Lithocarpus elegans* (Blume) Hatus ex	Medium tree	1
	40	*Quercus kerrii* Craib.	Medium tree	27
15. Hypericaceae	41	*Cratoxylum formosum* Byer subsp. *Pruniflorum*	Small tree	69
16. Irvingiaceae	42	*Irvingia malayana* Oliv. ex A. W. Benn.	Big tree	82
17. Lamiaceae	43	*Premna repens* H. R. Fletcher.	Shrub	1
	44	*Vitex peduncularis* Wall. ex Schauer.	Medium tree	25
18. Lauraceae	45	*Litsea glutinosa* (Lour.) C.B. Rob.	Medium tree	7
	46	*Phoebe lanceolata* (Nees) Nees.	Medium tree	19
19. Malvaceae	47	*Berrya mollis* Wall. ex Kurz.	Medium tree	1
	48	*Colona flagrocarpa* (C.B. Clarke).	Small tree	1
	49	*Decaschistia siamensis* Craib.	Shrub	2
	50	*Pterospermum semisagittatum* Buch.-Ham.ex	Small tree	2
20.	51	*Memecylon plebejum* Kurz var. *ellipsoideum.*	Shrub	3
	52	*Memecylon plebejum* Kurz var. *plebejum.*	Shrub	62
21. Meliaceae	53	*Chukrasia velutina* Wight & Arn.	Medium tree	4

Appendix Table 1 (Continued)

Family	No	Scientific name	Growth	Number of trees
22. Moraceae	54	*Ficus* sp.	Medium tree	1
23. Myrtaceae	55	*Eucalyptus camaldulensis* (Dehnh.	Medium tree	11
	56	*Syzygium albiflorum* (Duthie & Kurz) Bahadur &	Medium tree	2
	57	*Syzygium cumini* (L.) Skeels.	Small tree	67
24. Ochnaceae	58	*Ochna intergerrima* (Lour.) Merr.	shrub/shrubby	7
25. Oleaceae	59	*Chionanthus ramiflorus* Roxb.	Small tree	43
	60	*Olea salicifolia* Wall. Ex G. Don.	Small tree	4
26. Opiliaceae	61	*Meilentha suavis* Pierre.	Small tree	2
34.	62	*Anneslea fragrans* Wall.	Small tree	48
35. Pinaceae	63	*Pinus kesiya* Royle ex Gordon.	Big tree	233
36.	64	*Antidesma acidum* Retz.	Shrub	1
	65	*Antidesma ghaesembilla* Gaertn.	Shrub	1
	66	*Aporosa villosa* (Wall. ex Lindl.) Baill.	Shrub	425
	67	*Bridelia retusa* (L.) A. Juss.	Medium tree	54
	68	*Glochidion zeylanicum* (Gaaertn.) A. Juss.	Shrub	12
	69	*Phyllanthus emblica* L.	Small tree	15
37. Rhamnaceae	70	*Zizyphus rugosa* Ram.	Climber	30
38. Rubiaceae	71	*Catunaregam spathulifolia* Tirveng.	Shrub	19
	72	*Gardenia obtusifolia* Roxb. ex Gordon.	shrub	4
	73	*Gardenia sootepensis* Hutch.	Small tree	25
	74	*Haldina cordifolia* Ridsd.	Medium tree	2
	75	*Ixora cibdela* Craib.	Shrub	4
	76	*Morinda coreia* Ham.	Small tree	6
	77	*Pavetta indica* RL.	Shrub	1
	78	*Vangueria pubescens* Kurz.	Shrub	2
	79	*Wendlandia tinctoria* (Roxb.) DC.	Small tree	241
39. Saliciaceae	80	*Casearia gallifera* Tathana.	Small tree	3
40.	81	*Symplocos recemosa* Roxb.	Small tree	121
41.	82	*Strychnos nux-vomica* L.	Shrub	113
42. Ulmaceae	83	*Ulmus lancaefolia* Roxb. ex Wall.	tree	14
43. Unknown	84	Climber -1	Small	1
	85	Climber -2	Small	1
	86	Unknown	Small tree	1