CHAPTER 3

Growths and Productions of Para Rubber in Two-series Plantations

3.1 Introduction

Para rubber plantation is similar to the forest plantation. The planted rubber will grow up from seeding to small and mature trees. Many factors have influenced on the growth including planting space, fertilizer, soil erosion and nutrient recycling through litterfall. Normally, planting space is 3 x 7 meters that having enough space for the growth. The rubber may grow rapidly in early stage and become decrease as the canopy closure and light competition is begun. Management of rubber plantation by the farmer is the important factor. In the young plantations of 1-3 years old, the farmer can grow some agricultural crops such as pineapple between the rows of rubber trees. This can reduce soil erosion and loss of nutrients in the rubber plantations. The farmer cannot grow crop in the older plantations because the canopy shade is become a limiting factor. However, the rubber canopy can intercept rainfall and reduce soil erosion. The manure is usually applied between the rows of rubber trees to increase soil ferlility and nutrients. Some farmers may apply chemical fertilizer to rubber plantations. Therefore, fertilizer is important for the plantation growth, Morever, litterfall of rubber trees may be increased with the stand age, and it is the important pathway of nutrient recycling to soil, and can maintain soil fertility as well as plantation growth. The litter decomposition releases some nutrients into the soil. Khamyong and Seramethakul (2006) reported that leaf litter of the para rubber had pH = 5.7, and contained 49% carbon, 1.31% nitrogen, C/N raio of 37.5, 0.08% phosphorus, 1.38% potassium, 3.92% calcium and 0.32% magnesium.

The original forest and soil type are important that have relation to different growth and production of rubber plantations. Phon Phisai soil series is usually covered by the dry dipterocarp forest (DDF) whereas Chakkarat soil series is found under the dry evergreen forest (DEF). Clearing of these forests to grow rubber in plantations may affect on the rubber growth and production since these forests have different patterns of soil moisture and nutrient availability.

Development of northeastern region as part of the country's rubber production source will need a study on environmental affect on growth pattern in different areas of the region, especially rainwater, humidity, soil characteristic and rock formation. Different soil qualities have strong affect to the debt of water drainable, physical, chemical and biological properties (Bowen & Nambiar, 1989; Fisher & Binkley, 2000). It will also influence the amount of carbon stock stored in different age group of rubber trees hence will affect the environmental role of rubber plantation and will be an important data for better management at relevant organizations.

The northeastern region of Thailand has agricultural area of 15.90 million ha, of which 6.65 million ha are suitable for rubber plantation. However, only 3.09 million ha, have yield more than 1,562 kilogram per ha per year and currently 0.45 million ha are being used for rubber plantation. The remaining 2.65 million ha, an area equal of total

area being for rubber production today, is still available for additional rubber production. Hence, northeastern region of Thailand will be an important rubber production source for Thailand in the future.

Nong Khai province has the rubber plantation area of 724,590 ha with the suitable areas suitable of 340,606 ha. It is also the province in the region which most areas are used for the rubber plantation, 102,051 ha, and also has the remaining potential land use of 238,3994 ha. Moreover, it is the province which had the pioneer pilot plantation project of the Rubber Research Institute of Thailand (RRIT) in 1978, and had many trial plantations with age between 1 to 20 years old. Investigation of the Land Development Department found that most soil type in the area is Phon Phisai soil series, covering 153,410 ha. The second order was Chakkarat soil series. Studies on the growth pattern, bio-productivity, and carbon stock potential of rubber plantations on these two soils are interesting works, and will provide important data for improving management and encouraging appropriate rubber plantation to give the high yields and rehabilitate the environment.

3.2 Results

3.2.1 Rubber Growths

A. Phon Phisai Soil Series

Growths of rubber trees (RRIM600 clone) consisted of the stem girth, tree height and crown width which were different with the stand age.

Table 3-1 (**Figure 3-1**) shows the growths of rubber trees in each age class plantation. It was found that the density of the rubber tree varied a little. The average densities in 1, 5, 10, 15 and 20 years old plantations were 75, 75, 75, 73 and 86 trees/rai (468, 468, 468, 456 and 537 trees/ha), respectively. The average stem girths of the rubber increased with the plantation age: 8.23, 29.42, 36.76, 53.54 and 54.45 cm, respectively. The average tree heights were 6.49, 8.83, 11.98, 15.41 and 14.46 m and had the crown width in the order: 2.63, 4.79, 5.27, 6.36 and 5.68 cm.

According to recommendations of the Rubber Research Institute of Thailand, Department of Agriculture, it was found that the 5 years old plantations do not have rubber trees with the stem girth bigger than 50 cm, which is the appropriate size for opening tapping. Only 1.69% of the 10 years old rubber trees had the stem girth bigger than 50 cm. The percentages were increased to 65.88% and 67.45% for the 15 and 20 years old plantations, respectively.

For the standard of rubber wood purchases, it was found that the rubber trees in the 10 years old plantation had stem diameters of 6 inches (15.24 cm) or more only 5.91%. The figures were increased to 53.31% and 56.86% for the 15 and 20 years old plantations, respectively.

Compared to the rubber plantations (RRIM600 clone) in the southern region, the growths of rubber trees including stem girth, tree height and crown width were lower. These caused by the lower soil fertility in the northeastern region.

B. Chakkarat Soil Series

Table 3-2 (**Figure 3-2**) shows rubber growths in the five age class plantations. The tree densities varied between 75-80 trees/rai (468-500 trees/ha). The growths were increased with the plantation age. The mean stem girths in 1 , 5, 10, 15 and 20 years old plantations were 15.61, 34.88, 51.67, 56.83 and 73.18 cm, respectively. The tree heights were 5.56, 9.61, 11.98, 22.50 and 23.95 m, respectively, and their crown widths were in the order: 2.46, 5.58, 6.19, 5.92 and 6.90 m.

The growths either stem or tree heights of the rubber trees on Chakkarat soil were more rapid than those on Phon Phisai soil. It is thought that the soil fertility was not the factor that resulted in the different growths between two soils because both soils had the low fertility. The Phon Phisai soils contained many rocks in the profiles and had poor water drainage whereas the Chakkarat soils had the deep sandy texture that allowed better root penetration and water drainage. However, the growth rates were still slower than the plantations in the South due to the lower soil fertility.

Table 3-1 Rubber growth and biomass in different age plantations on Phon Phisai soil series

Plantation age (years)	Plot No.	Density (trees/rai)	GBH (cm)	Height (m)	Crown width (m)
1	1	76	8.86 ± 1.97	6.57 ± 0.83	2.68 ± 0.19
	2	76	7.69 ± 1.56	6.53 ± 0.69	2.63 ± 0.19
	3	73	8.13 ± 2.22	6.36 ± 0.70	2.58 ± 0.23
	Mean	**75**	**8.23 ± 1.99**	**6.49 ± 0.75**	**2.63 ± 0.21**
5	1	75	31.92 ± 4.86	8.86 ± 0.30	5.07 ± 0.77
	2	75	30.86 ± 5.33	8.84 ± 0.39	5.21 ± 0.79
	3	75	25.50 ± 5.39	8.78 ± 0.41	4.09 ± 0.81
	Mean	**75**	**29.42± 5.89**	**8.83 ± 0.37**	**4.79 ± 0.93**
10	1	76	34.79 ± 9.12	12.04 ± 1.45	4.77 ± 0.61
	2	76	34.60 ± 6.66	12.03 ± 1.26	5.17 ± 0.77
	3	74	40.96 ± 7.23	11.87 ± 1.17	5.90 ± 0.63
	Mean	**75**	**36.76 ± 8.26**	**11.98 ± 1.30**	**5.27 ± 0.82**
15	1	80	50.92 ± 10.63	15.34 ± 0.93	5.91 ± 1.63
	2	68	52.23 ± 11.77	15.34 ± 0.66	6.57 ± 1.54
	3	70	57.67 ± 11.25	15.55 ± 0.61	7.16 ± 1.58
	Mean	**73**	**53.54 ± 11.54**	**15.41 ± 0.76**	**6.36 ± 1.64**
20	1	86	54.90 ± 11.20	15.07 ± 1.58	5.71 ± 1.36
	2	87	53.05 ± 8.89	14.22 ± 1.18	5.66 ± 1.37
	3	85	55.44 ± 10.65	14.08 ± 1.14	5.68 ± 1.45
	Mean	**86**	**54.45 ± 10.30**	**14.46 ± 1.38**	**5.68 ± 1.39**

Table 3-2 Growth and biomass of rubber in different age plantations on Chakkarat soils

Plantation age (years)	Plot No.	Density (trees/rai)	GBH (cm)	Height (m)	Crown width (m)
1	1	76	15.24 ± 1.28	5.93 ± 1.54	2.49 ± 0.32
	2	76	16.04 ± 3.58	6.14 ± 0.57	2.50 ± 0.39
	3	76	15.54 ± 1.32	4.93 ± 1.96	2.39 ± 0.28
	Mean	**76**	**15.61 ± 2.33**	**5.56 ± 1.55**	**2.46 ± 0.34**
5	1	76	35.55 ± 5.09	9.85 ± 0.92	5.63 ± 0.48
	2	76	35.37 ± 6.24	9.47 ± 1.33	5.40 ± 0.64
	3	76	33.71 ± 6.02	9.51 ± 1.04	5.72 ± 0.72
	Mean	**76**	**34.88± 5.84**	**9.61 ± 1.12**	**5.58 ± 0.64**
10	1	76	50.18 ± 9.57	16.07 ± 0.83	6.11 ± 0.67
	2	76	52.97 ± 9.18	15.95 ± 1.03	6.26 ± 0.71
	3	76	51.87 ± 9.72	16.11 ± 0.65	6.21 ± 0.97
	Mean	**76**	**51.67 ± 9.52**	**11.98 ± 0.85**	**6.19 ± 0.79**
15	1	80	57.23 ± 10.19	21.64 ± 2.60	5.74 ± 0.88
	2	80	56.35 ± 10.09	23.15 ± 2.25	6.02 ± 0.79
	3	80	56.91 ± 11.40	23.04 ± 4.05	5.99 ± 0.93
	Mean	**80**	**56.83 ± 10.55**	**22.50 ± 3.13**	**5.92 ± 0.87**
20	1	75	75.45 ± 18.59	24.19 ± 2.31	7.30 ± 1.23
	2	75	72.94 ± 17.80	23.69 ± 2.57	7.03 ± 1.45
	3	75	71.50 ± 18.15	24.01 ± 2.93	6.42 ± 1.38
	Mean	**75**	**73.18 ± 18.18**	**23.95 ± 2.63**	**6.90 ± 1.41**

3.2.2 Biological Productions of Rubber Trees

(1) Phon Phisai Soil Series

Table 3-3 shows the biomass of stem, branch, leaf and root components of 5, 1-5 years old sample rubber trees which were cut by the stratified clip technique for Phon Phisai soil series (**Figure 3-3**). The data were used to make allometric equations for the rubber plantations **(Figure 3-4)** as follow:

$$Ws = 0.042 \times^{0.888} \quad , r^2 = 0.996$$
$$Wb = 0.001 \times^{1.370} \quad , r^2 = 0.961$$
$$Wl = 0.052 \times^{0.602} \quad , r^2 = 0.765$$
$$Wr = 0.044 \times^{0.826} \quad , r^2 = 0.993$$

In **Table 3-5**, the average amounts of rubber biomass in 1, 5, 10, 15 and 20 years old plantations were calculated to 3.08, 39.79, 85.31, 243.95 and 231.74 kg per tree respectively. The average biomass amounts per area of 1, 5, 10, 15 and 20 years old plantations were 1.50, 17.66, 42.07, 122.64 and 123.07 Mg/ha, respectively.

The one year old plantation had average biomass of 240.72 kg/rai (1.50 Mg/ha), divided into stem, branch, leaf and root components of 100.48, 16.52, 40.38 and 83.34 kg/rai (41.74, 6.86, 16.77 and 34.62%), respectively. In the 5 years old plantation, the average biomass was 2,825.32 kg/rai (17.66 Mg/ha), separated to stem, branch, leaf and root components of 1125.51, 704.53, 203.35 and 791.94 kg/rai

(39.84, 24.94, 7.2 and 28.03%), respectively. For the 10 years old plantation, the average biomass was 6,731.78 kg/rai (42.07 Mg/ha), partitioned into stem, branch, leaf and root components of 2453.74, 2273.92, 355.39 and 1,648.72 kg/rai (36.45, 33.78, 5.28 and 24.49%), respectively. In the 15 years old plantation, the average biomass was 19,622.85 kg/rai (122.64 Mg/ha), composed of stem, branch, leaf and root biomass in the order: 6096.49, 8997.37, 664.62 and 3,864.38 kg/rai (31.07, 45.85, 3.39 and 19.69%). For the 20 years old plantation, the average biomass was 19,691.91 kg/rai (123.07 Mg/ha), including the stem, branch, leaf and root biomass in the order: 6200.04, 8862.89, 685.98 and 3,943.0 kg/rai (31.49, 45.01, 3.48 and 20.02%).

The biomass of rubber trees increased with plantation age. The rate was very fast from 1 to 15 years old, and slow down during 15 to 20 years old. The stem biomass percentages in 1 to 20 years old plantations varied between 31.07 and 41.74. The values were decreased with plantation age. The percentages in branch component were adversely increased with plantation age, 6.86 to 45.01/45.85. For the leaf component, the percentages were declined with the age, 16.77 to 3.39/3.48. The root component percentages were similar to the stem and leaf that decreasing with the age, 34.62 to 19.69/20.02. For the older plantations of 15 and 20 years old, the biomass allocation in branch component was become higher than the stem, and low for the leaf. It is indicated that the mature rubber trees on Phon Phisai soil had too many branches.

(2) Chakkarat Soil Series

Table 3-4 shows the biomass of stem, branch, leaf and root components of 5, 1-5 years old sampling rubber trees which were cut by the stratified clip technique for Chakkarat soil series. The data were used to make allometric equations for the rubber plantations (**Figure 3-5**).

$$Ws = 0.049 \times^{0.888} \quad , r^2 = 0.991$$
$$Wb = 0.002 \times^{1.231} \quad , r^2 = 0.917$$
$$Wl = 0.051 \times^{0.584} \quad , r^2 = 0.857$$
$$Wr = 0.022 \times^{0.826} \quad , r^2 = 0.945$$

In **Table 3-6**, the mean rubber biomass in 1 , 5, 10, 15 and 20 years old were calculated as 3.75, 27.07, 100.46, 184.97 and 406.13 Mg/ha (7.50, 54.14, 192.14, 325.22 and 598.20 kg/tree), respectively.

The one year old plantation had average biomass of 599.83 kg/rai (3.75 Mg/ha), divided into stem, branch, leaf and root components of 303.76, 74.20, 71.76 and 150.11 kg/rai (50.64, 12.37, 11.96 and 25.03%), respectively. In the 5 years old plantation, the average biomass was 4,330.85 kg/rai (27.07 Mg/ha), separated to stem, branch, leaf and root components of 2018.28, 1020.09, 254.46 and 1038.02 kg/rai (46.60, 23.55, 5.88 and 23.97%), respectively. For the 10 years old plantation, the average biomass was 16072.83 kg/rai (100.46 Mg/ha), partitioned into stem, branch, leaf and root components of 6658.19, 5334.24, 569.64 and 3510.77 kg/rai (41.43, 33.19, 3.54 and 21.84%), respectively. In the 15 years old plantation, the average biomass was 29,595.13 kg/rai (184.97 Mg/ha), composed of stem, branch, leaf and

root biomass in the order: 11510.34, 11112.03, 842.11 and 6,130.65 kg/rai (38.89, 37.55, 2.85 and 20.72%). For the 20 years old plantation, the average biomass was 64,980.33 kg/rai (406.13 Mg/ha), including the stem, branch, leaf and root biomass in the order: 23133.85, 27966.94, 1,409.49 and 12,470.04 kg/rai (35.60, 43.04, 2.17 and 19.19%).

The biomass storages of rubber trees on Chakkarat soil were higher than those on Phon Phisai soil. The 1 to 20 years old plantations on Phon Phisai soils had the biomass storages between 1.50 and 123.07 Mg/ha, while the plantations on Chakkarat soil had 3.75-406.13 Mg/ha. As already mentioned, the difference in soil physical properties might affect on the growths and biomass production.

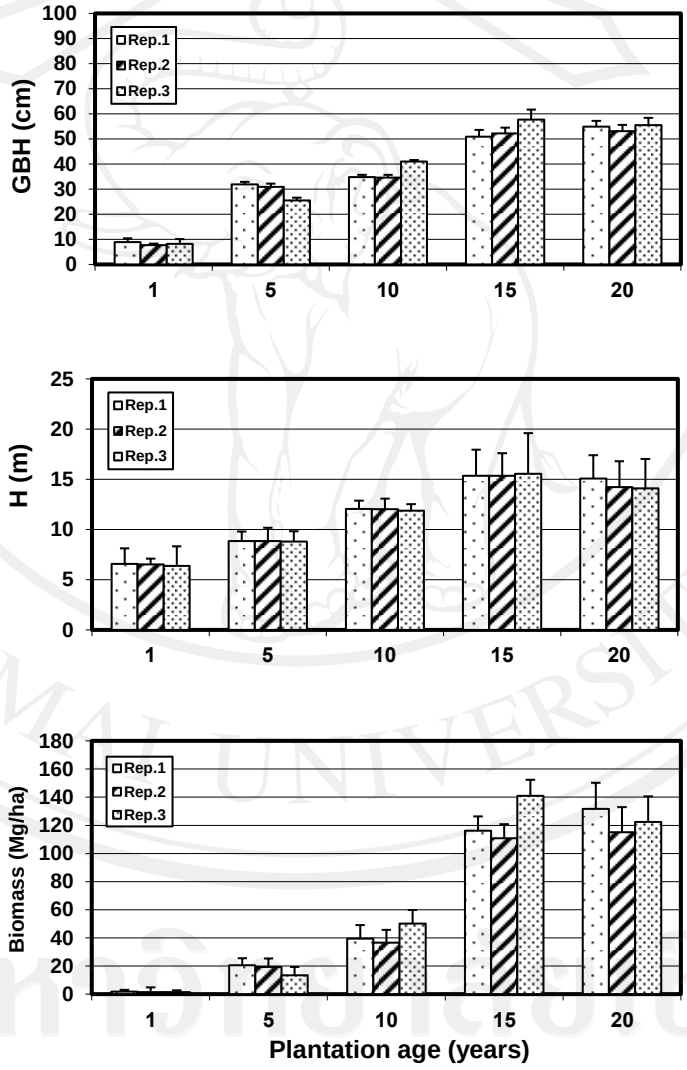

Figure 3-1 Stem girth and height growths, and biomass of para rubber in 1, 5, 10, 15 and 20 years old plantations on Phon Phisai soil series

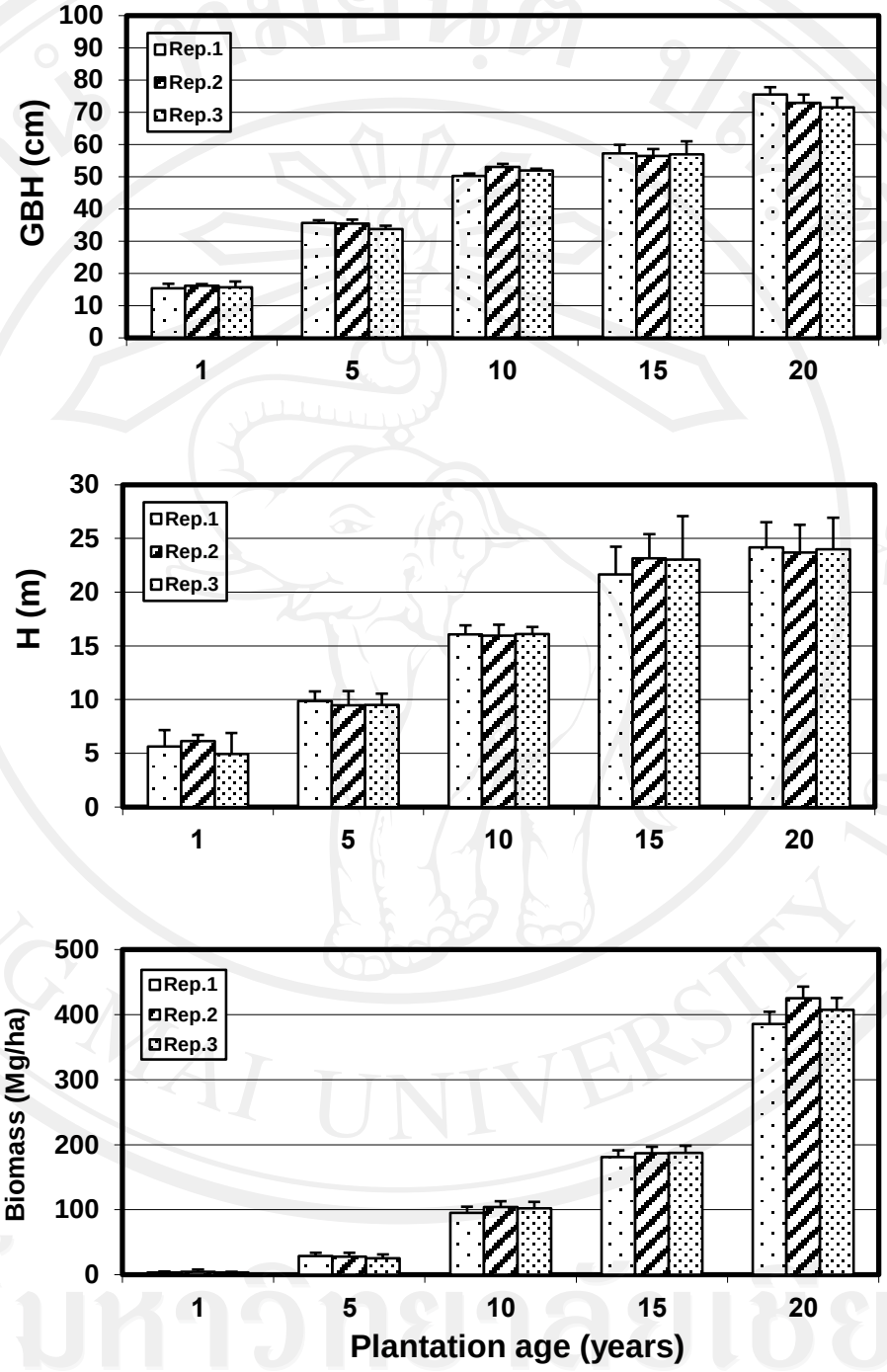

Figure 3-2 Stem girth and height growths, and biomass of para rubber in 1, 5, 10, 15 and 20 years old plantations on Chakkarat soil

Figure 3-3 Use of a stratified clip technique for biomass study of rubber trees including 10, 1-20 years old rubber trees on two soil series

Table 3-3 Data of sample cutting rubber trees used for making allometric equations for calculating biomass on Phonpisai soil series

Age (years)	Organ	GBH (cm)	DBH (cm)	H (m)	D^2H (cm^2.m)	Biomass	
						kg/tree	%
1 year old	stem	8.5	2.70	3.82	27.90	0.77	43.50
	branch					0.09	5.09
	leaf					0.26	14.69
	root					0.65	36.72
	Total					**1.77**	**100**
5 years old	stem	32.5	10.34	9.10	973.10	22.76	33.57
	branch					24.26	35.79
	leaf					6.96	10.27
	root					13.81	20.37
	Total					**67.79**	**100**
10 years old	stem	36.3	11.55	8.65	1,153.90	22.28	24.29
	branch					43.31	47.21
	leaf					6.88	7.50
	root					19.27	21.01
	Total					**91.74**	**100**
15 years old	stem	55.5	17.66	14.30	4,459.40	68.29	36.29
	branch					71.72	38.11
	leaf					7.30	3.88
	root					40.89	21.73
	Total					**188.20**	**100**
20 years old	stem	54.1	17.21	14.37	4,258.0	66.52	32.43
	branch					92.00	44.85
	leaf					3.32	1.62
	root					43.31	21.10
	Total					**205.15**	**100**

Table 3-4 Data of sample cutting rubber trees used for making allometric equations for calculating biomass on Chakkarat soil series

Age (years)	Organ	GBH (cm)	DBH (cm)	H (m)	D^2H (cm^2.m)	Biomass	
						kg/tree	%
1 year old	stem	15.5	4.94	7.20	175.4	4.22	56.57
	branch					0.75	10.05
	root					1.72	23.06
	leaf					0.77	10.32
	Total					**7.46**	**100**
5 years old	stem	34.5	10.99	10.7	1,291.7	32.68	35.72
	branch					30.83	33.70
	leaf					6.14	6.71
	root					21.84	23.87
	Total					**91.49**	**100**
10 years old	stem	48	15.29	15.76	3,682.8	72.35	36.95
	branch					71.53	36.53
	leaf					7.19	3.67
	root					44.75	22.85
	Total					**195.82**	**100**
15 years old	stem	53	16.88	17.2	4,900.3	89.38	39.68
	branch					85.42	37.93
	leaf					5.81	2.58
	root					44.62	19.81
	Total					**225.23**	**100**
20 years old	stem	74	23.57	20.3	11,274.6	160.90	46.89
	branch					104.76	30.53
	leaf					9.62	2.80
	root					67.83	19.77
	Total					**343.11**	**100**

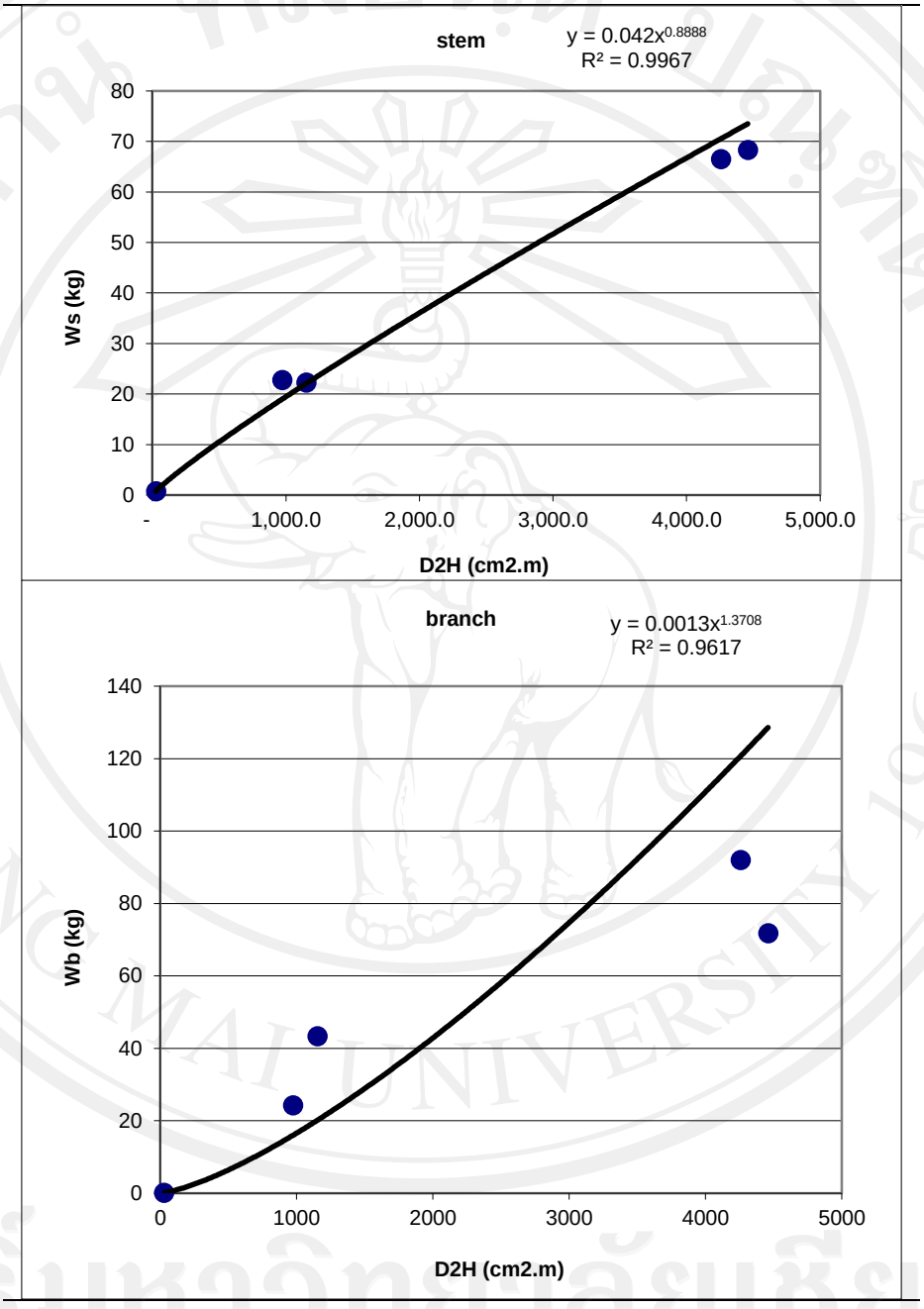

Figure 3-4 Allometric equations of rubber trees on Phon Phisai soil series for stem and branch components

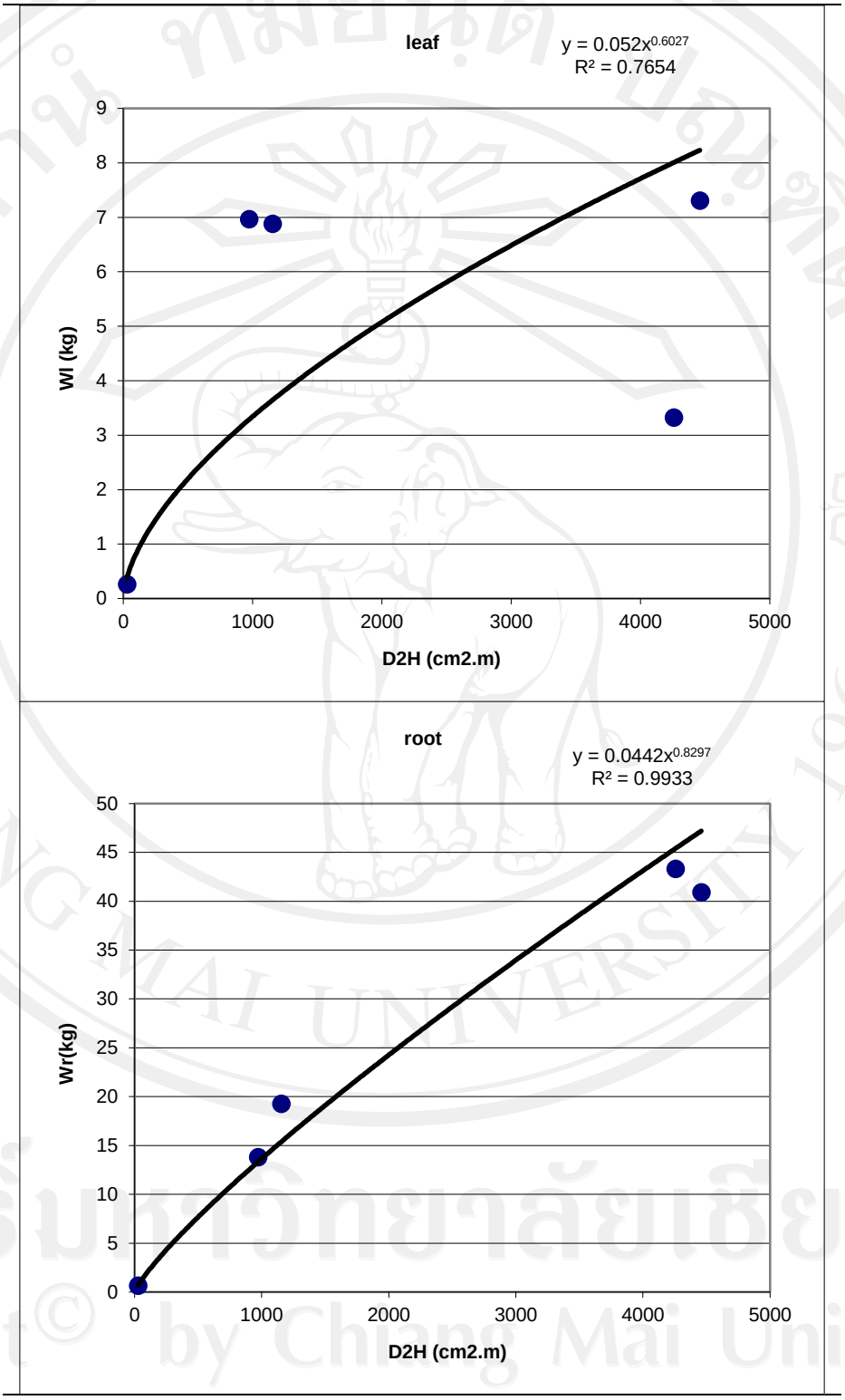

Figure 3-5 Allometric equations of rubber trees on Phon Phisai soil series for leaf and root components

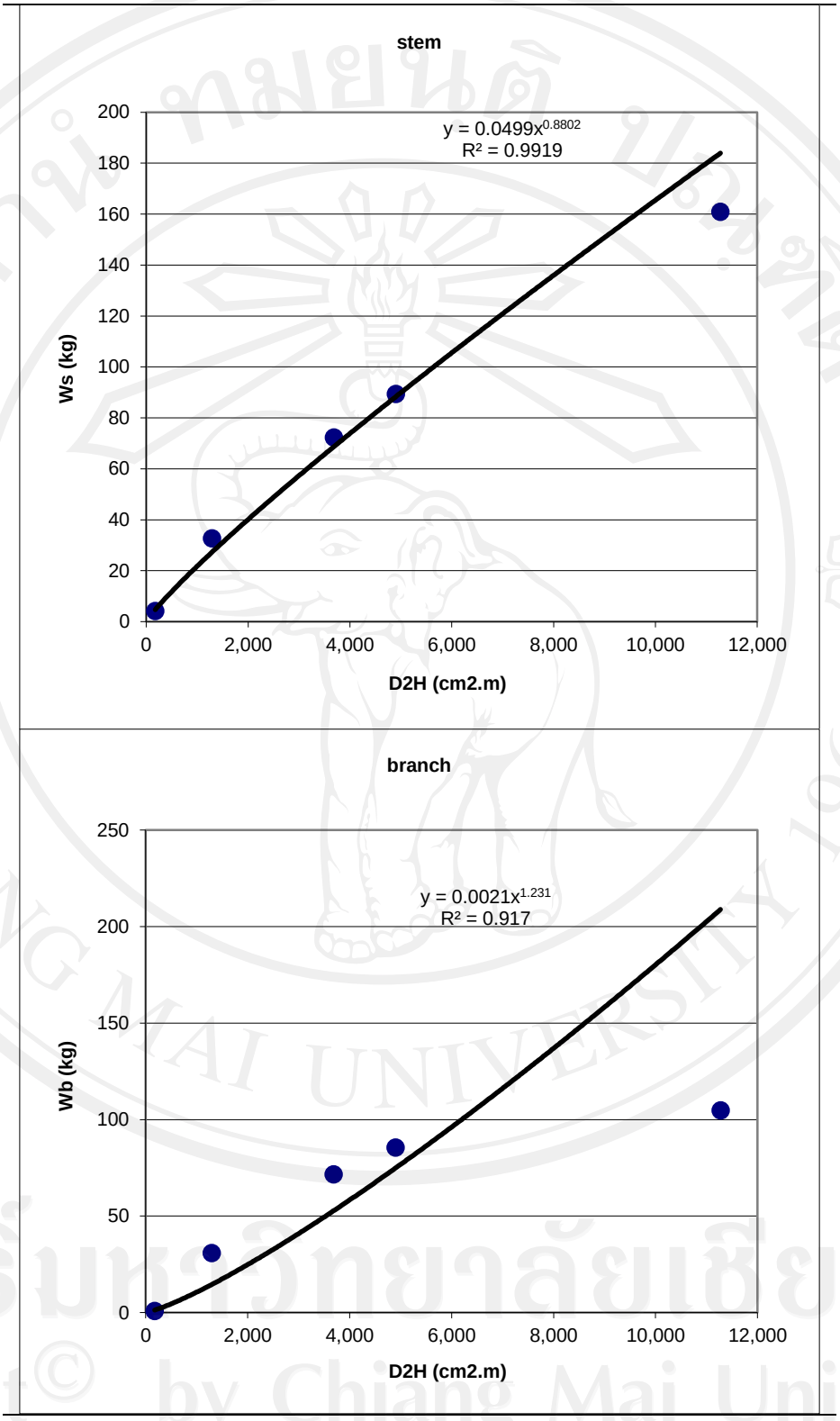

Figure 3-6 Allometric equations of rubber trees on Chakkarat soil series for stem and branch components

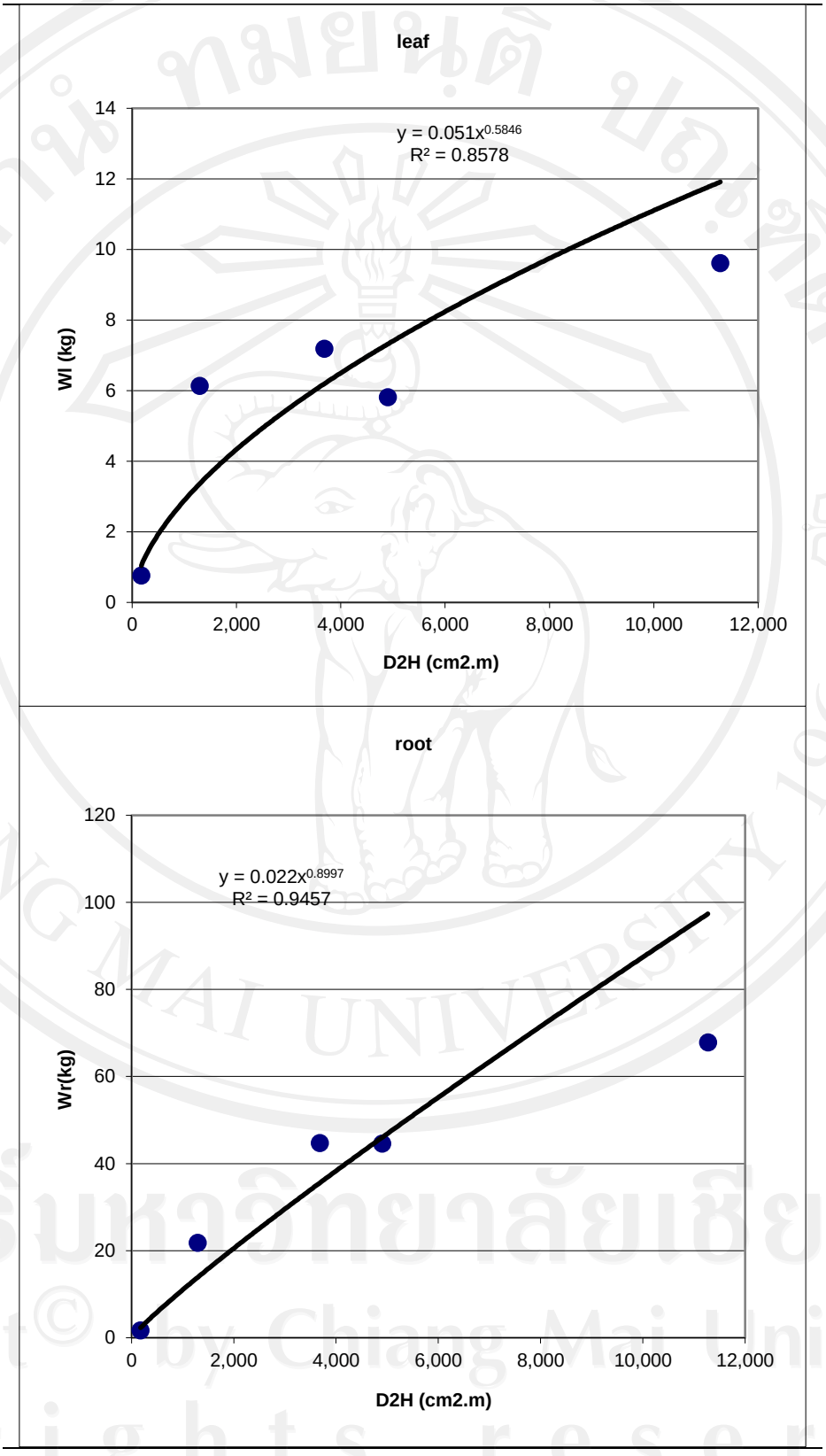

Figure 3-7 Allometric equations of rubber trees on Chakkarat soil series for leaf and root components

According to Sivicultural Division, Royal Forest Department (1993), the tree species which has the normal growth rate should have stem girth increment of 2.5-4.0 cm per year. Therefore, the rubber tree is identified as the normal growing tree species. The other tree species which are classified in this class include *Tectona grandis*, *Pinus kesiya*, *P. merkusii* and so on. Tapping of rubber resin is important factor affecting the rubber growths. The fast growing tree species have the stem girth increment of 5.0 cm per year, and if the tree species have the increment more than 5.0 cm per year, they are the very fast growing species.

Table 3-5 Biomass of rubber trees in different age plantations on Phon Phisai soil series

Plantation	**Plot**	**Density**	**Biomass** (kg/rai)					**Total Biomass**	
age (years)	**No.**	(Tree/rai)	**Ws**	**Wb**	**Wl**	**Wr**	**Total**	(kg/tree)	(Mg/ha)
1	1	79	116.27	20.26	44.92	95.69	277.15	3.51	1.73
	2	78	88.46	13.27	37.27	74.12	213.13	2.73	1.33
	3	77	96.71	16.03	38.94	80.21	231.89	3.01	1.45
		Mean	**100.48**	**16.52**	**40.38**	**83.34**	**240.72**	**3.08**	**1.50**
		S.D.	14.29	3.52	4.02	11.12	32.91	0.39	0.21
		%	**41.74**	**6.86**	**16.77**	**34.62**	**100**		
5	1	71	1,290.73	853.43	224.38	901.36	3,269.91	46.06	20.44
	2	71	1,216.20	784.23	215.10	852.22	3,067.75	43.21	19.17
	3	71	869.59	475.92	170.55	622.24	2,138.30	30.12	13.36
		Mean	**1,125.51**	**704.53**	**203.35**	**791.94**	**2,825.32**	**39.79**	**17.66**
		S.D.	224.74	200.98	28.78	149.00	603.50	8.50	3.77
		%	**39.84**	**24.94**	**7.20**	**28.03**	**100**		
10	1	80	2,289.33	2,148.13	338.15	1,542.79	6,318.39	78.98	39.49
	2	79	2,190.82	1,848.53	330.80	1,485.69	5,855.83	74.12	36.60
	3	78	2,881.08	2,825.11	397.21	1,917.70	8,021.11	102.83	50.13
		Mean	**2,453.74**	**2,273.92**	**355.39**	**1,648.72**	**6,731.78**	**85.31**	**42.07**
		S.D.	373.35	500.30	36.41	234.68	1,140.29	15.37	7.13
		%	**36.45**	**33.78**	**5.28**	**24.49**	**100**		
15	1	86	5,907.30	8,243.24	664.75	3,769.34	18,584.63	216.10	116.15
	2	77	5,554.63	8,026.08	614.09	3,530.83	17,725.62	230.20	110.79
	3	79	6,827.53	10,722.81	715.01	4,292.96	22,558.31	285.55	140.99
		Mean	**6,096.49**	**8,997.37**	**664.62**	**3,864.38**	**19,622.85**	**243.95**	**122.64**
		S.D.	657.20	1,498.21	50.46	389.85	2,578.21	36.71	16.11
		%	**31.07**	**45.85**	**3.39**	**19.69**	**100**		
20	1	85	6,540.14	9,675.97	710.05	4,142.65	21,068.82	247.87	131.68
	2	86	5,893.56	8,087.13	666.54	3,765.63	18,412.86	214.10	115.08
	3	84	6,166.42	8,825.55	681.36	3,920.72	19,594.05	233.26	122.46
		Mean	**6,200.04**	**8,862.89**	**685.98**	**3,943.00**	**19,691.91**	**231.74**	**123.07**
		S.D.	324.60	795.08	22.12	189.50	1,330.68	16.93	8.32
		%	**31.49**	**45.01**	**3.48**	**20.02**	**100**		

Table 3-6 Rubber biomass in different age plantations on Chakkarat soil series

Plantation age (years)	**Plot No.**	**Density** (Tree/rai)	**Biomass** (kg/rai)					**Total Biomass**	
			Ws	**Wb**	**Wl**	**Wr**	**Total**	(kg/tree)	(Mg/ha)
1	1	80	293.07	68.89	70.44	144.62	577.01	7.21	3.61
	2	80	352.37	92.57	79.30	174.72	698.97	8.74	4.37
	3	80	265.83	61.15	65.54	130.99	523.52	6.54	3.27
		Mean	**303.76**	**74.20**	**71.76**	**150.11**	**599.83**	**7.50**	**3.75**
		S.D.	44.25	16.37	6.98	22.38	89.93	1.12	0.56
		%	**50.64**	**12.37**	**11.96**	**25.03**	**100**		
5	1	80	2,124.79	1,088.00	264.10	1,093.69	4,570.58	57.13	28.57
	2	80	2,046.14	1,045.41	256.31	1,052.87	4,400.72	55.01	27.50
	3	80	1,883.91	926.87	242.97	967.51	4,021.26	50.27	25.13
		Mean	**2,018.28**	**1,020.09**	**254.46**	**1,038.02**	**4,330.85**	**54.14**	**27.07**
		S.D.	122.84	83.49	10.68	64.39	281.25	3.52	1.76
		%	**46.60**	**23.55**	**5.88**	**23.97**	**100**		
10	1	84	6,347.51	4,978.78	552.58	3,343.18	15,222.05	181.21	95.14
	2	83	6,868.80	5,582.77	580.37	3,624.68	16,656.61	200.68	104.10
	3	84	6,758.26	5,441.18	575.96	3,564.44	16,339.84	194.52	102.12
		Mean	**6,658.19**	**5,334.24**	**569.64**	**3,510.77**	**16,072.83**	**192.14**	**100.46**
		S.D.	274.67	315.87	14.94	148.22	753.63	9.95	4.71
		%	**41.43**	**33.19**	**3.54**	**21.84**	**100**		
15	1	91	11,299.74	10,825.53	831.69	6,016.10	28,973.06	318.39	181.08
	2	91	11,605.74	11,232.71	847.59	6,182.16	29,868.21	328.22	186.68
	3	91	11,625.55	11,277.84	847.06	6,193.67	29,944.13	329.06	187.15
		Mean	**11,510.34**	**11,112.03**	**842.11**	**6,130.65**	**29,595.13**	**325.22**	**184.97**
		S.D.	182.66	249.14	9.03	99.37	540.07	5.93	3.38
		%	**38.89**	**37.55**	**2.85**	**20.72**	**100**		
20	1	97	21,793.03	26,862.74	1,304.90	11,759.98	61,720.66	636.30	385.75
	2	116	24,270.51	29,194.61	1,486.00	13,078.85	68,029.98	586.47	425.19
	3	114	23,338.01	27,843.46	1,437.58	12,571.29	65,190.34	571.85	407.44
		Mean	**23,133.85**	**27,966.94**	**1,409.49**	**12,470.04**	**64,980.33**	**598.20**	**406.13**
		S.D.	1,251.30	1,170.83	93.76	665.24	3,159.90	33.79	19.75
		%	**35.60**	**43.04**	**2.17**	**19.19**	**100**		

(2) Natural forests

A. Phopisai Soil Series

Table 3-7 shows the quantitative characteristics of tree species in dry dipterocarp forest (DDF) in the Nong Khrai Rubber Research Center. Dominant trees in the forest included Teng (*Shorea obtusa*), Rung (*S. siamensis*) and Hiang (*Dipterocarpus obtusifolius*). Tree density in the forest was 1,119 trees/rai. It was the high density since it was the seconday forest. The dominant tree, Teng (*S. obtusa*), had the highest density in the forest, followed by *S. siamensis* (135), *Canarium subulatum* (83), *Cratoxylum pruniflorum* (68), *Memecylon* sp. (54), *Syzygium cumini* (48), *Irvingia malayana* (34), etc. *S. obtusa* had also the highest importance value index, 18.0% of all species. They were followed by *S. siamensis* (15.80), *Canarium subulatum* (10.2), *Syzygium cumini* (4.68), *Terminalia alata* (4.63), *Dipterocarpus obtusifolius* (4.56), *Cratoxylum pruniflorum* (3.61), *Memecylon* sp. (2.77), *Irvingia malayana* (2.66), etc. The forest had 3.19 m^2/rai of total stem basal area that implied

to the moderate biological production. The species diversity index using Shannon-Wiener index (SWI) was high, 4.92. Many tree species from the DEF exited in this forest, and resulted in the higher species diversity.

In **Table 3-8**, biomass production of all tree species in the forest was 14,796.51 kg/rai (92.48 Mg/ha), separated into stem, branch, leaf and root components to 60.21, 15.54, 2.84 and 13.89 Mg/ha, respectively. The biomass productions of tree species in the forest were different. *S. siamensis* had the highest biomass, 3,075.55 kg/rai, followed by *S. obtusa* (2,790.49), *C. subulatum* (2,006.09), *T. alata* (1302.44), *D. obtusifolius* (1,093.66), *Syzygium cumini* (713.63), etc.

Khamyong *et al.* (2011) reported that the dry dipterocarp forest with dominant *D. tuberculatus*, *S. obtuse*, *S.siamensis* and *D. obtusifolius* communites at the Huai Hong Khrai Royal Development Study Center had the plant biomass amounts of 145.38, 95.38 and 84.19 Mg/ha, respectively. These forest communities were recovered from the poor forest for about 20 years. Thus, the DDF in the Nong Khai Rubber Research Center was similar to the forest at this center.

The original dry dipterocarp forest had in the poor condition. After establishment of the Nong Khai Rubber Research Center, the forest has been protected from tree cutting for about 20 years. It was the forest recovering forest which had the biomass storage of 92.48 Mg/ha. Most of the biomass, 53.20%, was the contribution of three species: *S. obtusa*, *S. siamensis* and *C. subulatum*. The rest of 46.80% were biomass of the remaining 73 plant species. The biomass of 20 years plod rubber plantation on Phon Phisai soil series was 123.07 Mg/ha, and had 30.59 Mg/ha higher than the biomass of the dry dipterocarp forest. Therefore, the rubber plantations could store carbon and reduce CO_2 in atmosphere in the rapid rate.

B. Chakkarat Soil Series

The original areas before changing to be rubber plantations on Chakkarat soil series had been covered by the dry evergreen forest (DEF) on shale, siltstone and sand stones. It was a poor soil with the deep fine-sandy profiles.

Table 3-9 shows the quantitative characteristics of tree species in dry evergreen forest (DEF) in the Nong Krai Rubber Research Center. It is thought that the original dominant trees of mesic dipterocarps the forest such as *Dipterocarpus alatus*, etc. were disappeared from the forest, and remained some evergreen tree species. The dominant trees existed in the forest were some oaks (*Quercus elegans*, *Lithocarpus* spp.) and *Schima wallichii*. Tree density in the forest was 528 trees/rai, lower than the DDF. *Diospyros* sp. had the highest density, 122 trees/rai, followed by *Quercus elegans* (41), *Cratoxylum pruniflorum* (31), *Lithocarpus* sp. (29), *Dalbergia* sp. (24), *Garcinia cowa* and *Aporosa villosa* (23), etc. *Q. elegans* had also the highest importance value index, 13.30% of all species. They were followed by *Diospyros* sp. (12.60), *S. wallichii* (6.88), *Lithocarpus* sp. (6.83), *Dalbergia* sp. (5.73), *Garcinia cowa* (4.42), etc. The forest had 4.63 m^2/rai of total stem basal area, higher than the DDF, and implied to the higher biological production. The species diversity index using Shannon-Wiener index (SWI) was high, 4.63, a little lower than the DDF.

In **Table 3-10**, the biomass production of all tree species in the forest was 40,235.10 kg/rai (251.47 Mg/ha), separated into stem, branch, leaf and root components to 161.98, 47.44, 5.18 and 36.87 Mg/ha, respectively. The biomass

productions of tree species in the forest were greatlty different. *Q. elegans* had the highest biomass, 8,285.72 kg/rai, followed by *S. wallichii* (5,120.23), *Castanopsis* sp. (3,478.62), *Parinai anamense* (2,829.28), *Terminalia chebula* (2,532.03), *Pterocarpus macrocarpus* (1,733.87), etc.

The biomass production of all tree species in the DEF was high, 40,235.10 kg/rai (251.47 Mg/ha), where as the biomass in the 20 years old rubber plantation on Chakkarat soil was 64,980.33 kg/rai (406.13 Mg/ha). Seeloy-ounkeaw (2011) found that the montane community forest for conservation at Mae Wang district, Chiang Mai province had the species richness of 256 species and the average plant biomass of 252.36 Mg/ha wheras Khamyong and Anongrak (2011) reported the virgin montane forest at the Doi Inthanon summit had the highest record (703.8 Mg/ha). Planting of tree species in plantations may increase the biomass of the older plantations because most trees can grow well between the regular spacing with enough light.

Table 3-7 Quantitative characteristics of tree species in a dry dipterocarp forest

No	Plant name	Tree density	Basal area	Relative value (%)		IVI		SWI		
			(cm^2/plot)	Den.	Dom.	(200)	%	*pi*	$\log_2 pi$	$pi.\log_2 pi$
1	*Shorea obtusa*	181	6,355.86	16.18	19.92	36.1	18.05	0.16	-2.63	-0.43
2	*Shorea siamensis*	135	6,273.17	12.06	19.66	31.73	15.86	0.12	-3.05	-0.37
3	*Canarium subulatum*	83	4,162.79	7.42	13.05	20.47	10.23	0.07	-3.75	-0.28
4	*Syzygium cumini*	48	1,614.78	4.29	5.06	9.35	4.68	0.04	-4.54	-0.19
5	*Terminalia alata*	21	2,353.53	1.88	7.38	9.25	4.63	0.02	-5.74	-0.11
6	*Dipterocarpus obtusifolius*	30	2,054.28	2.68	6.44	9.12	4.56	0.03	-5.22	-0.14
7	*Cratoxylum pruniflorum*	68	365.29	6.08	1.15	7.22	3.61	0.06	-4.04	-0.25
8	*Memecylon* sp.	54	230.84	4.83	0.72	5.55	2.77	0.05	-4.37	-0.21
9	*Irvingia malayana*	34	728.8	3.04	2.28	5.32	2.66	0.03	-5.04	-0.15
10	*Garcinia cowa*	32	101.18	2.86	0.32	3.18	1.59	0.03	-5.13	-0.15
11	*Dalbergia velutina*	20	347.47	1.79	1.09	2.88	1.44	0.02	-5.81	-0.1
12	*Careya sphaerica*	7	705.03	0.63	2.21	2.84	1.42	0.01	-7.32	-0.05
13	*Walsura robusta*	15	479.3	1.34	1.5	2.84	1.42	0.01	-6.22	-0.08
14	*Sindora siamensis*	23	221.51	2.06	0.69	2.75	1.37	0.02	-5.6	-0.12
15	*Quercus kerrii*	11	549.02	0.98	1.72	2.7	1.35	0.01	-6.67	-0.07
16	*Buchanania latifolia*	20	274.87	1.79	0.86	2.65	1.32	0.02	-5.81	-0.1
17	*Ulmus lancaefolia*	6	576.19	0.54	1.81	2.34	1.17	0.01	-7.54	-0.04
18	*Antidesma* sp.	17	254.17	1.52	0.8	2.32	1.16	0.02	-6.04	-0.09
19	*Aporosa villosa*	18	188.28	1.61	0.59	2.2	1.1	0.02	-5.96	-0.1
20	*Stereospermum fimbriatum*	9	429.31	0.8	1.35	2.15	1.08	0.01	-6.96	-0.06
21	*Antidesma acidum*	21	61.69	1.88	0.19	2.07	1.04	0.02	-5.74	-0.11
22	*Macaranga denticulata*	17	157.14	1.52	0.49	2.01	1.01	0.02	-6.04	-0.09
23	*Mimusops elengi*	15	122.74	1.34	0.38	1.73	0.86	0.01	-6.22	-0.08
24	*Memecylon scutellatum*	16	79.39	1.43	0.25	1.68	0.84	0.01	-6.13	-0.09
25	*Vitex peduncularis*	16	46.06	1.43	0.14	1.57	0.79	0.01	-6.13	-0.09
26	*Bombax anceps*	1	447.44	0.09	1.4	1.49	0.75	0	-10.13	-0.01
27	*Spondias pinnata*	7	225.51	0.63	0.71	1.33	0.67	0.01	-7.32	-0.05
28	*Litsea glutinosa*	9	169.67	0.8	0.53	1.34	0.67	0.01	-6.96	-0.06
29	*Mitragyna rotundifolia*	11	104.72	0.98	0.33	1.31	0.66	0.01	-6.67	-0.07
30	*Zizyphus oenoplia*	7	213.2	0.63	0.67	1.29	0.65	0.01	-7.32	-0.05
31	*Schoepfia fragrans*	8	158.53	0.71	0.5	1.21	0.61	0.01	-7.13	-0.05
32	*Phyllanthus emblica*	11	70.66	0.98	0.22	1.2	0.6	0.01	-6.67	-0.07
33	*Olea salicifolia*	8	106.71	0.71	0.33	1.05	0.52	0.01	-7.13	-0.05
34	*Bridelia affinis*	4	214.61	0.36	0.67	1.03	0.52	0	-8.13	-0.03
35	*Symplocos recemosa*	7	130.08	0.63	0.41	1.03	0.52	0.01	-7.32	-0.05

Table 3-7 (Continued)

No.	Plant name	Tree density	Basal area	Relative value (%)		IVI		SWI		
			(cm^2/plot)	Den.	Dom.	(200)	%	*pi*	$\log_2 pi$	$pi.\log_2 pi$
36	*Catunaregam spathulifolia*	10	40.35	0.89	0.13	1.02	0.51	0.01	-6.81	-0.06
37	*Vitex pinnata*	10	31.52	0.89	0.1	0.99	0.5	0.01	-6.81	-0.06
38	*Mitrephora vandaeflora*	9	43.83	0.8	0.14	0.94	0.47	0.01	-6.96	-0.06
39	*Strychnos nux-vomica*	3	209.94	0.27	0.66	0.93	0.46	0	-8.54	-0.02
40	*Irvingia malayana*	9	23.94	0.8	0.08	0.88	0.44	0.01	-6.96	-0.06
41	*Dalbergia oliverli*	8	43.47	0.71	0.14	0.85	0.43	0.01	-7.13	-0.05
42	*Ampelocissus martinii*	7	60.3	0.63	0.19	0.81	0.41	0.01	-7.32	-0.05
43	*Pterocarpus macrocarpus*	2	201.49	0.18	0.63	0.81	0.41	0	-9.13	-0.02
44	*Garcinia sootepensis*	4	70.32	0.36	0.22	0.58	0.29	0	-8.13	-0.03
45	*Artocarpus lakoocha*	5	39.22	0.45	0.12	0.57	0.28	0	-7.81	-0.03
46	*Lithocarpus elegans*	5	27.2	0.45	0.09	0.53	0.27	0	-7.81	-0.03
47	*Ochna intergerima*	5	15.35	0.45	0.05	0.49	0.25	0	-7.81	-0.03
48	*Garcinia cowa*	3	51.63	0.27	0.16	0.43	0.21	0	-8.54	-0.02
49	*Pavetta tomentosa*	4	8.59	0.36	0.03	0.38	0.19	0	-8.13	-0.03
50	*Wendlandia tinctoria*	2	66.18	0.18	0.21	0.39	0.19	0	-9.13	-0.02
51	*Garuga pinnata*	2	53.61	0.18	0.17	0.35	0.17	0	-9.13	-0.02
52	*Cratoxylum pruniflorum*	3	24.02	0.27	0.08	0.34	0.17	0	-8.54	-0.02
53	*Antidesma velutinosum*	3	21.18	0.27	0.07	0.33	0.17	0	-8.54	-0.02
54	*Tristaniopsis burmanica*	2	47.43	0.18	0.15	0.33	0.16	0	-9.13	-0.02
55	*Macalanga* sp.	2	46.45	0.18	0.15	0.32	0.16	0	-9.13	-0.02
56	*Dalbergia cultrata*	3	8.03	0.27	0.03	0.29	0.15	0	-8.54	-0.02
57	*Pavetta* sp.	3	9.41	0.27	0.03	0.3	0.15	0	-8.54	-0.02
58	*Croton roxburghii*	2	32.22	0.18	0.1	0.28	0.14	0	-9.13	-0.02
59	*Brucea javanica*	3	4.53	0.27	0.01	0.28	0.14	0	-8.54	-0.02
60	*Antidesma ghaesembilla*	2	16.31	0.18	0.05	0.23	0.11	0	-9.13	-0.02
61	*Rhus javanica*	2	8.99	0.18	0.03	0.21	0.1	0	-9.13	-0.02
62	*Lepisanthes rubiginosa*	2	2.55	0.18	0.01	0.19	0.09	0	-9.13	-0.02
63	*Terminalia chebula*	1	25.77	0.09	0.08	0.17	0.09	0	-10.13	-0.01
64	*Colona floribunda*	1	15.59	0.09	0.05	0.14	0.07	0	-10.13	-0.01
65	*Arytera littoralis*	1	13.44	0.09	0.04	0.13	0.07	0	-10.13	-0.01
66	*Hymenodictyono rixense*	1	17.9	0.09	0.06	0.15	0.07	0	-10.13	-0.01
67	*Ilex umbellate*	1	9.63	0.09	0.03	0.12	0.06	0	-10.13	-0.01
68	*Artabotrys vanprukii*	1	9.63	0.09	0.03	0.12	0.06	0	-10.13	-0.01
69	*Bridelia affinis*	1	1.99	0.09	0.01	0.1	0.05	0	-10.13	-0.01
70	*Gnetum montanum*	1	1.99	0.09	0.01	0.1	0.05	0	-10.13	-0.01
71	*Flacourtia indica*	1	6.44	0.09	0.02	0.11	0.05	0	-10.13	-0.01
72	*Mitragyna hirsuta*	1	1.99	0.09	0.01	0.1	0.05	0	-10.13	-0.01
73	*Antidesma acidum*	1	1.27	0.09	0	0.09	0.05	0	-10.13	-0.01
74	*Aganosma marginata*	1	5.09	0.09	0.02	0.11	0.05	0	-10.13	-0.01
75	*Euodia roxburghiana*	1	3.9	0.09	0.01	0.1	0.05	0	-10.13	-0.01
76	*Anneslea fragrans*	1	3.9	0.09	0.01	0.1	0.05	0	-10.13	-0.01
	Total	1,119	31,900	100	100	200	100	1	-577.9	-4.92

Table 3-8 Biomass of tree species in the dry dipterocarp forest nearby rubber plantations

Species No.	Plant name	Biomass (kg/rai)				
		Stem	Branch	Leaf	Root	Total
1	*Shorea siamensis*	2,017.58	477.95	103.48	476.76	3,075.77
2	*Shorea obtusa*	1,828.23	425.48	96.17	440.62	2,790.49
3	*Canarium subulatum*	1,309.90	354.00	55.39	286.79	2,006.09
4	*Terminalia alata*	811.76	342.82	13.59	134.26	1,302.44
5	*Dipterocarpus obtusifolius*	716.11	190.89	30.63	156.03	1,093.66
6	*Syzygium cumini*	466.03	117.73	22.04	107.84	713.63
7	*Careya sphaerica*	233.48	67.63	8.50	47.85	357.46
8	*Ulmus lancaefolia*	204.37	54.84	8.59	43.95	311.75
9	*Irvingia malayana*	181.66	39.90	10.29	46.32	278.18
10	*Bombax anceps*	173.79	62.21	3.55	30.45	270.00
11	*Quercus kerrii*	166.93	41.22	8.08	38.40	254.62
12	*Walsura robusta*	144.48	36.02	6.89	33.13	220.51
13	*Stereospermum fimbriatum*	129.51	32.44	6.13	29.54	197.63
14	*Dalbergia velutina*	121.78	23.28	7.91	33.20	186.16
15	*Spondias pinnata*	77.28	20.51	3.34	17.15	118.28
16	*Cratoxylum pruniflorum*	73.94	11.42	5.71	24.09	115.17
17	*Flemingia macrophylla*	72.88	18.40	3.44	17.25	111.98
18	*Zizyphus oenoplia*	70.28	17.87	3.26	16.06	107.47
19	*Strychnos nux-vomica*	65.63	15.91	3.25	15.13	99.91
20	*Buchanania latifolia*	63.18	11.77	4.21	17.89	97.05
21	*Pterocarpus macrocarpus*	55.23	14.67	2.36	12.01	84.28
22	*Sindora siamensis*	46.49	7.96	3.32	14.04	71.82
23	*Litsea glutinosa*	46.79	10.07	2.71	12.01	71.59
24	*Memecylon sp.*	42.82	5.85	3.56	14.94	67.16
25	*Aporosa villosa*	39.98	6.42	2.98	12.33	61.72
26	*Zizyphus mauritiana*	38.73	8.55	2.17	9.60	59.05
27	*Macaranga denticulata*	37.90	6.41	2.73	11.43	58.47
28	*Schoepfia fragrans*	33.01	5.80	2.30	9.56	50.67
29	*Symplocos recemosa*	29.53	5.81	1.87	7.98	45.19
30	*Olea salicifolia*	27.55	4.74	1.95	8.08	42.32
31	*Mimusops elengi*	23.90	3.50	1.89	7.85	37.13
32	*Mitragyna rotundifolia*	20.19	3.10	1.55	6.43	31.27
33	*Ampelocissus martinii*	20.25	3.24	1.51	6.22	31.21
34	*Garuga pinnata*	19.01	4.25	1.05	4.65	28.95
35	*Tristaniopsis burmanica*	18.69	4.20	1.03	4.54	28.46
36	*Wendlandia tinctoria*	16.99	3.35	1.07	4.51	25.91
37	*Garcinia sootepensis*	16.14	3.04	1.06	4.44	24.69
38	*Phyllanthus emblica*	14.57	2.12	1.16	4.83	22.68
40	*Memecylon scutellatum*	11.85	1.56	1.00	4.23	18.65
41	*Macalanga denticulata*	9.46	1.72	0.64	2.67	14.49
42	*Antidesma acidum*	8.59	0.94	0.80	3.43	13.77
43	*Vitex pinnata*	8.34	1.09	0.71	3.02	13.17
44	*Croton roxburghii*	8.29	1.48	0.57	2.37	12.72
45	*Dalbergia oliverli*	7.45	0.96	0.64	2.67	11.72
46	*Mitrephora vandaeflora*	6.70	0.85	0.58	2.44	10.57
47	*Climber*	6.83	1.03	0.53	2.17	10.56
48	*Catunaregam spathulifolia*	6.56	0.80	0.58	2.45	10.38
49	*Vitex peduncularis*	6.45	0.95	0.52	2.18	10.09
50	*Terminalia chebula*	6.28	1.14	0.43	1.76	9.61
51	*Artocarpus lakoocha*	6.09	0.81	0.51	2.12	9.53
52	*Hymenodictyon orixense*	5.10	0.89	0.36	1.47	7.81
53	*Garcinia cowa*	4.97	0.71	0.40	1.65	7.74
54	*Lithocarpus elegans*	4.85	0.66	0.40	1.68	7.59
55	*Bridelia affinis*	4.06	0.45	0.38	1.61	6.49
56	*Antidesma ghaesembilla*	4.07	0.67	0.30	1.23	6.27
57	*Antidesma velutinosum*	3.76	0.53	0.30	1.26	5.86
58	*Colona floribunda*	2.95	0.46	0.22	0.92	4.55
59	*Pavetta sp.*	2.14	0.26	0.19	0.79	3.38
60	*Arytera littoralis*	2.11	0.31	0.17	0.69	3.27

Table 3-8 (Continued)

Species No.	Plant name	Biomass (kg/rai)				
		Stem	**Branch**	**Leaf**	**Root**	**Total**
61	*Ochna intergerima*	1.94	0.20	0.19	0.80	3.12
62	*Ilex umbellate*	1.91	0.27	0.15	0.63	2.96
63	*Artabotrys vanprukii*	1.91	0.27	0.15	0.63	2.96
64	*Rhus javanica*	1.41	0.17	0.13	0.53	2.24
65	*Pavetta tomentosa*	1.36	0.14	0.13	0.56	2.20
66	*Flacourtia indica*	1.33	0.18	0.11	0.46	2.08
67	*Aganosma marginata*	1.27	0.17	0.11	0.44	1.98
68	*Dalbergia cultrata*	1.06	0.11	0.10	0.44	1.70
69	*Euodia roxburghiana*	0.84	0.10	0.07	0.31	1.33
70	*Brucea javanica*	0.68	0.06	0.07	0.30	1.10
71	*Anneslea fragrans*	0.53	0.06	0.05	0.21	0.85
72	*Gnetum montanum*	0.46	0.05	0.04	0.19	0.74
73	*Lepisanthes rubiginosa*	0.39	0.03	0.04	0.18	0.64
74	*Bridelia affinis*	0.38	0.04	0.04	0.16	0.61
75	*Mitragyna hirsuta*	0.25	0.02	0.02	0.11	0.40
76	*Antidesma sp.*	0.13	0.01	0.01	0.06	0.22
	Total (kg/rai)	**9,633.24**	**2,487.11**	**453.64**	**2,222.51**	**14,796.51**
	Total (Mg/ha)	**60.21**	**15.54**	**2.84**	**13.89**	**92.48**

Table 3-9 Quantitative characteristics of tree species in a dry evergreen forest

No.	Plant name	Tree density	Basal area	Relative value (%)		IVI		SWI		
			(cm^2/plot)	Den.	Dom.	(200)	%	*pi*	$\log_2 pi$	$pi.\log_2 pi$
1	*Quercus elegans*	41	8,767.94	7.77	18.93	26.7	13.35	0.08	-3.69	-0.29
2	*Diospyros* sp.1	122	993.72	23.11	2.15	25.25	12.63	0.23	-2.11	-0.49
3	*Schima wallichii*	10	5,496.19	1.89	11.87	13.76	6.88	0.02	-5.72	-0.11
4	*Lithocarpus* sp.2	29	3,783.82	5.49	8.17	13.66	6.83	0.05	-4.19	-0.23
5	*Dalbergia* sp.	24	3,205.38	4.55	6.92	11.47	5.73	0.05	-4.46	-0.2
6	*Garcinia cowa*	23	2,078.85	4.36	4.49	8.85	4.42	0.04	-4.52	-0.2
7	*Terminalia chebula*	14	2,744.78	2.65	5.93	8.58	4.29	0.03	-5.24	-0.14
8	*Cratoxylum pruniflorum*	31	966.6	5.87	2.09	7.96	3.98	0.06	-4.09	-0.24
9	*Xerospermum noronhianum*	21	1,523.06	3.98	3.29	7.27	3.63	0.04	-4.65	-0.19
10	*Sindora siamensis*	22	1,434.60	4.17	3.1	7.26	3.63	0.04	-4.58	-0.19
11	*Aporosa villosa*	23	862.33	4.36	1.86	6.22	3.11	0.04	-4.52	-0.2
12	*Pterocarpus macrocarpus*	7	1,764.80	1.33	3.81	5.14	2.57	0.01	-6.24	-0.08
13	*Dillenia obovata*	16	718.08	3.03	1.55	4.58	2.29	0.03	-5.04	-0.15
14	*Syzygium* sp.	11	1,092.66	2.08	2.36	4.44	2.22	0.02	-5.58	-0.12
15	*Wendlandia tinctoria*	5	1,601.33	0.95	3.46	4.41	2.2	0.01	-6.72	-0.06
16	*Syzygium albiflorum*	7	1,088.60	1.33	2.35	3.68	1.84	0.01	-6.24	-0.08
17	*Canarium subulatum*	9	801.66	1.7	1.73	3.44	1.72	0.02	-5.87	-0.1
18	*Lithocarpus* sp.1	4	1,209.25	0.76	2.61	3.37	1.68	0.01	-7.04	-0.05
19	*Ardisia* sp.	17	53.18	3.22	0.11	3.33	1.67	0.03	-4.96	-0.16
20	*Lophopetalum duperreanum*	8	806.39	1.52	1.74	3.26	1.63	0.02	-6.04	-0.09
21	*Dipterocarpus intricatus*	2	955.9	0.38	2.06	2.44	1.22	0	-8.04	-0.03
22	*Casaeria grewiifolia*	1	644.32	0.19	1.39	1.58	0.79	0	-9.04	-0.02
23	*Memecylon scutellatum*	4	377.54	0.76	0.82	1.57	0.79	0.01	-7.04	-0.05
24	*Olea salicifolia*	7	100.88	1.33	0.22	1.54	0.77	0.01	-6.24	-0.08
25	*Irvingia malayana*	4	221.38	0.76	0.48	1.24	0.62	0.01	-7.04	-0.05
26	*Castanopsis* sp.	2	389.65	0.38	0.84	1.22	0.61	0	-8.04	-0.03
27	*Dalbergia foliacea*	2	351.59	0.38	0.76	1.14	0.57	0	-8.04	-0.03
28	*Dalbergia nigrescens*	1	389.77	0.19	0.84	1.03	0.52	0	-9.04	-0.02
29	*Aporosa wallichii*	5	46.16	0.95	0.1	1.05	0.52	0.01	-6.72	-0.06
30	*Quercus kerii*	2	203.95	0.38	0.44	0.82	0.41	0	-8.04	-0.03
31	*Dalbergia lanceolaria*	3	87.34	0.57	0.19	0.76	0.38	0.01	-7.46	-0.04
32	*Artocarpus* sp.	2	176.99	0.38	0.38	0.76	0.38	0	-8.04	-0.03
33	*Dalbergia velutina*	3	76.52	0.57	0.17	0.73	0.37	0.01	-7.46	-0.04
34	*Symplocos* sp.	3	70.08	0.57	0.15	0.72	0.36	0.01	-7.46	-0.04
35	*Gardenia coronaria*	2	143.26	0.38	0.31	0.69	0.34	0	-8.04	-0.03

Table 3-9 (Continued)

No.	Plant name	Tree density	Basal area (cm^2/plot)	Relative value (%)		IVI		SWI		
				Den.	Dom.	(200)	%	*pi*	$\log_2 pi$	$pi.\log_2 pi$
36	*Parinaria anamense*	3	12.67	0.57	0.03	0.6	0.3	0.01	-7.46	-0.04
37	*Vitex peduncularis*	2	72.31	0.38	0.16	0.53	0.27	0	-8.04	-0.03
38	*Schoutenia ovata*	1	147.08	0.19	0.32	0.51	0.25	0	-9.04	-0.02
39	*Colona flagrocarpa*	1	147.08	0.19	0.32	0.51	0.25	0	-9.04	-0.02
40	*Syzygium cumini*	1	147.08	0.19	0.32	0.51	0.25	0	-9.04	-0.02
41	Climber-1	2	49.72	0.38	0.11	0.49	0.24	0	-8.04	-0.03
42	*Elaeocarpus sphaericus*	2	49.72	0.38	0.11	0.49	0.24	0	-8.04	-0.03
43	*Diospyros glandulosa*	2	33.67	0.38	0.07	0.45	0.23	0	-8.04	-0.03
44	*Mimusops elengi*	2	40.49	0.38	0.09	0.47	0.23	0	-8.04	-0.03
45	*Dalbergia cochinchinensis*	2	7.72	0.38	0.02	0.4	0.2	0	-8.04	-0.03
46	*Pavetta wallichiana*	2	1.43	0.38	0	0.38	0.19	0	-8.04	-0.03
47	*Catunaregum spathulifolia*	2	1.43	0.38	0	0.38	0.19	0	-8.04	-0.03
48	*Goniothalamus laoticus*	1	81.45	0.19	0.18	0.37	0.18	0	-9.04	-0.02
49	*Ficus prostrata*	1	64.61	0.19	0.14	0.33	0.16	0	-9.04	-0.02
50	*Wendlandia tinctoria*	1	31.82	0.19	0.07	0.26	0.13	0	-9.04	-0.02
51	*Dalbergia volubilis*	1	35.08	0.19	0.08	0.27	0.13	0	-9.04	-0.02
52	*Symplocos recemosa*	1	31.82	0.19	0.07	0.26	0.13	0	-9.04	-0.02
53	*Catunaregum logispina*	1	22.99	0.19	0.05	0.24	0.12	0	-9.04	-0.02
54	*Engelhardtia spicata*	1	17.9	0.19	0.04	0.23	0.11	0	-9.04	-0.02
55	Climber-1	1	17.9	0.19	0.04	0.23	0.11	0	-9.04	-0.02
56	*Gnetum montanum*	1	11.45	0.19	0.02	0.21	0.11	0	-9.04	-0.02
57	*Lagerstroemia duperreana*	1	13.44	0.19	0.03	0.22	0.11	0	-9.04	-0.02
58	*Croton roxburghii*	1	16.72	0.19	0.04	0.23	0.11	0	-9.04	-0.02
59	*Schoefia fragrans*	1	5.09	0.19	0.01	0.2	0.1	0	-9.04	-0.02
60	*Melodorum fruticosum*	1	1.61	0.19	0	0.19	0.1	0	-9.04	-0.02
61	*Mitrephora vandaeflora*	1	1.99	0.19	0	0.19	0.1	0	-9.04	-0.02
62	*Memecylon* sp.	1	7.95	0.19	0.02	0.21	0.1	0	-9.04	-0.02
63	*Diospyros* sp.2	1	0.72	0.19	0	0.19	0.1	0	-9.04	-0.02
64	*Antidesma velutinosum*	1	2.86	0.19	0.01	0.2	0.1	0	-9.04	-0.02
65	*Euodia roxburghiana*	1	1.27	0.19	0	0.19	0.1	0	-9.04	-0.02
66	*Litsea glutinosa*	1	1.27	0.19	0	0.19	0.1	0	-9.04	-0.02
	Total	528	46,306.8	100	100	200	100	1	-8.09	-4.63

Table 3-10 Biomass of tree species in the dry evergreen forest nearby rubber plantations

Species No.	**Plant name**	**Biomass (kg/rai)**				
		Stem	**Branch**	**Leaf**	**Root**	**Total**
1	*Quercus elegans*	5,357.70	1,586.64	157.77	1,183.61	8,285.72
2	*Schima wallichii*	3,333.01	1,027.89	81.39	677.94	5,120.23
3	*Castanopsis* sp.	2,240.15	650.81	72.44	515.23	3,478.62
4	*Parinari anamense*	1,814.00	513.87	64.45	436.95	2,829.28
5	*Terminalia chebula*	1,633.63	476.38	50.92	371.10	2,532.03
6	*Pterocarpus macrocarpus*	1,124.31	337.58	30.87	241.11	1,733.87
7	*Garcinia cowa*	1,001.75	283.22	36.17	242.56	1,563.70
8	*Lithocarpus* sp.1	819.25	247.87	22.28	174.06	1,263.46
9	*Sindora siamensis*	762.16	210.38	30.79	193.93	1,197.27
10	*Xerospermum noronhianum*	768.98	225.13	24.58	174.95	1,193.63
11	*Syzygium albiflorum*	664.59	196.90	19.66	146.84	1,027.98
12	*Lithocarpus* sp.2	653.38	203.57	15.93	131.45	1,004.33
13	*Dipterocarpus intricatus*	643.84	197.16	16.15	132.67	989.82
14	*Syzygium* sp.	618.85	181.28	19.47	140.20	959.80
15	*Melodorum fruticosum*	520.81	156.03	14.63	112.41	803.88
16	*Canarium subulatum*	496.14	141.75	17.21	117.84	772.94
17	*Casaeria grewiifolia*	449.72	140.00	10.44	89.59	689.76
18	*Cratoxylum pruniflorum*	412.69	108.20	21.26	116.82	658.96
19	*Dalbergia nigrescens*	294.19	89.16	7.67	61.77	452.80
20	*Aporosa villosa*	269.66	69.33	14.84	78.97	432.80
21	*Diospyros* sp.1	240.69	58.05	19.14	81.87	399.74
22	*Dalbergia* sp.	236.08	69.87	6.97	52.18	365.10

Table 3-10 (Continued)

Species No.	Plant name	Biomass (kg/rai)				
		Stem	**Branch**	**Leaf**	**Root**	**Total**
23	*Dillenia obovata*	218.19	55.73	12.11	64.42	350.46
24	*Diospyros* sp.2	203.02	59.42	6.30	45.90	314.63
25	*Symplocos* sp.	148.41	40.05	6.45	39.25	234.16
26	*Quercus kerii*	130.13	37.37	4.33	30.46	202.29
27	*Artocarpus* sp.	102.13	28.18	4.06	25.91	160.27
28	*Syzygium cumini*	97.86	27.67	3.44	23.55	152.52
29	*Gardenia coronaria*	81.67	22.10	3.52	21.50	128.78
30	*Irvingia malayana*	56.12	14.09	3.31	17.08	90.61
31	*Schoutenia ovata*	51.75	14.06	2.16	13.48	81.46
32	*Colona flagrocarpa*	51.75	14.06	2.16	13.48	81.46
33	*Mitrephora vandaeflora*	51.61	14.01	2.16	13.45	81.23
34	*Dalbergia velutina*	47.42	12.05	2.67	14.11	76.25
35	*Symplocos recemosa*	40.08	10.71	1.80	10.78	63.36
36	*Dalbergia volubilis*	35.47	9.04	1.96	10.48	56.95
37	*Memecylon scutellatum*	27.25	6.71	1.76	8.63	44.36
38	*Vitex peduncularis*	26.79	6.97	1.36	7.60	42.72
39	*Olea salicifolia*	24.16	5.70	1.88	8.32	40.07
40	*Ficus prostrata*	24.30	6.29	1.25	6.95	38.80
41	*Memecylon* sp.	19.63	4.70	1.42	6.55	32.30
42	*Dalbergia foliacea*	13.86	3.46	0.83	4.25	22.41
43	Climber-1	13.65	3.41	0.82	4.19	22.07
44	Climber-1	12.82	3.19	0.78	3.97	20.76
45	*Mimusops elengi*	12.53	3.09	0.80	3.94	20.37
46	*Catunaregum spathulifolia*	11.60	2.84	0.78	3.73	18.94
47	*Diospyros glandulosa*	11.00	2.64	0.80	3.66	18.11
48	*Aporosa wallichii*	10.27	2.42	0.84	3.58	17.11
49	*Ardisia* sp.	7.97	1.63	1.16	3.66	14.41
50	*Croton roxburghii*	5.06	1.19	0.40	1.76	8.40
51	*Engelhardtia spicata*	4.67	1.09	0.38	1.64	7.78
52	*Gnetum montanum*	4.04	0.93	0.34	1.44	6.75
53	*Lagerstroemia duperreana*	3.59	0.82	0.31	1.30	6.03
54	*Wendlandia tinctoria*	3.55	0.81	0.31	1.29	5.95
55	*Elaeocarpus sphaericus*	2.82	0.60	0.34	1.20	4.96
56	*Dalbergia cochinchinensis*	2.22	0.49	0.22	0.85	3.78
57	*Dalbergia lanceolaria*	1.84	0.40	0.21	0.75	3.20
58	*Schoefia fragrans*	1.24	0.27	0.14	0.51	2.17
59	*Antidesma velutinosum*	0.60	0.12	0.08	0.27	1.07
60	*Goniothalamus laoticus*	0.33	0.06	0.05	0.16	0.61
61	*Lophopetalum duperreanum*	0.19	0.04	0.04	0.10	0.36
62	*Catunaregum logispina*	0.18	0.03	0.04	0.10	0.35
63	*Pavetta wallichiana*	0.17	0.03	0.04	0.10	0.34
64	*Euodia roxburghiana*	0.15	0.03	0.03	0.08	0.29
65	*Litsea glutinosa*	0.15	0.03	0.03	0.08	0.29
66	*Buchanania latifolia*	0.09	0.02	0.02	0.05	0.18
	Total (kg/rai)	**25,917.90**	**7,589.63**	**828.94**	**5,898.62**	**40,235.10**
	Total (Mg/ha)	**161.98**	**47.44**	**5.18**	**36.87**	**251.47**
	%	64.42	18.86	2.06	14.66	100