CHAPTER 3

Growths and Biomass Production of Teak and Pine Plantations

3.1 Introduction

Forest clearing and fragmentation in highland watershed of northern Thailand are the serious problem and may lead to extinction of local plant species. Forest plantations can play the key role in harmonizing long-term forest ecosystem restoration goals. To recover the degraded land, fast growing native tree species like *P. kesiya* has been widely planted on highland watershed areas of the northern region of Thailand.

P. kesiya is a fast growing species with the height growth after the first year of establishment, 1-2 m annually, with a canopy closure in three to four years (Armitage and Wood, 1980). Oberhauser (1997) stated that *P. kesiya* plantation might indeed speed up the succession process. It is well adapted to fire according to a thick bark and deep roots (Stott et al., 1990). It even promotes fires and thus excludes other species, by its abundant flammable litter which is nitrogen poor when decomposed (Singh and Singh, 1984). Little and Moore (1953) noted that a severe deeply burned fire can promote pine regeneration by exposing the mineral soil and by eliminating competition with sprouting species. In fact, in total absence of fire, pines could only be found on the very poorest soils (Turakka et al., 1982). On the other hand, broad-leaved species coppice after fire (Koskela, 1993), and if fires are almost annual these species can slowly colonize the understory of a forest stand (Savage, 1994). Previous studies have suggested that *P. kesiya* plantations posses a capability as a foster environment for native broad-leaved tree species, but little is known about the extent of regeneration in these plantations.

Two types of reforestation have been recognized, plantations for commercial and conservation purposes. Commercial plantations are conducted by both government and private sectors. For conservation purposes, the aim of plantation is for land restoration in the highland watershed. The commercial plantation is divided into two groups; (1) fast growing tree species for short rotation such as *Eucalyptus* spp., and (2) economic tree species such as teak (*Tectona grandis* L.f.). The forest plantation in highland is the responsible of government to improve watershed ecosystems. Watershed Development Units under Royal Forest Department took over the plantation establishment in the 1970s, and the plantation establishment was subsequently escalated. Many tree species have been planted including *Pinus kesiya*, *Prunus cerasoides*, *Docynia indica* and *Betula alnoides*. *P. kesiya* is still the most common species for highland plantation. About 150,000 ha of *P. kesiya* plantations in northern Thailand have been reported (RFD, 1993).

Some research works on *P. kesiya* plantations have been accumulated, Homjeen (1997) reviewed pine growth at Huey Bong Experimental Station, Chiang Mai Province. Annual height increments during 1-10 and 10-20 year-old were 1.22 and

0.66 m, while those of diameter growth were 1.67 and 0.40 cm, respectively. Decreased growth rates during 10-20 year-old were influenced by canopy closure. However, its growth rate may be varied with sites. At Doi Suthep, the annual height and diameter increments of 17 year-old pine were 1.02 m and 1.39 cm, respectively. In natural forest, the height growth at Omkoi district, Chiang Mai, was the best during 20-25 year-old, 1.14 m/yr, whereas the best stem diameter growth was 15-20 year-old, 1.06 cm/yr. Khamyong (2001) concluded that stem girth and height of *P. kesiya* at Doi Boa Luang Plantations, Chiang Mai, were increased with stand age. The growth rates varied among stands. It was very rapid during the first ten year after planning, very slow during 12 and 32 years, and more rapid from the age of 32 to 37. The yield of these plantations at age 7, 10, 12, 18, 21, 28, 32 and 37 years old were 7.25, 53.25, 115.31, 47.06, 298.94, 156.31, 273.81 and 201.94 m^3/ha. Many factors particularly tree density, thinning and nutrient availability are affected on these variations. Decomposition of needles of *P. kesiya* resulted in strong acid of soils. Nildam (2002) studied on timber volume of *P. kesiya* plantations at Phrao Watershed Management Unit, Chiang Mai, at age 9, 12, 15, 18, 21 and 24 years old. They were 120.82, 149.68, 262.99, 218.52, 379.91 and 316.84 m^3/ha, respectively.

Sirikul (1974) carried out a research on environmental factors affecting *P. kesiya* growth in two sites of Thailand, one in the south (Surat Thani) and another in the north (Chiang Mai). The initial height growth in the south was about 70% higher than the north. The site in the south was located at 40 m altitude with high rainfall (1,600-2,000 mm/yr) and fertile soil, while the north site was situated at 800 m altitude with lower rainfall (1,200-1,400 m/yr) and poor soil.

Provenance trial has been taken to select good varieties of this pine. It is found that the best provenance in Thailand was Doi Inthanon, Chiang Mai. The volume increment was 4-9 m^3/ha/yr, and produced 250 m^3/ha in about 28 years at best with the intensive management (Granhof, 1983). Boa Luang provenance had the lower increment volume (1.92-6.00 m^3/ha/yr) (Pousujja, 1984). Silvicultural practices in pine plantation are very important for growth and productivity. Farnum et al. (1983 cited by Nambiar, 1984) compared the productivity of two contrasting types of forests in the USA (*Pseudotsuga menziessi* (douglas fir) in Washington and *P. taeda* (loblolly pine) in the lower coastal plains of North Carolina, and concluded that these plantations increased the productivity by 70 and 300% respectively over natural forests on the same time.

In Thailand, Homjeen (1997) reported that wood production of 10-year-old *P. kesiya* at Doi Boa Luang plantation using 2 x 2 m^2 spacing was 161% higher than 4 x 4 m^2. Intensive plough and weeding in the first three years after planting could increase 157% growth rate of *P. kesiya* (Granhof and Homjeen, 1983). Sakulmeerit and Duangsathaporn (2000) studied the effects of thinning on the growth of *P. kesiya* plantation at Doi Boa Luang plantation in Chiang Mai. They found that width of annual ring was increased 70.3% of unthinned stand.

After 40 years, forest rehabilitation at Khun Khong Watershed Research Station, Chiang Mai province which mainly recover the degraded land by *P. kesiya* shown that the planting stands had no clear aged structure distribution and most planting trees were found in 14.5-24.5 cm DBH class to 24.5-34.5 cm DBH class. The native tree species had established in the lowest class of 4.5-14.5 cm DBH. The rehabilitation of the degraded land through natural watershed recovery period was estimated at least about 84-153 years. (Viranant, *et al.*, 2008).

Plantations can facilitate forest succession in their understory through modification of both physical and biological site conditions. Changes in light, temperature and moisture at the soil surface enable germination and growth of seeds transported to the site by wildlife and other vectors from adjacent forest remnants (Parrotta *et al.*, 1997). Pine plantations in Thailand found on or less succession in understory because silvicultural management in the past aimed to clear cut the deteriorate forests before planting and eliminated understory regeneration to promote the growth of the monospecific plantations. Afterward development tree plantations require only some tree planting and remained local tree species as mother trees to produce seeds, additionally silvicultural management was neglected in order to allow the establishment of high concentrations of native tree species in their understory. Today many pine plantations found a lot of broadleaved tree species succession. Successful implementation of reforestation on highland watershed requires knowledge on the growth dynamics in pine plantations, as well as their age and growth potential and basic ecological features of the native tree species involed. The purpose of this study was to evaluated pine growth, wood production and plant succession in different aged of *Pinus kesiya* plantations in northern Thailand in order to restore highland watershed areas.

Teak (*Tectona grandis* L.f.) is the most important economic tree species in Thailand. It has the normal growth rate. The aim of planting teak is for commercial purpose. However, teak planting in the Doi Tung area is for restore the watershed in the areas below 800 m m.s.l. Some bamboo species are also planted in the teak plantations. The bamboo species can restore the ecosystem and give benefits to local people particulary bamboo shoots and stems. The growths and biomass production of teak were explained in this chapter.

3.2 Materials and Methods

See Chapter 2, section 2.2.1

3.3 Results

The growths and standing biomass of tree species in teak and pine plantation were given. The growths included stem girths and tree heights of teak, pine and sucessional broad-leaved tree species. The biomass amounts of these standing trees in the two plantations were esmimated using the allometric equations.

3.3.1 Growths of Tree Species in Teak and Pine Plantations

A. Teak and successional species

Using five sampling plots, each of size 40×40 m, for vegetation survey in the 22-year-old teak plantation the growths of teak and successional tree species including stem girth and tree height were studied as shown in **Table 3-1**. The tree densities of teak and successional tree species varied greatly with plots. The values were 114, 116, 84, 88 and 237 trees/plot, and the mean value was calculated to be 85.0±48.73 trees/plot. Teak densities varied between 77 and 146 trees/plot, whereas those values of the successional tree species had the greatly variation, 1-91 trees/plot.

The stem girths of the 22-year-old teak varied between 51.73±16.56 and 73.18±20.84 cm with the mean value of 63.87±7.85 cm. The heights of teak varied between 13.39±1.56 and 19.40±3.12 m with the mean value of 16.62±3.12 m. The growths of succesional tree species were given in Appendix A and B.

Some teak seedlings were died after planting since most planted areas had very steep slope. Thus, teak densities were different among plots. The growth rates of teak were identified as intermediate. The teak did not have the straight bole since the seeds used for producing seedlings come from the natural forest, not from the seed production area (good mother trees).

Plant succession by broad-leaved tree species was occurred in each sampling plot, but it was greatly varied among the plots. The total number of successional species was 21 species. The highest density of succesional tree species (12 species) was observed in Plot 1, 91 trees/plot. The tree species having the high abundance were *Lithocarpus glandufolius*, *Cratoxylum formosum* and *Aporosa villosa*. The species richness and tree densities of successional species in the remained plots were 1-8 species and between 1-10 trees/plot. The species list was given in Table 3-4. Their growths were shown in Appendix A and B.

The total number of planted teak was 360,000 trees, and the remained number was found as 306,000 trees. The total tree volume was estimated to 131,580 m^3. Thus, the survival rate was 85%.

B. Pine and successional species

In the past, no pine forest was covered on the Doi Tung area. It is thought that the lower montane forest might cover on areas above 1,000 m m.s.l., and the lower areas were covered by the mixed deciduous forest. The land before the pine platation was almost bare land after forest clearing.

Using ten sampling plots, each of size 40×40 m, for vegetation survey in the 22-year-old pine plantation the growths of pine and successional tree species including stem girth and tree height were studied as shown in **Table 3-2**. The tree densities of pine and successional tree species varied with plots. The values were between 75 and 101

trees/plot with the mean value of 84.0±7.8 trees/plot. The densities of pine varied between 60 and 84 trees/plot. Those values of the successional tree species were in range of 2-26 trees/plot.

The stem girths of the 22-year-old pine varied between 98.30±17.90 and 129.50±18.70 cm with the mean value of 112.29±19.46 cm. The heights of pine varied between 28.0±3.40 and 30.8±1.40 m with the mean value of 28.30±2.50 m. The growths of successional tree species were given in Table 3-14, 3-16, 3-18, 3-20, 3-22, 3-24, 3-26, 3-28 and 3-30.

Standing dead individuals of pine in the plantation were observed since it was the dense stand. Thus, some weak individuals were died caused by light competition and damaged by fungi. Damage by strong wind was also observed in many areas of the pine plantation. The growth rates of pine in Doi Tung area were identified as good. Compare to teak, pine could grow more rapid than teak since it is a fast growing tree species.

The succession in pine plantation by broad-leaved species is proceed to be the climax forest, but it need more ten years until the broad-leaved tree species become the dominant trees in the forest. Plant succession was occurred in each sampling plot as only the initial stage. The total number of successional species was similar to the teak plantation, 24 species. The species richness and tree densities of succesional species in these plots varied between 2-13 species and 2-26 trees/plot. The highest density of succesional tree species (12 species) was observed in Plot 9. The main species were *Diospyros glandulosa, Litsea glutinosa, Lithocarpus glandifolius, Albizia odoratissima, Ficus ribes, Bauhinia variegate, Dalbergia cultrate* and *Vitex pinnata.* The species list of succesional species was given in Table 3-5. Their growths were shown in Appendix A and B.

The total number of planted pine was 640,000 trees, and the remained number was found as 473,600 trees. The total tree volume was estimated to 1,117,696 m^3. Therefore, the survival rate was 74%.

Table 3-1 Tree densities of teak and successional species, and growths of teak in five sampling plots

Plot	Tree density (trees/plot)			Stem GBH	Tree height
no.	Teak	Others	Total	(cm)	(m)
1	146	91	237	51.73±16.56 (32.01)	16.05±8.45 (52.65)
2	78	10	88	66.62±21.65 (32.50)	13.66±2.47 (18.08)
3	77	7	84	65.44±20.21 (30.88)	13.39±1.56 (11.65)
4	115	1	116	73.18±20.84 (28.48)	20.09±2.28 (11.24)
5	110	4	114	62.36±18.11 (29.04)	19.40±3.12 (16.08)
Mean	**85.0**	**23.0**	**128.0**	**63.87**	**16.62**
±S.D	±48.73	±38.0	±63.0	±7.85	±3.12

Note: Coefficient of varience in parenthesis

Table 3-2 Tree densities of pine and successional species, and growths of pine in ten sampling plots

Plot no.	Tree density (trees/plot)			Mean GBH (cm)	Mean tree height (m)
	Teak	Others	Total		
1	83	18	101	98.30±17.90 (18.21)	28.0±3.40 (12.10)
2	76	10	86	107.70±22.10 (20.56)	28.50±2.10 (7.21)
3	84	4	88	101.30±21.00 (20.71)	28.90±1.50 (5.29)
4	83	4	87	99.10±17.30 (17.48)	30.80±1.40 (4.55)
5	62	13	75	128.40±18.20 (14.15)	29.80±3.50 (11.70)
6	75	5	80	118.60±18.10 (15.30)	28.90±2.10 (7.39)
7	79	3	82	109.80±18.40 (16.78)	29.30±1.80 (6.16)
8	74	2	76	129.50±18.70 (14.48)	29.90±3.50 (11.59)
9	62	26	88	122.00±23.10 (18.94)	20.10±2.80 (11.36)
10	60	10	77	108.15±19.84 (18.34)	28.30±2.70 (9.42)
Mean ±S.D	**74.0** ±9.0	**10.0** ±8.0	**84.0** ±8.0	**112.29** ±19.46 (17.35)	**28.30** ±2.50 (8.79)

Note: Coefficient of varience in parenthesis

Table 3-3 A species list of tree species in the 22-year-old teak plantation

Species No.	Thai Name	Scientific Name	Family	Growth Form
1	สัก	*Tectona grandis* L.f.	Labitae	Big tree
2	กางขี้มอด	*Albizia odoratissima* (L.f.) Benth.	Leguminosae	Medium tree
3	เก็ดดำ	*Dalbergia cultrata* Graham ex Benth.	Leguminosae	Big tree
4	เก็ดแดง	*Dalbergia dongnaiensis* Pierre Benth.	Leguminosae	Big tree
5	ก่อหม่น	*Lithocarpus glandifolius* (D.Don)	Fagaceae	Medium tree
6	แคบิด	*Markhamia pierrei* Dop	Bignoniaceae	Medium tree
7	งิ้วป่า	*Bombax anceps* Pierre var. *anceps*	Bombacaceae	Big tree
8	ชมพู่ป่า	*Syzygium aqueum* (Burm.f.) Alston	Myrtaceae	Small tree
9	ตะคร้ำ	*Garuga pinnata* Roxb.	Burseraceae	Big tree
10	ตับเต่าต้น	*Diospyros ehretioides* Wall. ex G. Don	Ebenaceae	Small tree
11	ติ้วขน	*Cratoxylum formosum* (Jack) Dyer	Guttiferae	Small tree
12	ซ้อ	*Gmelina arborea* Roxb.	Labitae	Big tree
13	ปอเลียงฝ้าย	*Eriolaena candollei* Wall.	Sterculiaceae	Medium tree
14	มะกอก	*Spondias pinnata* (L.f.) Kurz	Anacardiaceae	Big tree
15	มะขามป้อม	*Phyllanthus emblica* L.	Euphorbiaceae	Small tree
16	มะเดื่อ	*Ficus hispida* L.f.	Moraceae	Small tree
17	มะแฟน	*Protium serratum* Engl.	Sapindaceae	Medium tree
18	หมีเหม็น	*Litsea glutinosa* (Lour.) C.B.Roxb.	Lauraceae	Medium tree
19	หาด	*Artocarpus gomezianus* Wall. ex Trecul	Moraceae	Medium tree
20	หว้า	*Syzygium cumini* (L.) Skeels	Myrtaceae	Medium tree
21	เหมือดหลวง	*Aporosa villosa* (Wall. ex Lindl.) Baill.	Euphorbiaceae	Small tree

Figure 3-1 Overall views of 22-year-old teak plantation (above), and 22-year-old pine plantation (below)

Table 3-4 A species list of tree species in the 22-year-old pine plantation

Species No.	Thai Name	Scientific Name	Family	Growth Form
1	สนสามใบ	*Pinus kesiya* Royle ex Gordon	Pinaceae	Big tree
2	กล้วยฤาษี	*Diospyros glanduolsa* Lace	Ebenaceae	Medium tree
3	กางขี้มอด	*Albizia odoratissima* (L.f.) Benth.	Leguminosae	Medium tree
4	เก็ดดำ	*Dalbergia cultrata* Graham ex Benth.	Leguminosae	Big tree
5	ก่อหม่น	*Lithocarpus glandifolius* (D.Don)	Fagaceae	Medium tree
6	แคบิด	*Markhamia pierrei* Dop	Bignoniaceae	Medium tree
7	เดื่อน็อต	*Ficus ribes* Reinw. ex Blume	Moraceae	Small tree
8	ตะคร้ำ	*Garuga pinnata* Roxb.	Burseraceae	Big tree
9	ตะแบก	*Lagerstroemia duperreana* Pierre ex	Lythraceae	Big tree
10	โมกมัน	*Wrightia arborea* (Dennst.) Mabb.	Apocynaceae	Small tree
11	ติ้วขน	*Cratoxylum formosum* (Jack) Dyer	Guttiferae	Small tree
12	ตีนนก	*Vitex pinnata* L.	Labitae	Big tree
13	ซ้อ	*Gmelina arborea* Roxb.	Labitae	Big tree
14	รักใหญ่	*Gluta usitata* (Wall.) Ding Hou	Anacardiaceae	Big tree
15	มะม่วงป่า	*Mangifera indica* L.	Anacardiaceae	Big tree
16	มะแฟน	*Protium serratum* Engl.	Sapindaceae	Medium tree
17	หมีเหม็น	*Litsea glutinosa* (Lour.) C.B.Roxb.	Lauraceae	Medium tree
18	ทะโล้	*Schima wallichii* (DC.) Korth	Theaceae	Big tree
19	ปอเต๊า	*Macaranga denticulata* (Blume)	Sterculiaceae	Big tree
20	ปอสำโรง	*Sterculia foetida* L.	Sterculiaceae	Big tree
21	ประดู่	*Pterocarpus macrocarpus* Willd.	Leguminosae	Big tree
22	เสี้ยวดอกขาว	*Bauhinia variegata* L.	Leguminosae	Small tree
23	สักขี้ไก่	*Premma tomentosa* Wild.	Labitae	Medium tree
24	เหมือดหลวง	*Aporosa villosa* (Wall. ex Lindl.) Baill.	Euphorbiaceae	Small tree

3.3.2 Standing Biomass of Teak and Pine in Plantations

The biomass amounts of standing trees of in teak and pine plantations were estimated as following results.

A. Teak and successional species

The total amounts of standing biomass of teak and succesional tree species in five sampling plots of the 22-year-old teak plantation were calculated using allometric equations. As shown in Table 3-5, the values varied greatly between 27.06 and 68.42 Mg plot^{-1} with the mean value of **42.24±0.65** Mg plot^{-1} (**264.0±103.42** Mg ha^{-1}). The biomass amounts of teak in these plots were 15.68, 25.60, 27.77, 47.38 and 68.15 Mg plot^{-1} (mean value = 36.92±20.90 Mg plot^{-1}), whereas those of the succesional tree species were 0.27, 0.83, 1.46, 5.84 and 18.23 Mg plot^{-1} (mean value = 5.33±36.92 Mg plot^{-1}).

The contribution of teak biomass to the plantation ecosystem in the five sampling plots varied between 46.25% and 99.61%. The remained values were those of the successional tree species.

B. Pine and successional species

The total amounts of standing biomass of pine and succesional tree species in ten sampling plots of the 22-year-old pine plantation were calculated using allometric equations. The values varied between 49.32 and 71.25 Mg plot^{-1} with the mean value of **64.59±9.41** Mg plot^{-1} (**403.70±58.80** Mg ha^{-1}). The biomass amounts of pine tree in these plots varied in a range of 46.26-82.22 Mg plot^{-1} (mean value = 62.14±3.05 Mg plot^{-1}), whereas those of the succesional tree species varied between 0.36 and 4.98 Mg plot^{-1} (mean value = 3.05±2.21 Mg plot^{-1}).

The contribution of pine biomass to the plantation ecosystem in the ten sampling plots varied between 92.79% and 99.43%. The remained values were those of the successional tree species. The biomass productions of successional tree species in these plots were relatively small because these broad-leaved trees were still small. Thus, it is thought that plant succession in the pine plantation is at the initial stage. The standing biomass production of pine plantation was higher than teak plantation since the growth rate of pine was more rapid than teak.

Table 3-5 Standing biomass allocated in various organs of teak and tree species in five sampling plots

Plot No.	**Tree species**	**Plant biomass** (kg/plot)					
		Stem	Branch	Leaf	Root	Total	%
1	**Teak**	10,505.81	3,173.22	909.43	1,094.71	15,683.17	46.25
	Successional species						
	1. *C. formosum*	5,034.77	1,526.08	133.98	1,062.23	7,757.05	22.88
	2. *A. villosa*	3,885.34	1,133.63	122.46	884.76	6,026.19	17.77
	3. *E. candollei*	947.19	309.06	17.96	172.03	1,446.25	4.27
	4. *L. glandifolius*	854.75	238.14	32.89	213.16	1,338.94	3.95
	5. *P. serratum*	476.54	148.89	10.89	94.25	730.58	2.15
	6. *A. gomezianus*	295.53	89.59	7.69	62.02	454.83	1.34
	7. *F. hispida*	112.71	30.83	4.58	28.97	177.09	0.52
	8. *L. glutinosa*	81.26	21.76	3.62	21.78	128.42	0.38
	9. *M. pierrei*	30.18	7.77	1.62	8.77	48.34	0.14
	10. *D. cultrata*	29.54	7.43	1.72	8.94	47.64	0.14
	11. *A. odoratissima*	16.92	4.28	0.96	5.06	27.22	0.08
	12. *D. ehretioides*	13.73	3.43	0.82	4.22	22.20	0.07
	13. *S. aqueum*	11.31	2.79	0.72	3.56	18.38	0.05
	Sum (excluding teak)	11,789.77	3,523.70	339.91	2,569.75	18,223.13	53.75
	Total	22,295.58	6,696.91	1,249.34	3,664.46	33,906.30	100
2	**Teak**	18,683.30	5,620.76	1,572.02	1,897.04	27,773.12	82.64
	Successional species						
	1. *D. dongnaiensis*	1,227.08	389.57	26.18	235.19	1,878.03	5.59
	2. *G. arboreas*	970.97	303.81	22.07	191.52	1,488.37	4.43
	3. *S. pinnata*	586.80	185.77	12.68	113.10	898.35	2.67
	4. *P. emblica*	514.75	155.43	13.72	109.05	792.95	2.36
	5. *C. formosum*	320.15	97.55	8.15	66.52	492.37	1.46
	6. *B. anceps*	113.89	32.51	3.84	26.90	177.15	0.53
	7. *M. pierrei*	69.42	19.21	2.68	17.44	108.74	0.32
	Sum (excluding teak)	3,803.06	1,183.84	89.32	759.73	5,835.95	17.36
	Total	22,486.36	6,804.60	1,661.34	2,656.77	33,609.08	100

Table 3-5 (Continued)

Plot No.	Tree species	Plant biomass (kg/plot)					
		Stem	Branch	Leaf	Root	Total	%
3	**Teak**	17,176.85	5,182.96	1,471.67	1,773.50	25,604.97	94.63
	Successional species						
	1. *C. formosum*	442.80	133.13	12.09	94.74	682.76	2.52
	2. *D. dongnaiensis*	408.60	118.00	13.12	94.35	634.06	2.34
	3. *P. emblica*	73.84	20.51	2.80	18.41	115.56	0.43
	4. *S. cumini*	13.62	3.40	0.82	4.19	22.03	0.08
	Sum (excluding teak)	938.86	275.04	28.83	211.68	1,454.41	5.37
	Total	18,115.71	5,457.99	1,500.50	1,985.18	27,059.38	100
4	**Teak**	46,589.65	13,758.43	3,518.11	4,279.13	68,145.33	99.61
	Successional species						
	1. *G. pinnata*	174.33	51.12	5.24	39.06	269.75	0.39
	Sum (excluding teak)	174.33	51.12	5.24	39.06	269.75	0.39
	Total	46,763.98	13,809.55	3,523.35	4,318.19	68,415.07	100
5	**Teak**	32,049.10	9,582.37	2,599.11	3,145.13	47,375.72	98.26
	Successional species						
	1. *C. formosum*	293.18	83.64	10.02	69.50	456.33	0.95
	2. *D. dongnaiensis*	246.64	73.93	6.74	52.93	380.25	0.79
	Sum (excluding teak)	539.82	157.56	16.76	122.44	836.58	1.74
	Total	32,588.92	9,739.93	2,615.88	3,267.57	48,212.30	100
Mean (kg rai^{-1})		28,450.11	8,501.80	2,110.08	3,178.43	42,240.43	
± S.D.		11,540.93	3,358.13	944.32	899.89	16,546.88	

Table 3-6 Standing biomass allocated in various organs of pine and tree species in ten sampling plots

Plot no.	Tree species	Plant biomass (kg/plot)					
		Stem	**Branch**	**Leaf**	**Root**	**Total**	**%**
1	**Pine**	33,635.05	7,981.87	1,385.32	9,904.41	52,906.65	94.70
	Successional species						
	1. *L. glutinosa*	807.64	238.24	47.16	179.43	1,272.46	2.28
	2. *D. glandulosa*	798.36	237.44	45.58	174.27	1,255.66	2.25
	3. *G. usitata*	200.20	56.71	12.87	48.01	317.79	0.57
	4. *F. ribes*	70.29	19.46	4.78	17.63	112.15	0.20
	Sum (excluding pine)	1,876.48	551.86	110.39	419.34	2,958.06	5.30
	Total	35,511.53	8,533.72	1,495.71	10,323.75	55,864.71	100.0
2	**Pine**	37,185.42	9,265.60	1,529.80	10,776.90	58,757.73	93.76
	Successional species						
	1. *L. glandifolius*	1,011.29	310.34	53.38	207.46	1,582.46	2.53
	2. *A. odoratissima*	469.29	146.49	23.70	92.99	732.48	1.17
	3. *W. tomentosa*	435.68	132.56	23.63	91.26	683.12	1.09
	4. *D. glandulosa*	372.88	112.71	20.57	79.14	585.29	0.93
	5. *G. pinnata*	122.06	35.00	7.61	28.59	193.26	0.31
	6. *F. ribes*	85.18	23.87	5.62	20.86	135.53	0.22
	Sum (excluding pine)	2,496.38	760.95	134.51	520.29	3,912.14	6.24
	Total	39,681.81	10,026.56	1,664.31	11,297.19	62,669.86	100.0

Table 3-6 (Continued)

Plot no.	Tree species	Plant biomass (kg/plot)					
		Stem	**Branch**	**Leaf**	**Root**	**Total**	**%**
3	**Pine**	37,260.59	9,067.86	1,533.76	10,884.88	58,747.09	98.99
	Successional species						
	1. *A. odoratissima*	262.27	78.91	14.51	55.86	411.55	0.69
	2. *M. indica*	72.59	19.28	5.47	19.75	117.09	0.20
	3. *D.cultrata*	44.65	12.01	3.26	11.85	71.77	0.12
	Sum (excluding pine)	379.50	110.21	23.24	87.46	600.41	1.01
	Total	37,640.09	9,178.07	1,557.01	10,972.34	59,347.50	100.0
4	**Pine**	37,380.13	9,055.01	1,538.79	10,928.64	58,902.57	97.16
	Successional species						
	1. *B. variegata*	647.82	198.26	34.42	133.61	1,014.12	1.67
	2. *A. odoratissima*	395.97	122.28	20.54	80.14	618.93	1.02
	3. *L. glandifolius*	56.56	15.45	3.98	14.57	90.56	0.15
	Sum (excluding pine)	1,100.36	335.99	58.94	228.32	1,723.61	2.84
	Total	38,480.48	9,391.00	1,597.73	11,156.96	60,626.18	100.0
5	**Pine**	41,965.38	11,237.95	1,723.47	11,870.19	66,796.99	95.35
	Successional species						
	1. *F. ribes*	377.37	111.21	21.98	83.73	594.30	0.85
	2. *L. durperreanum*	320.15	97.55	17.17	66.52	501.38	0.72
	3. *A. villosa*	304.78	92.58	16.47	63.72	477.54	0.68
	4. *D. cultrata*	279.47	80.88	17.04	64.28	441.66	0.63
	5. *A. odoratissima*	246.48	73.87	13.77	52.90	387.02	0.55
	6. *Fcus* sp.	196.99	55.72	12.71	47.38	312.80	0.45
	7. *D. glandulosa*	126.43	36.33	7.84	29.48	200.08	0.29
	8. *S. wallichii*	84.31	23.61	5.57	20.67	134.17	0.19
	9. *G. pinnata*	68.93	19.06	4.70	17.33	110.02	0.16
	10. *P. serratum*	63.32	17.42	4.38	16.09	101.19	0.14
	Sum (excluding pine)	2,068.22	608.23	121.63	462.09	3,260.17	4.65
	Total	44,033.60	11,846.18	1,845.10	12,332.27	70,057.16	100.0
6	**Pine**	43,281.64	11,157.92	1,779.14	12,398.87	68,617.57	96.31
	Successional species						
	1. *A. odoratissima*	965.70	302.01	48.55	190.66	1,506.92	2.11
	2. *M. dentriculata*	439.44	136.60	22.43	87.79	686.26	0.96
	3. *F. ribes*	178.78	52.51	10.50	39.93	281.72	0.40
	4. *D. glandulosa*	99.29	28.10	6.40	23.86	157.64	0.22
	Sum (excluding pine)	1,683.21	519.22	87.87	342.24	2,632.54	3.69
	Total	44,964.85	11,677.14	1,867.01	12,741.10	71,250.11	100.0
7	**Pine**	40,535.31	10,162.89	1,667.34	11,719.58	64,085.12	99.43
	Successional species						
	1. *P. serratum*	87.08	24.44	5.73	21.27	138.52	0.21
	2. *P. macrocarpus*	76.89	21.41	5.16	19.07	122.52	0.19
	3. *F. ribes*	66.39	18.32	4.55	16.77	106.03	0.16
	Sum (excluding pine)	230.36	64.17	15.44	57.10	367.06	0.57
	Total	40,765.67	10,227.06	1,682.78	11,776.68	64,452.18	100.0
8	**Pine**	51,534.99	13,920.96	2,116.06	14,536.30	82,108.31	98.72
	Successional species						
	1. *F. ribes*	345.11	105.66	18.29	71.04	540.11	0.65
	2. *G. usitata*	334.53	102.21	17.82	69.13	523.69	0.63
	Sum (excluding pine)	679.64	207.87	36.11	140.18	1,063.79	1.28
	Total	52,214.63	14,128.83	2,152.17	14,676.47	83,172.10	100.0

Table 3-6 (Continued)

Plot no.	Tree species	Plant biomass (kg/plot)					
		Stem	**Branch**	**Leaf**	**Root**	**Total**	**%**
9	**Pine**	40,315.33	10,789.76	1,655.80	11,414.72	64,175.62	92.79
	Successional species						
	1. *B. variegata*	900.06	255.61	57.75	215.46	1,428.88	2.07
	2. *D. gladulosa*	597.94	189.52	29.08	114.98	931.51	1.35
	3. *L. duperreanum*	597.94	189.52	29.08	114.98	931.51	1.35
	4. *P. tomentosa*	313.47	89.11	19.98	74.68	497.24	0.72
	5. *G. arborea*	234.83	67.60	14.54	54.67	371.65	0.54
	6. *D. cultrate*	191.08	53.61	12.65	46.87	304.20	0.44
	7. *F. ribes*	121.36	34.78	7.58	28.44	192.16	0.28
	8. *Ficus* sp.	83.88	23.49	5.55	20.58	133.49	0.19
	9. *A. odoratissima*	58.70	16.07	4.11	15.05	93.93	0.14
	10. *C. pruniflorum*	36.97	9.83	2.78	10.04	59.63	0.09
	11. *S. wallichii*	15.88	4.00	1.36	4.79	26.04	0.04
	12. *M. pierrei*	8.52	2.07	0.81	2.78	14.17	0.02
	Sum (excluding pine)	3,160.64	935.20	185.26	703.32	4,984.42	7.21
	Total	43,475.97	11,724.97	1,841.06	12,118.04	69,160.03	100.0
10	**Pine**	29,284.44	7,271.40	1,204.84	8,494.34	46,255.02	93.78
	Successional species						
	1. *G. arborea*	1,044.86	328.60	51.82	204.07	1,629.35	3.30
	2. *D. cultrata*	432.25	134.23	22.11	86.53	675.12	1.37
	3. *A. odoratissima*	205.20	58.25	13.13	49.02	325.59	0.66
	4. *L.gutinosa*	102.30	27.75	7.39	26.87	164.31	0.33
	5. *G. usitata*	71.52	19.83	4.85	17.90	114.10	0.23
	6. *M. pierrei*	32.73	8.45	2.67	9.47	53.32	0.11
	7. *Sterculia* sp.	26.95	7.02	2.13	7.61	43.71	0.09
	8. *V. pinnata*	18.33	4.30	1.88	6.38	30.89	0.06
	9. *S. wallichii*	18.11	4.60	1.52	5.37	29.61	0.06
	Sum (excluding pine)	1,952.25	593.03	107.50	413.22	3,066.00	6.22
	Total	31,236.69	7,864.43	1,312.34	8,907.56	49,321.02	100.0
Mean (kg/plot)		**40,800.53**	**10,459.80**	**1,701.52**	**11,630.24**	**64,592.09**	
Standard deviation		5,785.98	1,883.82	235.18	1,533.10	9,408.04	

3.4 Discussion

The mean stem girths at breast height (gbh) and heights of teak in the 22-year-old plantation at the Doi Tung area were measured to 63.87±7.85 cm and 16.62±3.12 m, respectively. The growth rate of teak in this area was identified as intermediate. This area was not the poor and good sites of teak plantation. The teak plantations at the Doi Tung areas underlain by granite rock with very steep slope, and the growths varied greatly with different topographic conditions. Silvicultural Division, Royal Forest Department (1993) described that in the intermediate site of teak plantation, the growths of teak in the 22-year-old stand were 57.06 cm of gbh and 16.94 m in height. In the good site, their growths were 78.79 cm of gbh and 28.92 m in height. However, the objective of teak plantation at the Doi Tung areas is for the ecological restoration, but not for the economic purpose. The growth rate of teak may be less important. In general, the good site of teak is usually found on limestone area with the high enough rainfall.

The growths of pine in the 22-year-old pine plantation at Doi Tung areas were better than other sites as compared to those data observed at Hot district (Khamyong, 2001) and Samoeng district (Pornleesangsuwan *et al*., 2012), Chiang Mai province. In this study area, the mean stem girth and height of pine were 112.29±19.46 cm and 28.3±2.5 m, respectively, whereas those at Hot and Samoeng districts were in the following order: 80.32 cm, 18.24 m, and 82.80 cm, 21.20 m. The pine plantation at Doi Tung area had been established for restoration the devastated highland watershed, not for the commercial purpose. It is thought that the highland watershed might be covered by the lower montane forest, not the pine-lower montane forest. Thus, the moisture condition might be high, and therefore the growths of this pine were more rapid than other areas. However, the high moisture condition of the site is thought to affect on the root system of pine. At the present, the pine is easily damaged by strong wind, and many individuals are fallen down. In the pine forest, the soil is usually compacted and dry, and thus it is difficult to fallen down. In Doi Tung area, the soil is deep and loose which does not have the strong support to root system of this pine.

In forest plantations, plant succession may proceed, and the stands can be developed to reach the climax stage. Khamyong (2001) reported that plant succession is poor in 7-37 years old pine plantations at Hot district which had been covered by the pine-dry dipterocarp forest. The poor succession caused by weeding in the plantations which was the old silvicultural practice employed by the Royal Forest Department in the past. In some plantations, all individuals of other broad-leaved tree species were removed to stimulate the pine growths. However, the succession by broad-leaved species including oaks and some dipterocarp species were observed in some plots which had the long distance from the Watershed Development Station. Pornleesangsuwan *et al.* (2012) found that plant succession in the pine plantations at Samoeng district consisted of 72 broad-leaved tree species which also existed in the nearby fragmented lower montane forests.