Profitability of combined farm management with teak plantations in Northeast Thailand

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Abstract

Farmers want to select a suitable land use pattern for their agricultural land management. Profitability criteria can be useful for decision-making to select a better practice. Teak plantations are said to be highly profitable, but the farmer would have no benefit during the period of time up until teak log harvesting. In this study, we focused on a typical farmer who planted a teak plantation in Nong Bua Lam Phu Province of Northeast Thailand, in terms of land size and land use pattern for crops. The profitability of cash flow models of combined farm management with teak plantation was examined using the equivalent annual income (EAI), among others. The combined approach to farm management improved profitability and mitigated the negative earnings caused by focusing only on teak, and increased the estimated EAIs by 19–315% in comparison with an approach focusing only on teak. In terms of the EAI and benefit/cost (B/C) ratio, the results were 20-year rotation > 15-year, and 4x4 m spacing > 2x4 m. The EAIs were highly sensitive to the log prices at the final cutting age. Second rice allocation was the most important among all crops, and sugarcane and cassava allocations decreased profitability. Thus, producing a higher quality logs at the final cutting age and selecting better land allocation for the combined management approach could effectively improve the level of profitability.

Keywords: teak forest management, land use, farmers, discounted cash flow

Introduction

In Northeast Thailand, some farmers have given up on teak plantations and returned to the cultivation of other cash crops, or chosen to plant other fast-growing tree species. Yokota et al. (2009) and others have pointed out that one of the main reasons for this is that such farmers could not wait for 10 or more years with no benefits until teak harvesting. In terms of farmers' forestry approaches using a valuable indigenous tree species, teak (*Tectona grandis*), in Thailand, Noda et al. (2004) suggested multiple use of their lands, and Yokota et al. (2009) suggested a forest future profit projection method, suitable forest planning, and the adoption of combined farm management with teak plantation to cover the no-profit period before teak harvesting. In addition, Phothitai (1993) and Niskanen (1998), among others, previously studied the profitability of a teak only plantation management approach or its combination with other activities. Niskanen (1998) studied the profitability of teak and cash crop management using agroforestry (intercropping) methods. However, the profitability of combined farm management with teak plantation excluding intercropping systems has not been studied. Therefore, the aim of this study was to compare the profitability of combined farm management with teak plantations and that of teak only plantation management by farmers in Northeast Thailand, and to examine the effects of factors influencing the profitability in order to develop better management practices.

This research was conducted under the RFD-JIRCAS Joint Research Project: 'Development of Techniques for Nurturing Beneficial Indigenous Tree Species and Combined Management of Agriculture and Forestry in the Northeast of Thailand'.

Table 1. The standard costs and benefits for teak plantation management with 15-year rotation in Nong Bua Lam Phu Province

(rotation 15 years, spacing 2x4 m)

Activities	Unit	Year of period														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Survey	man·day	0.5														
Land preparation	man·day	4														
Slash and burn	man·day	4														
Survey road	man·day	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fire line	man·day	1														
Alignment and Staking	man·day	2														
Planting and seedling transportation	man·day	3														
Weeding	man·day	4	6	6	6	6	6	2	2	2	2	6	2	2	2	2
Fertilizing	man·day	0.5	0.5	0.5				0.5	0.5				0.5	0.5		
Replanting and survival rate checking	man·day	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pruning	man·day							1	1	1	1		1	1	1	1
Thinning 50%	man·day					5										
Logging	man·day										7					7
Number of seedlings	tree	220														
Amount of fertilizer	kg	100	100	100			100	100				100	100			
Yield	m^3	0	0	0	0	4	0	0	0	0	5	0	0	0	0	8
Yield log price	baht/m^3	0	0	0	0	1,500	0	0	0	0	3,000	0	0	0	0	5,000

(rotation 15 years, spacing 4x4 m)

Activities	Unit	Year of period														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Survey	man·day	0.5														
Land preparation	man·day	4														
Slash and burn	man·day	4														
Survey road	man·day	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fire line	man·day	1														
Alignment and Staking	man·day	2														
Planting and seedling transportation	man·day	3														
Weeding	man·day	4	6	6	6	6	6	2	2	2	2	6	2	2	2	2
Fertilizing	man·day	0.5	0.5	0.5				0.5	0.5				0.5	0.5		
Replanting and survival rate checking	man·day	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pruning	man·day							1	1	1	1		1	1	1	1
Thinning 50%	man·day					5										
Logging	man·day										7					7
Number of seedlings	tree	120														
Amount of fertilizer	kg	50	50	50			50	50				100	100			
Yield	m^3	0	0	0	0	3	0	0	0	0	5	0	0	0	0	9
Yield log price	baht/m^3	0	0	0	0	1,500	0	0	0	0	3,000	0	0	0	0	5,000

Source: Royal Forest Department(2006). The data is noted as a case model for Nong Bua Lam Phu Province.

Table 2. The standard costs and benefits of teak plantation management with 20-year rotation in Nong Bua Lam Phu Province

(rotation 20 years, spacing 2x4 m)

Activities	Unit	Year of period																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Survey	man·day	0.5																			
Land preparation	man·day	4																			
Slash and burn	man·day	4																			
Survey road	man·day	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fire line	man·day	1																			
Alignment and Staking	man·day	2																			
Planting and seedling transportation	man·day	3																			
Weeding	man·day	4	6	6	6	6	6	2	2	2	2	6	2	2	2	2	6	2	2	2	2
Fertilizing	man·day	0.5	0.5	0.5				0.5	0.5				0.5	0.5				0.5	0.5		
Replanting and survival rate checking	man·day	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pruning	man·day							1	1	1	1		1	1	1	1		1	1	1	1
Thinning 50%	man·day					5															
Logging	man·day										7					7					7
Number of seedlings	tree	220																			
Amount of fertilizer	kg	100	100	100			100	100				100	100				100	100			
Yield	m^3	0	0	0	0	3	0	0	0	0	5	0	0	0	0	5	0	0	0	0	11
Yield log price	baht/m^3	0	0	0	0	1,500	0	0	0	0	3,000	0	0	0	0	5,000	0	0	0	0	7,000

(rotation 20 years, spacing 2x4 m)

Activities	Unit	Year of period																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Survey	man·day	0.5																			
Land preparation	man·day	4																			
Slash and burn	man·day	4																			
Survey road	man·day	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Fire line	man·day	1																			
Alignment and Staking	man·day	2																			
Planting and seedling transportation	man·day	3																			
Weeding	man·day	4	6	6	6	6	6	2	2	2	2	6	2	2	2	2	6	2	2	2	2
Fertilizing	man·day	0.5	0.5	0.5				0.5	0.5				0.5	0.5				0.5	0.5		
Replanting and survival rate checking	man·day	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pruning	man·day							1	1	1	1		1	1	1	1		1	1	1	1
Thinning 50%	man·day					5															
Logging	man·day										7					7					7
Number of seedlings	tree	120																			
Amount of fertilizer	kg	50	50	50			50	50				100	100				100	100			
Yield	m^3	0	0	0	0	3	0	0	0	0	5	0	0	0	0	5.5	0	0	0	0	12
Yield log price	baht/m^3	0	0	0	0	1,500	0	0	0	0	3,000	0	0	0	0	5,000	0	0	0	0	7,000

Source: Royal Forest Department(2006). The data is noted as a case model for Nong Bua Lam Phu Province.

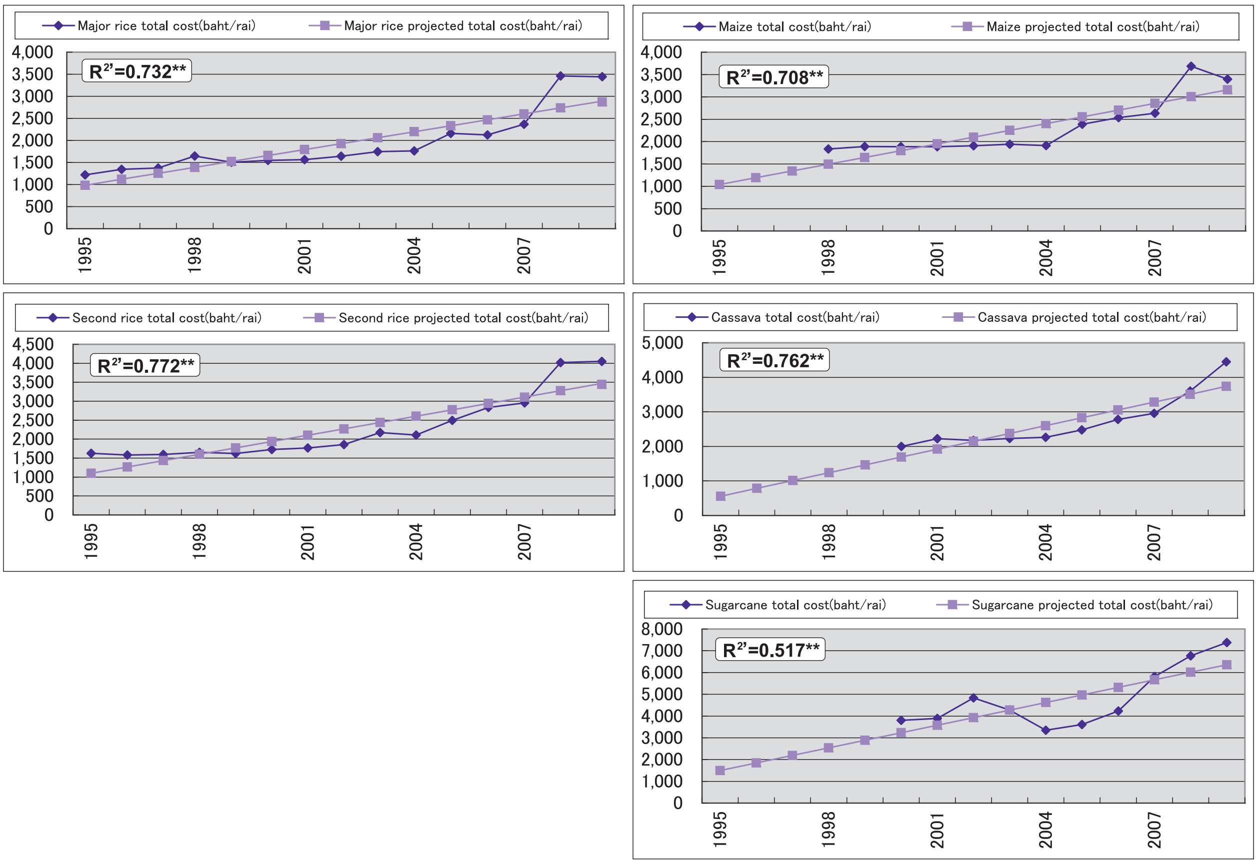

Fig. 1. Cost trend of cash crops in Northeast Thailand. X- and Y-axis mean year and total cost, respectively.

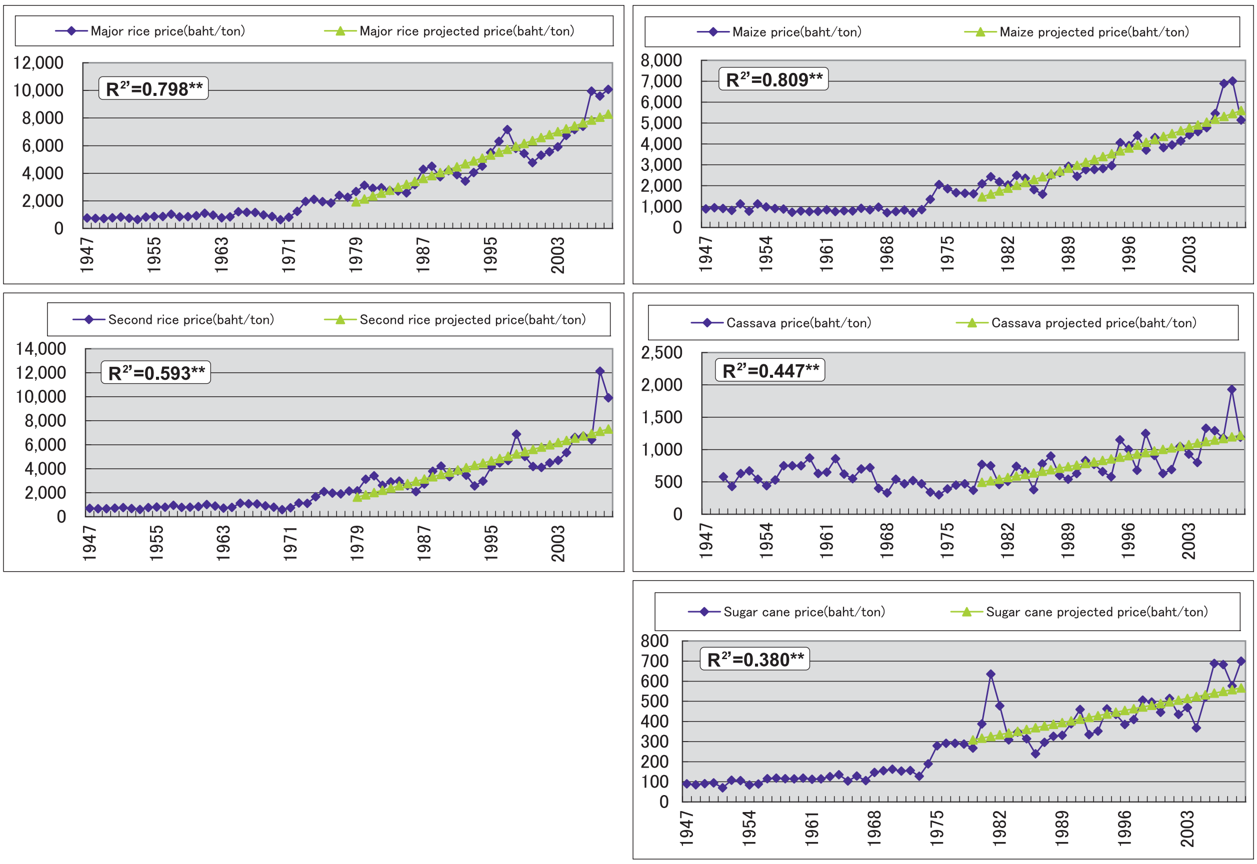

Fig. 2. Farmer's price trends of cash crops in the whole of Thailand. X- and Y-axis mean year and price, respectively.

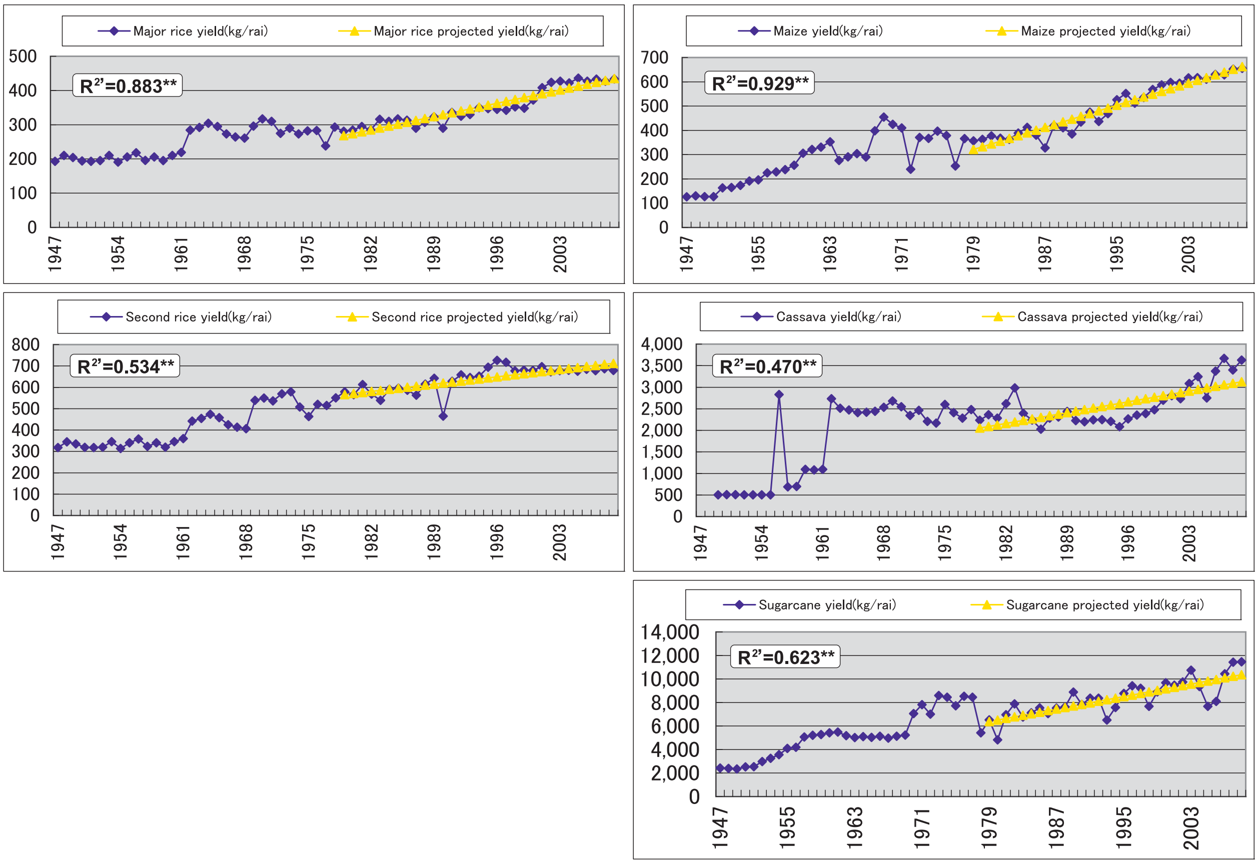

Fig. 3. Yield trends of cash crops in the whole of Thailand. X- and Y-axis mean year and yield, respectively.

Materials and methods

1. Agricultural land allocation pattern

A land allocation pattern in Northeast Thailand was chosen as teak plantation management with the cultivation of typical cash crops such as major rice, second rice, maize, cassava, and sugarcane. We did not include an inter-cropping type. The study site was selected as Nong Bua Lam Phu Province in Northeast Thailand. We assumed a model farmer in the study as one who owned 20 rais of land (1 rai = 0.16 ha) because the mean area of land ownership of farmers is 19.7 rais in Nong Bua Lam Phu Province, according to the Thai Agricultural Statistics 2003 from the Office of Agricultural Economics (OAE). Furuya et al. (2011) showed that the land allocation was 40% for teak, 40% for paddy, 10% for field crops, and 10% for pond & others. Therefore, the model farmland was set with an allocation as follows: teak 8 rais, paddy 8 rais, field crops 2 rais, and pond & others 2 rais. We evaluated management of 18 rais of land, excluding the 2 rais for the pond & others.

In our model, the farmer cultivates major rice on 100% of the area of paddy. As a strict assumption, he cultivates second rice on half of the area of the paddy. This assumption is used because a proportion of farmers may not cultivate second rice. Therefore, in the model, we assumed that the farmland use was teak 8 rais, major rice 8 rais, second rice 4 rais, and field crops (maize, cassava, sugarcane) 2 rais.

2. Cash flow modeling of teak plantation and cash crop cultivation

(1) Teak plantation

We selected the rotation periods of 15 years and 20 years, and planting spacing of 2x4 m and 4x4 m in teak plantation management. The initial establishment, other silvicultural costs, and the benefits from the teak plantation were the same as the standard costs and benefits for reforestation in Nong Bua Lam Phu Province of Northeast Thailand as determined by the Royal Forest Department (2006) (Tables 1,2). For the financial analysis, the unit costs of labor, seedlings, and fertilizer were set at 180 baht/day/person, 5 baht/tree, and 10 baht/kg, respectively, according to the Royal Forest Department (2006).

All of the teak log prices for the study were assumed to be constant and to be free of inflation. For simplicity, administration costs were excluded from the analyses.

(2) Cash crop cultivation

The costs and benefits for cash crops were investigated from statistical data. We conducted regression analyses of production cost, yield ratio, and farmer price, for which the statistical data source was the OAE. As for the annual data

Table 3. Setting assumptions for teak log prices

Log prices	Base value	Range
Log price 20yr-old (baht/m^3)	7,000	6,300-7,700
Log price 15yr-old (baht/m^3)	5,000	4,500-5,500
Log price 10yr-old (baht/m^3)	3,000	2,700-3,300
Log price 5yr-old (baht/m^3)	1,500	1,350-1,650

Source: Royal Forest Department(2006)

used, the production cost was over a 16-year period, 1995-2009, in Northeast Thailand, and the yield ratio and farmer price were over a 31-year period, 1979-2009, in the whole of Thailand. Regression lines of the production cost, the yield ratio, and the farmer price were determined to be significant (R^{2}': adjusted R square. *: p<0.1, **: p<0.05) (Fig. 1-3), and the determination coefficients are shown. We estimated the future annual cost, C, and benefit, B, for the financial analysis using the regression lines, assuming the initial year of the evaluation period as 2010 for the profitability analysis. The C_{it} was obtained by the regression lines of Fig.1, and the B_{it} was obtained by Eq.1.

$$B_{it} = P_{it} \times Y_{it}/1000 \qquad (1)$$

where B_{it} is benefit of cash crop i (baht/rai), C_{it} is production cost of cash crop i (baht/rai), Y_{it} is yield ratio of cash crop i (kg/rai), P_{it} is farmer price of cash crop i (baht/ton), t is the t^{th} year of the management period, and i is a cash crop among major rice, second rice, maize, cassava, and sugarcane.

For cassava and sugarcane, the estimated costs were greater than the estimated benefits for the next 20 years. Therefore, the model farmer should not select cassava and sugarcane as field crops, and his land use would thus be teak 8 rais, major rice 8 rais, second rice 4 rais, maize 2 rais, cassava 0 rai, sugarcane 0 rai, and pond & others 2 rais.

(3) Profitability evaluation

The profitability analyses calculate criteria using discounted cash flow analysis techniques (Price, 1989). The criteria are the net present value (NPV), the benefit-cost ratio (B/C ratio), and the internal rate of return (IRR). For application of NPV, we should select in order of highest NPV from a group of compatible investments (Price, 1989), and can convert NPV to an annual amount called the equivalent annual income (EAI) to compare forestry investment with other land uses for a certain period using the following formula:

$$\mathrm{EAI} = \mathrm{NPV} \times \frac{i \cdot (1+i)^{n}}{(1+i)^{n-1}} \qquad (2)$$

where n is the number of years in the rotation and i is the discount rate (Friday et al. 2000). In this study, we basically used EAI to compare profitability because we have different rotations of investment project period, 20 years vs. 15 years. However, we also determined NPV and B/C ratio. The discount rate for the profitability evaluations was set to 10%.

Firstly, we evaluated the profitability of combined farm management with teak plantation for the model farmland use by rotation year and spacing, and made a comparison between the model farmland use (teak 8 rais, major rice 8 rais, second rice 4 rais, maize 2 rais, cassava and sugarcane 0 rai) and the teak only approach for the same area of 18 rais.

Secondly, the uncertainty associated with log price information and the influences of the selection of the allocated land area were examined with sensitivity analyses and parametric analyses, respectively. The sensitivity of the investment to variation in the input log price was examined using Oracle Crystal Ball 11 (Oracle Corp.) to fit a probability distribution to the log price variables and to run Monte Carlo simulations. A triangular distribution was obtained with maximum and minimum values ±10% of the base value (Table 3). The influence of the selection of the allocated land area to the EAI was also examined using the same software to test each variable independently of the others. Hence, the parametric analysis does not consider correlations defined between the variables, but the spider charts from the parametric analysis illustrate the differences between the minimum and maximum forecast values by graphically representing a curve through all the variable values tested.

Results

1. Profitability of combining farm management with teak plantation

The estimated EAIs of the four cases combining farm management with teak plantation were positive and in the range of 1,088–1,595 baht/rai/year (Table 4). The combined teak management of the cases with 20-year rotation, AL 2044 and AL2024, showed higher EAIs than the cases with 15-year rotation, AL1544 and AL1524. The cases with spacing of 4x4 m, AL2044 and AL1544, showed higher EAIs than the cases with spacing of 2x4 m, AL2024 and AL 1524. This means that AL2044 was the most profitable, with an EAI of 1,595 baht/rai/year, among the four cases. The estimated B/C ratios of the 4 cases were in the range of 1.27–1.40, and the values for the cases with 20-year rotation were higher than those with 15-year rotation; in addition, B/C ratio was higher in the cases with spacing of 4x4 m than in the 2x4 m cases (Table 4). Therefore, the case with 20-year rotation and spacing of 4x4 m was not only the most profitable but also the most efficient among the four cases.

In comparison to the teak only cases, the adoption of a combined approach increased the estimated EAIs by 19–315% (Table 4). The EAI by the adoption of a combined approach with 15-year rotation increased 109 and 315%, and the extent of increase was much greater than the corresponding values of 19 and 34% in the 20-year rotation cases, respectively. The estimated EAI by the adoption of

Table 4. The profitability criteria of the combined farm management and teak only management approaches

Rotation age(year) / Spacing		20 / 4x4m	20 / 2x4m	15 / 4x4m	15 / 2x4m
Combined farm management	Case code	AL2044	AL2024	AL1544	AL1524
	EAI (baht/rai/yr)	1,595	1,393	1,234	1,088
	B/C ratio	1.40	1.34	1.32	1.27
	NPV (baht/rai)	13,583	11,860	9,385	8,273
Teak only management	Case code	TK2044	TK2024	TK1544	TK1524
	EAI (baht/rai/yr)	1,337	882	591	262
	B/C ratio	1.70	1.41	1.30	1.12
	NPV (baht/rai)	11,383	7,509	4,495	1,993
Difference between the combined and teak only EAI (baht/rai/yr) and (%)		258(19%)	511(34%)	643(109%)	826(315%)

The discount rate was set to 10 %.

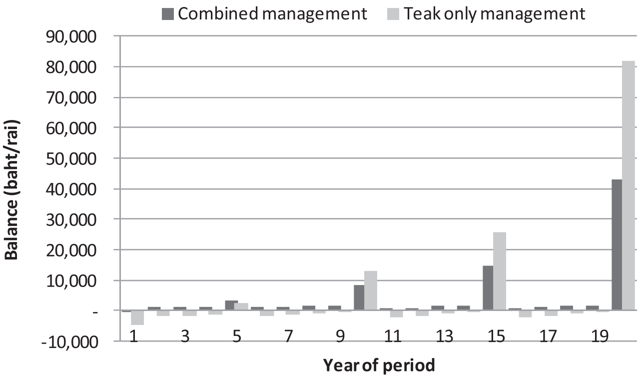

Fig. 4. Comparison of cash flow balances between the combined farm management and teak only in the case with 20-year rotation and 4x4 m spacing

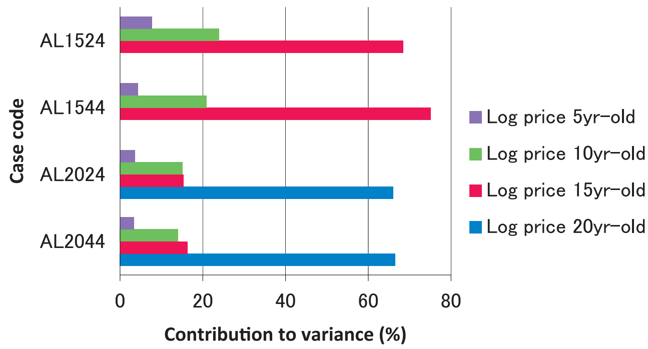

Fig. 5. The influences of log prices on the EAI

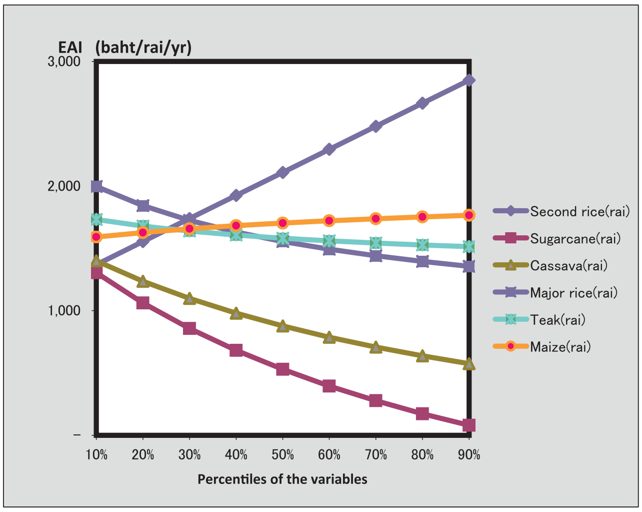

Fig. 6. Relationship between the crop land allocation and EAI by parametric analysis with 20-year rotation and spacing of 4x4 m

the combined approach in the cases with spacing of 2x4 m increased 34 and 315%, and the extent of increase was greater than the corresponding values of 19 and 109% in the cases with 4x4 m spacing, respectively. This means that the adoption of the combined approach increased the EAI the most with 15-year rotation and 2x4 m spacing among the four cases. As for the cash flow balance, the teak only approach showed negative earnings during the periods with no teak harvest (Fig. 4). However, the adoption of a combined approach mitigated the negative earnings.

2. Sensitivity analysis and parametric analysis

The estimated EAIs were highly sensitive to the log prices at the final cutting age in the cases with a combined approach (Fig. 5). The contributions to variance (CTVs) of the log prices at the final cutting age were 66–75%; the CTVs of the log prices at the last thinning age were 15–24%. Younger log prices before final cutting age in general affected less to the EAIs.

The spider chart as Fig. 6 illustrates the differences between the minimum and maximum forecast values by graphing a curve through all the variable values tested, and curves with steep slopes, positive or negative, indicate that those variables have a large effect on the forecast (Gentry et al. 2005). The spider chart showed that second rice allocation had the steepest positive slope, that is, the highest sensitivity ranking, and is the most important among all six variables (Fig. 6). The sugarcane and cassava allocations had the steepest negative slopes, that is, a large negative effect on the EAIs. The major rice and teak allocations had mild negative slope and showed little effect on the EAIs, while the maize allocation showed little positive effect.

Discussions

In this study, the assessed IRRs for the teak only approach were 16.6% in TK2044, 14.1% in TK2024, 14.2% in TK1544, and 11.8% in TK1524. Niskanen (1998) concluded that the estimated financial profitability of reforestation in Thailand was high, and showed that the estimated IRRs and financial land expectation values (LEV) of industrial (MAI 10 m^3/ha/year) and community-based (MAI 7.5 m^3/ha/year) teak reforestation options with 25-year rotation in Thailand were 19.0 and 17.4% and 99,974 and 70,594 baht/ha/year, respectively, with a 10% discount rate. The LEV can be converted to EAI using the following formula:

$$\mathrm{EAI} = i \times \mathrm{LEV} \quad (3)$$

where i is the discount rate (Friday et al. 2000). The EAIs are equal to 1,600 and 1,130 baht/rai/year, respectively. The profitability of TK2044 was close to and intermediate between the intensive and extensive teak management EAIs with 25-year rotation (Table 4), and the situation could be considered proper.

Farmers' net cash benefits from agriculture were 22,085 baht/household/year in Northeast Thailand and 19,920 baht/household/year in Nong Bua Lam Phu Province, according to the Thailand Agricultural Statistics 2005 (OAE). The amount of net cash benefits from agriculture would be 28,710 baht/household/year for AL 2044, 25,074 for AL2024, 22,212 for AL1544, 19,584 for AL1524, 24,066 for TK2044, 15,876 for TK2024, 10,638 for TK1544, and 4,716 for TK1524 from each EAI. The model farmer would have equivalent or more net cash benefits than the mean farmers' net cash benefit from agriculture, if he was to adopt one of AL2044, AL2024, AL 1544 or TK2044.

The case with 20-year rotation and spacing of 4x4 m was the most profitable and efficient among the four cases. The estimated EAIs of combined farm management with teak plantation varied between 1,088 and 1,595 baht/rai/year. The estimated profitability of the combined farm management with teak plantation was higher than that of the teak only approach for the same area. Thanks to the change from a teak only plantation to a combined approach with teak plantation, the EAI increases in the cases with 15-year rotation can be expected to be much greater than those in the cases with 20-year rotation. According to the results, it would be recommended that the farmer selects the combined farm management approach with teak management, and not selects a teak only approach; in addition, 20-year rotation should be preferable to 15-year rotation for the teak plantation management approach. If the farmer wants a final-cut income early and selects 15-year rotation, he would be strongly recommended to select the combined approach with teak plantation. Because he could expect much more annual income compared to teak only approach.

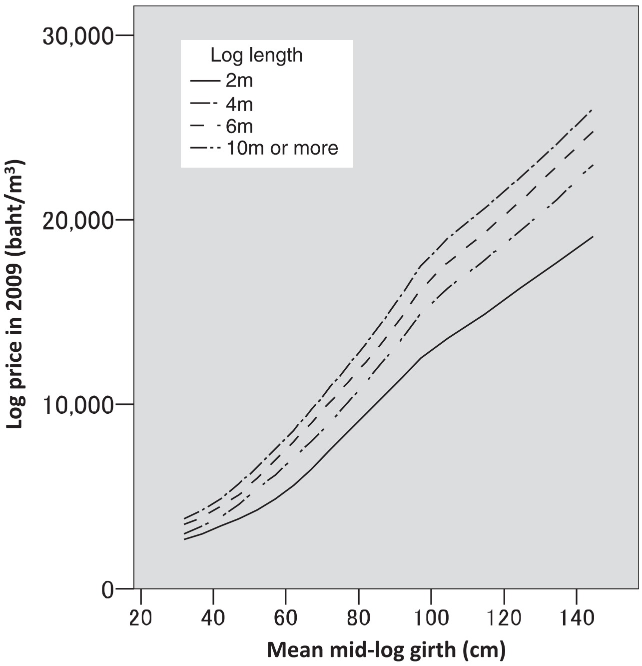

Fig. 7. Price-size relationship in teak log standard prices of FIO. Data source was FIO standard price table in 2009.

The log price at final cutting age was a very influential factor for the EAIs. The farmer could effectively increase the profitability of EAI by making efforts to produce higher-quality logs at the final cutting age as much as possible. Such quality refers to large diameter and heartwood ratio, straightness, and fewer branches, among others, which all affect the log price level. For example, a farmer who applied 20-year rotation would be better off targeting the production of high-quality logs at 20 years rather than thinning logs at 15 years or 10 years.

The price-size relationship has great significance in harvesting and silvicultural decisions (Price 1989). The decreasing gradient of the curve as volume increases, which reflects the facts that increasing size eventually secures no more advantageous markets, and that economics of dealing with larger sizes are gradually exhausted (Price 1989). Fig. 7 shows the price-size relationship for teak plantation logs of the Thailand Forestry Industry Organization (FIO). The curve was calculated from the FIO teak plantation log pricelist. The FIO is the biggest supplier of teak plantation logs in Thailand, and the FIO log price generally becomes the standard price of teak plantation logs (Noda et al. 2011). The curves show a slight decrease of gradient at around 100 cm mid-log girth, and also show a mostly linear relationship between price and mid-log girth. The girth refers to that without bark in accordance with an FIO rule. Therefore, growth that increases the thickness is preferable to increase log price, and it could be a target to produce logs of 100 cm mid-log girth without bark.

A larger proportion of heartwood is preferred by end users, and can increase the log price. Okuyama et al. (2005) concluded that the formation of heartwood depends on the tree diameter, that is, the proportion of heartwood of young trees increases abruptly up to 90% at a diameter of around 20 cm, as determined from teak logs from plantations in India, and West and Central Java. They also concluded that maturation age of planted teak was around 12-15 years on the basis of the density and microfibril angle distributions across the stem. It may be necessary to confirm such findings in Thai teak plantation timber. However, the rotation age should be at least 15 years, and a diameter over 20 cm could be a key to get a larger proportion of heartwood in order to increase log prices.

From the parametric analysis, we could find a more profitable farmer's land use pattern using the spider chart; this was the case of AL2044, with a new land use pattern of teak 8 rais, major rice 8 rais, second rice 8 rais, maize 2 rais, cassava 0 rai, and sugarcane 0 rai, which revised the EAI by 26%, up to 2,007 baht/rai/year, with the same effect on the B/C ratio at 1.40.

Conclusions

The profitability of combined farm management with teak plantations and that of teak only plantation management was compared. The results showed that a farmer was recommended to select the combined approach with teak management. In addition, 20-year rotation should be preferable to 15-year rotation for the teak plantation to expect higher profitability. If the farmer selects 15-year rotation, he would be strongly recommended to select the combined approach with teak plantation. The farmer should pay attention to produce higher quality logs at the final cutting age. It could be a target to produce teak logs of 100 cm mid-log girth without bark in the teak management. A better land use pattern for the combined management approach could effectively improve the level of profitability. However, the optimal land allocation for cash crops would be necessary to be studied in terms of the profitability of combined approach.

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