

OPTIMAL ROTATION OF TEAK PLANTATION : A CASE STUDY AT THONG PHA PHUM PLANTATION

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ABSTRACT

The study on optimal rotation of teak plantation with spacing of 4x4 m was carried out at Thong Pha Phum plantation, Kanchanaburi province. The 33 sampled plots were randomly laid out in 11 age classes of teak plantation with ranging from 10 to 26 years, and each age class including 3 sampled plots for good, medium and poor site quality. All trees in each sampled plot were measured their diameter at breast height, diameter at stump, diameter at merchantable height, total height and merchantable height. Results of the study indicated that the optimal rotations of teak in the good site quality and at 5 given discount rates of 4, 6, 8, 10 and 12 % were at 44, 44, 36, 10 and 10 years from growing and provided maximized NPV in values of 76,106.60, 28,359.44, 9,066.79, 4,117.59 and 2,723.77 baht per rai respectively. While the medium site quality, at 4 given discount rates of 4, 6, 8 and 10%, their optimal rotation were at 48, 40, 13 and 13 years from planting, and provide NPV in value of 31,264.98, 8,717.10, 1,393.48 and 0.40 baht per rai respectively. In addition, the poor site quality, at 3 given discount rates of 4, 6, and 8%, their optimal rotation were the same at 15 years from growing and provided maximized NPV in values of 5,425.95, 2,623.91 and 612.90 baht per rai respectively. The teak plantation which their optimal rotations were at 36, 40, 44 and 48 years provided timber with the large size which suitable for using in many different forms and having high selling price while the teak plantations which their optimal rotations were shorter to be 10, 13 and 15 years, provided rather small timber, so this will face the limitation of utilization and low selling price.

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INTRODUCTION

Teak is a very important economic tree of the country because of their high quality, beautiful color and with natural grains, suitable for using in various forms, preferential construction material and high price. Nowadays teak in the natural forest is very scarce, however it is used to play an important role in Thai economy in the past. Hence, to recall the former role of Thai teak, the extension program for teak reforestation have been wildly launched by both of government and private agencies in order to response the increasing demand for teak in the future. In present, the current teak plantations were established by various government agencies namely Royal Forest Department, Forest Industry Organization, and Thai Plywood Company Ltd., and private sector, this will assist to mitigate the teak shortage problem of the country.

In nature of the investment in teak reforestation needs a rather large amount of budget, and take a very long time until the rotation will be reached. Thus, the optimal rotation of teak plantation which provides the maximized Net Present Value (NPV) is the most important issue to be determined. Hence, the study on optimal rotation of teak plantation at Thong Pha Phum Plantation, Kanchanaburi Province is needed. The results of the study will be used as a guideline for setting the optimal rotation of teak plantation in each site quality in order to obtain the maximized NPV from the investment.

MATERIALS AND METHODS

Materials

1. Thong Pha Phum Plantation map
2. Tally sheet and tally board
3. Haga altimeter use for measuring the tree height
4. 50 meter tape use for measuring distance
5. String use for sampled plot establishment
6. Spraying color use for marking the standing tree in the sampled plot
7. Diameter tape use for measuring diameter of the tree at breast height
8. Spiegel Relascope use for measuring diameter of the tree at various height level
9. Laser Meter use for measuring the distance between Spiegel Relascope and the measured tree
10. Computer using for data compilation, and data analysis

Data Collection

1. Primary data. The information of growth was collected in 11 sampled plots of teak plantation spacing 4x4 m. which were grown in the year 1978, 1980, 1981, 1982, 1984, 1986, 1987, 1988, 1991, 1992 and 1994 of each age class of such teak plantations. Three sampled plots with the size of 40x40 m (1 rai: 6.25 rais = 1 ha) were laid out, in good, medium and poor site quality. Thus, the total number of sampled plots using for the study were 33

plots. The diameter at breast height (DBH), at stump and at merchantable height, and their total height and merchantable height; and volume of each log of all trees in each sample plot were measured, as well as the history of their thinning cuts, disturbance occurred to the plantation structure, condition of the studied areas, and the other essential information were collected in order to be used as the supporting matter for the data analysis.

2. Secondary data. This data type including information about Thong Pha Phum plantation and research works which were collected Forest Industry Organization (FIO), these were composed of the history of thinning of teak plantation by age, percentage of survival of each teak plantation, and its area, cost and benefit from teak plantation, the applied thinning cut method, as well as the history of disturbance occurred to teak plantation such as forest fire and others.

Data Analysis

1. Teak yield prediction. Due to the growth information of teak plantations by age were not continuously collected. Hence, the data collected from 33 sampled plots used as the representative of 11 age classes of teak plantation by 3 site quality for yield prediction of the individual teak tree in the future by site quality. Thus, the determination of the relationship between volume of individual teak tree in all sampled plots and their ages were carried out. Hence, the ob-

tained volume per each teak tree of each age class will be used for calculating the yield per rai of each age class by multiply with the number of teak trees per rai in each sampled plots by age. So, there were 3 yield prediction equation of each age class by site quality which to be used for predicting the yield of teak in such 3 site quality. The teak yield prediction function representing in form of the relationship between the volume of teak tree and age are as follows

$$V = f(X)$$

where:

$$V = \text{volume of each teak tree (m}^3\text{)}$$

$$X = \text{age (year)}$$

2. Optimal rotation. Optimal rotation of teak plantation could be determined from NPV. The optimal rotation should provide the maximized NPV and with the value over than 0. The formula using for calculating NPV was presented as follows

$$NPV = \sum_{t=1}^n \frac{(B_t - C_t)}{(1+i)^t}$$

where

$$B_t = \text{projected revenue in year } t \text{ (baht)}$$

$$C_t = \text{projected cost in year } t \text{ (baht)}$$

$$i = \text{discount rate (\%)}, \text{ the 5 given discount rates were 4, 6, 8, 10 and 12\%}$$

$$t = \text{duration of the project (1,2,...,n)}$$

$$n = 50 \text{ years}$$

The details of reforestation cost, revenue and thinning cut were represented as follows

2.1 Cost including reforestation cost and logging cost, their details represented as follows

2.1.1 Reforestation cost was composed of the cost of tree planting in the first year and the tending cost starting from the second year until the terminated year of the project (50 years). The first year reforestation cost including the cost for surveying the projected area, site preparation, marking the planting position, planting and replanting with seedling cost, first time circular weeding and apply fertilizer with cost of fertilizer, second time weeding and apply fertilizer with cost of fertilizer, third time weeding, fire prevention, enumerate percentage of seedling survival and construction the inspection road for 5-7 km. in distance, the total cost in the first year was 4,260 baht/rai. Reforestation cost in the second year including first time circular weeding and apply fertilizer with cost of fertilizer, second and third weeding, fire prevention, repair the inspection road, enumerate percentage of survival and cut for coppice, the total cost in the second year was 640 baht/rai. The reforestation cost in the third and fourth year including weed control, apply fertilizer with cost of fertilizer, growth measurement, enumerate percentage of survival, fire prevention, repair the inspection road and fire line, the total cost was 530 baht/rai. Reforestation cost in the fifth year including weed control for 2 times, apply fertilizer with the cost of fertilizer, fire prevention repair the inspection road and fire line, branch pruning and growth

measurement, and enumerate percentage of survival, the total cost was 400 baht/rai. Reforestation cost in the sixth year including weeding control, apply fertilizer and with cost of fertilizer, fire protection, repair the inspection road and fire line, branch pruning, and yield assessment, the total cost was 400 baht/rai. Reforestation cost in the seventh year up to the rotation age of the project (50 years) including weeding control, yield assessment, fire prevention, repair inspection road and fire line, and maintenance the forest plantation area, the total cost in each year was fixed at 320 baht/rai as showed in Appendix Table 1, 2 and 3. (Thong Pha Phum Forest Plantation, 2001)

2.1.2 Logging cost. The logging cost per rai could be calculated by summation the volume of all standing trees in each year with the timber volume obtained from thinning cuts and multiply by the average logging cost per 1 m³. The average logging cost per 1 m³ using for the study was 870 baht/m³. (Chanwowwam, 2002)

2.2 Revenue. The obtained revenue from teak plantation could be calculated by summation of the volume of standing tree and the timber volumes obtained from each thinning and multiply by teak timber price. The using forest plantation teak timber price was based on the Northern Conservation and Forest Plantation Department Office which was set since March, 1, 2004 (FIO, 2004). The revenue from teak plantation showed in Appendix Table 1, 2 and 3.

2.3 Duration of the project was 50

years. The appropriate ages of teak plantation for having thinning as well as the number of the remains of the standing trees after each thinning cut was carried out by site quality were set. In the plantation area with good site quality the first, second and third thinning cut will operate in the year 10, 15 and 20 after growing respectively, while in the medium and poor site quality their first, second and third thinning will be operated in the year 13, 19 and 25; and 15, 22 and 30 respectively and with their number of the remaining trees after the first, second and third thinning of 50, 35 and 25 trees per rai respectively.

RESULTS AND DISCUSSION

General Information of Teak Plantation

From the study indicated that 11 plots of teak plantation with spacing 4x4 m covered total area of 6,073 rais including their age classes ranging from 10 to 26 years. The average height of dominant trees were employed for classifying the site quality into 3 levels, namely good, medium and poor. The average total height of dominant trees, average total height, average merchantable height and average diameter at breast height of the sampled teak trees by site quality were represented in Table 1.

Table 1. Average height of dominant tree, average of total height, average of merchantable height and average diameter at breast height of sampled teak trees by age and site quality

Planted year	Age (years)	Good site quality				Medium site quality				Poor site quality			
		H _D	H _T	H _M	D	H _D	H _T	H _M	D	H _D	H _T	H _M	D
1994	10	17.56	13.96	8.47	17.68	15.06	11.54	5.96	12.61	13.18	9.64	5.06	12.08
1992	12	21.86	17.73	10.82	20.82	19.10	15.32	7.85	14.59	14.84	12.04	6.88	13.96
1991	13	21.34	18.90	10.87	21.22	19.84	16.96	8.46	15.24	15.68	13.40	7.15	14.19
1988	16	27.68	22.76	12.10	22.59	24.44	20.21	10.11	18.86	17.24	15.63	8.08	16.06
1987	17	27.42	23.68	13.35	23.01	25.98	20.79	11.60	21.79	18.84	16.25	8.57	16.61
1986	18	28.18	25.28	13.54	24.48	26.42	21.30	11.85	22.56	21.24	17.52	9.13	17.02
1984	20	35.06	27.51	14.97	27.58	27.20	22.88	12.56	24.03	21.86	19.69	10.59	17.85
1982	22	33.04	29.81	15.42	29.37	30.52	26.36	14.37	25.19	28.28	22.82	12.21	20.80
1981	23	33.00	30.92	15.51	29.84	32.86	28.31	14.62	25.71	30.06	24.85	12.68	21.58
1980	24	36.92	31.83	15.76	30.29	34.64	29.11	14.74	25.98	31.48	26.43	12.87	22.57
1978	26	38.04	34.03	15.82	33.15	36.12	33.07	15.03	28.92	35.06	28.29	13.48	23.41

Remark: H_D = Average height of dominant tree (m)

H_T = Average of total height (m)

H_M = Average of merchantable height (m)

D = Average diameter at breath height (cm)

The Relationship between Tree Volume and Age of Teak

The determination of the individual teak tree volume in each site quality could be done by formulating the relationship between age of teak in such planting years and volume of all teak trees in each sampled plots by age class. The relationship between individual teak tree and age of teak in each

site quality were presented in Table 2. Brought the ages of teak with merchantable size in good, medium and poor site quality which starting from 5, 7 and 7 years respectively, and then substituted them into the equation by site quality for obtaining the individual teak tree volume in each age class as showed in Appendix Table 1, 2 and 3 respectively.

Table 2. Equation representing the relationship between tree volume and age of teak using for volume prediction of individual teak tree by site quality

Site quality	Equation pattern	Equation	R ²
Good	Quadratic	$V = 0.0003X^2 + 0.0085X - 0.0453$	0.7739
Medium	Quadratic	$V = 0.0002X^2 + 0.0051X - 0.0419$	0.5638
Poor	Quadratic	$V = 0.00006X^2 + 0.0021X + 0.0182$	0.5893

Remark : V = Volume of individual teak tree (m³) and X = Age of teak tree (year)

Optimal Rotation

Optimal rotation means the age of teak plantation which provides the return per rai in term of NPV at maximized value and over than 0. Based on the computation of data showed in Appendix Table 1, 2 and 3, in order to determine NPV of teak in good, medium and poor site quality, at the given discount rates of 4, 6, 8, 10 and 12% and with the project duration of 50 years, indicated that in the good site quality at such given discount rates, the optimal rotation were 44, 44, 36, 10 and 10 years and with the NPV in value of 76,106.60, 28,359.44, 9,066.79, 4,177.59 and 2,723.77 baht/rai respectively. The medium site

quality, their optimal rotation and NPV at the given discount rates of 4, 6, 8 and 10% were 48, 40, 13 and 13 years; and 31,264.98, 8,717.10, 1,393.48 and 0.40 baht/rai respectively, while the discount rate at 12% provide the NPV < 0 so the optimal rotation could not be determined. The poor site quality, their optimal rotation and NPV at the given discount rates of 4, 6 and 8% were all at 15 years; and 5,425.95, 2,623.91 and 612.90 baht/rai respectively, while the discount rates of 10 and 12% the optimal rotation could not be determined because their NPV < 0 (Table 3). Chanwowwam, (2002) conducted the financial analysis of teak plantation project at Thong Pha Phum plantation,

Kanchanaburi province. The project duration was starting from 1977 to 2025 (50 years). At 8 given discount rates of 2, 4, 6, 8, 10, 12, 14 and 16 %, the obtained NPV were 349,560,945.29, 147,810,099.90, 60,338,124.43, 21,862,450.04, 4,902,707.50, -2,425,448.51, -5,388,643.65 and -6,370,247.23 baht respectively. In addition, the internal rate

of return (IRR) was 11.13 %. Dumrongthai *et.al.*, (1999) studied on NPV of normal teak which wasn't be infected by beehole borer of Mae Li Plantation, Lumphun Province, with rotation of 25 years, and using the discount rates of 6, 12 and 18%, they were 8,826, 252 and -1,765 baht/rai respectively.

Table 3. Optimal rotation of Thong Pha Phum Teak Plantation by site quality

Site quality	Discount rate (%)	Optimal rotation (year)	Net present value (baht/rai)
Good	4	44	76,106.60
	6	44	28,359.44
	8	36	9,066.79
	10	10	4,177.59
	12	10	2,723.77
Medium	4	48	31,264.98
	6	40	8,717.10
	8	13	1,393.48
	10	13	0.40
	12	-	-
Poor	4	15	5,425.95
	6	15	2,623.91
	8	15	612.90
	10	-	-
	12	-	-

Based on the obtained optimal rotation of teak at 36, 40, 44 and 48 years (Table 3) the teak plantation yielded the large size of merchantable teak timber and selling price, while the shorter optimal rotation of

teak plantation of 10, 13 and 15 years provided quite rather small size of teak timber. This will cause the limitation of use and it's selling price was rather low.

CONCLUSION AND RECOMMENDATION

The study on optimal rotation of Thong Pha Phum teak plantation, Kanchanaburi Province with spacing 4x4 m. for 11 age classes plantation plots, it covered total area of 6,073 rais. The studied teak having ages ranging from 10 to 26 years, these were classified by site quality in to 3 levels namely good, medium and poor. 33 sampled plots with 40x40 m. were randomly laid out in such 11 age classes of teak plantation and the number of sampled plots of each age class was 3 including one sample plot in each site quality. Base on the study on optimal rotation (the year that provides the maximized NPV per rai and with value over than 0) indicated that in good site quality their optimal rotation and NPV at the given discount rates of 4, 6, 8, 10 and 12% were 44, 44, 36, 10 and 10 years; and 76,106.60, 28,359.44, 9,066.79, 4,177.59 and 2,723.77 baht/rai respectively. Medium site quality, their optimal rotation and NPV at the given discount rates of 4, 6, 8 and 10% were 48, 40, 13 and 13 years; and 31,264.98, 8,717.10, 1,393.48, and 0.40 baht/rai respectively. In addition, the poor site quality, their optimal rotation and NPV at the given discount rate of 4, 6 and 8 were all at 15 years; and 5,425.95, 2,623.91 and 612.90 baht/rai respectively.

Optimal rotation of teak at 10, 13 and 15 years provided the small size of teak timber. This will cause the limitation of use and it's selling price is quite low. Thus,

the related government agencies should encourage the entrepreneurs of general wood industry as well as the people to utilize the small teak timber and in the same time the searching for market to absorb the small teak timber is also needed in order to expand it's utilization level and to raise it's price. The small teak timber could be used in various forms such as to be used as raw material of wood carving industry, toy making which were preference goods in the foreign market, and it was the suitable material for log cabin construction.

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Appendix Table 1. Cost and revenue of teak plantation aged 1-50 years in the good site Quality

Year	Tree volume (m ³)	No. of tree per rai	Yield per rai (m ³)	Average teak price per tree (baht)	Cost (baht/rai)		Revenue (baht/rai)	
					Reforestation cost per rai	Logging cost per rai	Value of the remaining standing trees	Value of thinning cut timber
1					4,260			
2					640			
3					530			
4					530			
5	0.0047	100	0.4700	17.27	400	408.90	1,727.25	
6	0.0165	100	1.6500	60.64	400	1,435.50	6,063.75	
7	0.0289	100	2.8900	124.27	320	2,514.30	12,427.00	
8	0.0419	100	4.1900	180.17	320	3,645.30	18,017.00	
9	0.0555	100	5.5500	238.65	320	4,828.50	23,865.00	
10	0.0697	50	3.4850	299.71	320	3,031.95	14,985.50	14,985.50
11	0.0845	50	4.2250	426.73	320	3,675.75	21,336.25	
12	0.0999	50	4.9950	504.50	320	4,345.65	25,224.75	
13	0.1159	50	5.7950	585.30	320	5,041.65	29,264.75	
14	0.1325	50	6.6250	771.81	320	5,763.75	38,590.63	
15	0.1497	35	5.2395	872.00	320	4,558.37	30,520.09	13,080.04
16	0.1675	35	5.8625	975.69	320	5,100.38	34,149.06	
17	0.1859	35	6.5065	1,222.29	320	5,660.66	42,780.24	
18	0.2049	35	7.1715	1,347.22	320	6,239.21	47,152.61	
19	0.2245	35	7.8575	1,689.36	320	6,836.03	59,127.69	
20	0.2447	25	6.1175	1,841.37	320	5,322.23	46,034.19	18,413.68
21	0.2655	25	6.6375	1,997.89	320	5,774.63	49,947.19	
22	0.2869	25	7.1725	2,467.34	320	6,240.08	61,683.50	
23	0.3089	25	7.7225	2,656.54	320	6,718.58	66,413.50	
24	0.3315	25	8.2875	3,207.26	320	7,210.13	80,181.56	
25	0.3547	25	8.8675	3,431.72	320	7,714.73	85,793.06	
26	0.3785	25	9.4625	4,078.34	320	8,232.38	101,958.44	
27	0.4029	25	10.0725	4,341.25	320	8,763.08	108,531.19	
28	0.4279	25	10.6975	5,145.50	320	9,306.83	128,637.44	
29	0.4535	25	11.3375	5,453.34	320	9,863.63	136,333.44	
30	0.4797	25	11.9925	6,404.00	320	10,433.48	160,099.88	
31	0.5065	25	12.6625	6,761.78	320	11,016.38	169,044.38	
32	0.5339	25	13.3475	7,861.68	320	11,612.33	196,541.94	
33	0.5619	25	14.0475	9,116.83	320	12,221.33	227,920.69	
34	0.5905	25	14.7625	9,580.86	320	12,843.38	239,521.56	
35	0.6197	25	15.4925	10,054.63	320	13,478.48	251,365.81	
36	0.6495	25	16.2375	11,528.63	320	14,126.63	288,215.63	
37	0.6799	25	16.9975	12,068.23	320	14,787.83	301,705.63	
38	0.7109	25	17.7725	12,618.48	320	15,462.08	315,461.88	
39	0.7425	25	18.5625	14,348.81	320	16,149.38	358,720.31	
40	0.7747	25	19.3675	14,971.08	320	16,849.73	374,276.94	
41	0.8075	25	20.1875	15,604.94	320	17,563.13	390,123.44	
42	0.8409	25	21.0225	17,553.79	320	18,289.58	438,844.69	
43	0.8749	25	21.8725	18,263.54	320	19,029.08	456,588.44	
44	0.9095	25	22.7375	20,395.54	320	19,781.63	509,888.44	
45	0.9447	25	23.6175	21,184.90	320	20,547.23	529,622.44	
46	0.9805	25	24.5125	21,987.71	320	21,325.88	549,692.81	
47	1.0169	25	25.4225	22,803.98	320	22,117.58	570,099.56	
48	1.0539	25	26.3475	23,633.71	320	22,922.33	590,842.69	
49	1.0915	25	27.2875	24,476.89	320	23,740.13	611,922.19	
50	1.1297	25	28.2425	25,333.52	320	24,570.98	633,338.06	

Appendix Table 2. Cost and revenue of teak plantation aged 1-50 years in the medium site Quality

Year	Tree volume (m ³)	No. of tree per rai	Yield per rai (m ³)	Average teak price per tree (baht)	Cost (baht/rai)		Revenue (baht/rai)	
					Reforestation cost per rai	Logging cost per rai	Value of the remaining standing trees	Value of thinning cut timber
1					4,260			
2					640			
3					530			
4					530			
5					400			
6					400			
7	0.0036	100	0.3600	10.71	320	313.20	1,071.00	
8	0.0117	100	1.1700	34.81	320	1,017.90	3,480.75	
9	0.0202	100	2.0200	66.16	320	1,757.40	6,615.50	
10	0.0291	100	2.9100	95.30	320	2,531.70	9,530.25	
11	0.0384	100	3.8400	141.12	320	3,340.80	14,112.00	
12	0.0481	100	4.8100	176.77	320	4,184.70	17,676.75	
13	0.0582	50	2.9100	150.26	320	2,531.70	12,513.00	12,513.00
14	0.0687	50	3.4350	195.41	320	2,988.45	14,770.50	
15	0.0796	50	3.9800	401.98	320	3,462.60	20,099.00	
16	0.0909	50	4.5450	459.05	320	3,954.15	22,952.25	
17	0.1026	50	5.1300	597.65	320	4,463.10	29,882.25	
18	0.1147	50	5.7350	668.13	320	4,989.45	33,406.38	
19	0.1272	35	4.4520	836.34	320	3,873.24	29,271.90	12,545.10
20	0.1401	35	4.9035	921.16	320	4,266.05	32,240.51	
21	0.1534	35	5.3690	1,154.34	320	4,671.03	40,401.73	
22	0.1671	35	5.8485	1,257.43	320	5,088.20	44,009.96	
23	0.1812	35	6.3420	1,363.53	320	5,517.54	47,723.55	
24	0.1957	35	6.8495	1,683.02	320	5,959.07	58,905.70	
25	0.2106	25	5.2650	1,811.16	320	4,580.55	45,279.00	18,111.60
26	0.2259	25	5.6475	2,185.58	320	4,913.33	54,639.56	
27	0.2416	25	6.0400	2,337.48	320	5,254.80	58,437.00	
28	0.2577	25	6.4425	2,493.25	320	5,604.98	62,331.19	
29	0.2742	25	6.8550	2,954.51	320	5,963.85	73,862.63	
30	0.2911	25	7.2775	3,136.60	320	6,331.43	78,415.06	
31	0.3084	25	7.7100	3,708.51	320	6,707.70	92,712.75	
32	0.3261	25	8.1525	3,921.35	320	7,092.68	98,033.81	
33	0.3442	25	8.6050	4,139.01	320	7,486.35	103,475.13	
34	0.3627	25	9.0675	4,842.05	320	7,888.73	121,051.13	
35	0.3816	25	9.5400	5,094.36	320	8,299.80	127,359.00	
36	0.4009	25	10.0225	5,352.02	320	8,719.58	133,800.38	
37	0.4206	25	10.5150	6,193.34	320	9,148.05	154,833.38	
38	0.4407	25	11.0175	6,489.31	320	9,585.23	162,232.69	
39	0.4612	25	11.5300	6,791.17	320	10,031.10	169,779.25	
40	0.4821	25	12.0525	7,822.07	320	10,485.68	195,551.81	
41	0.5034	25	12.5850	8,167.67	320	10,948.95	204,191.63	
42	0.5251	25	13.1275	8,519.75	320	11,420.93	212,993.69	
43	0.5472	25	13.6800	8,878.32	320	11,901.60	221,958.00	
44	0.5697	25	14.2425	9,243.38	320	12,390.98	231,084.56	
45	0.5926	25	14.8150	9,614.94	320	12,889.05	240,373.38	
46	0.6159	25	15.3975	9,992.98	320	13,395.83	249,824.44	
47	0.6396	25	15.9900	10,377.51	320	13,911.30	259,437.75	
48	0.6637	25	16.5925	11,780.68	320	14,435.48	294,516.88	
49	0.6882	25	17.2050	12,215.55	320	14,968.35	305,388.75	
50	0.7131	25	17.8275	12,657.53	320	15,509.93	316,438.13	

Appendix Table 3. Cost and revenue of teak plantation aged 1-50 years in the poor site Quality

Year	Tree volume (m ³)	No. of tree per rai	Yield per rai (m ³)	Average teak price per tree (baht)	Cost (baht/rai)		Revenue (baht/rai)	
					Reforestation cost per rai	Logging cost per rai	Value of the remaining standing trees	Value of thinning cut timber
1					4,260		4,377.40	
2					640		4,867.60	
3					530		5,383.60	
4					530		5,925.40	
5					400		6,493.00	
6					400		9,805.60	
7	0.0358	100	3.5840	106.62	320	3,118.08	10,662.40	
8	0.0388	100	3.8840	115.55	320	3,379.08	11,554.90	
9	0.0420	100	4.1960	137.42	320	3,650.52	13,741.90	
10	0.0452	100	4.5200	148.03	320	3,932.40	14,803.00	
11	0.0486	100	4.8560	178.46	320	4,224.72	17,845.80	
12	0.0520	100	5.2040	191.25	320	4,527.48	19,124.70	
13	0.0556	100	5.5640	204.48	320	4,840.68	20,447.70	
14	0.0594	100	5.9360	218.15	320	5,164.32	21,814.80	
15	0.0632	50	3.1600	271.76	320	2,749.20	13,588.00	13,588.00
16	0.0672	50	3.3580	288.79	320	2,921.46	14,439.40	
17	0.0712	50	3.5620	306.33	320	3,098.94	15,316.60	
18	0.0754	50	3.7720	380.97	320	3,281.64	19,048.60	
19	0.0798	50	3.9880	402.79	320	3,469.56	20,139.40	
20	0.0842	50	4.2100	425.21	320	3,662.70	21,260.50	
21	0.0888	50	4.4380	448.24	320	3,861.06	22,411.90	
22	0.0934	35	3.2704	544.29	320	2,845.25	19,050.08	8,164.32
23	0.0982	35	3.4384	572.25	320	2,991.41	20,028.68	
24	0.1032	35	3.6106	600.91	320	3,141.22	21,031.75	
25	0.1082	35	3.7870	630.27	320	3,294.69	22,059.28	
26	0.1134	35	3.9676	745.34	320	3,451.81	26,086.97	
27	0.1186	35	4.1524	780.06	320	3,612.59	27,302.03	
28	0.1240	35	4.3414	815.56	320	3,777.02	28,544.71	
29	0.1296	35	4.5346	851.86	320	3,945.10	29,815.00	
30	0.1352	25	3.3800	888.94	320	2,940.60	22,223.50	8,889.40
31	0.1410	25	3.5240	1,060.72	320	3,065.88	26,518.10	
32	0.1468	25	3.6710	1,104.97	320	3,193.77	27,624.28	
33	0.1528	25	3.8210	1,150.12	320	3,324.27	28,753.03	
34	0.1590	25	3.9740	1,196.17	320	3,457.38	29,904.35	
35	0.1652	25	4.1300	1,243.13	320	3,593.10	31,078.25	
36	0.1716	25	4.2890	1,475.42	320	3,731.43	36,885.40	
37	0.1780	25	4.4510	1,531.14	320	3,872.37	38,278.60	
38	0.1846	25	4.6160	1,587.90	320	4,015.92	39,697.60	
39	0.1914	25	4.7840	1,645.70	320	4,162.08	41,142.40	
40	0.1982	25	4.9550	1,704.52	320	4,310.85	42,613.00	
41	0.2052	25	5.1290	1,764.38	320	4,462.23	44,109.40	
42	0.2122	25	5.3060	2,053.42	320	4,616.22	51,335.55	
43	0.2194	25	5.4860	2,123.08	320	4,772.82	53,077.05	
44	0.2268	25	5.6690	2,193.90	320	4,932.03	54,847.58	
45	0.2342	25	5.8550	2,265.89	320	5,093.85	56,647.13	
46	0.2418	25	6.0440	2,339.03	320	5,258.28	58,475.70	
47	0.2494	25	6.2360	2,413.33	320	5,425.32	60,333.30	
48	0.2572	25	6.4310	2,771.76	320	5,594.97	69,294.03	
49	0.2652	25	6.6290	2,857.10	320	5,767.23	71,427.48	
50	0.2732	25	6.8300	2,943.73	320	5,942.10	73,593.25	