

## A Socio-economic Simulation of Rubber Smallholding Systems: A Case Study of Phatthalung and Songkhla Provinces in Southern Thailand

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*Under the current rubber production system, Thai rubber smallholders are forced to adjust farming strategies and systems to maintain viability. Rubber smallholders need relevant information to incorporate into their decision-making process. A simulation approach can provide an important piece of this information. This paper presents a comparison of economic simulation models over a period of ten years (2005-14) of three smallholding rubber-based farming systems—rubber-fruit, rubber-rice, and rubber monoculture—in two southern Thai provinces, Songkhla and Phatthalung. The results revealed that the rubber-rice system yielded the lowest income, which was correlated with the proportion of rubber on the farm. The rubber-fruit system had the highest expenditure. The income for the rubber monoculture system stabilized over the simulation period. This study suggests that the rubber-fruit combination should be promoted to rubber smallholders.*

**Keywords:** Rubber smallholders, Simulation model, Socio-economic, Agricultural system, Rubber intercropping

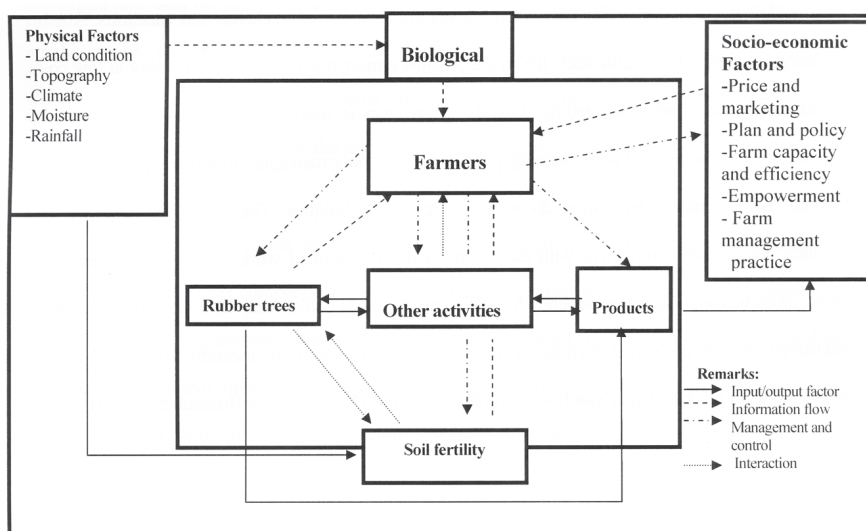
### Introduction

Improving the productivity of rubber farming systems is important, especially for rubber smallholding farms, which account for 70% of the world's natural rubber production. Thailand, Malaysia, and Indonesia are the world's three main rubber-producing countries. The smallholding sector is an important component using various cultivation patterns, including the three main rubber-based systems of rubber monoculture, rubber-rice, and rubber-fruit farming systems that have been practiced in Thailand for many years (Somboonsuke, 2001). However, rubber farmers currently face many constraints including deficient capital for investment, labor shortages, a lack of access to credit, an inefficient market system,

and inefficient smallholder groups in local areas. The objectives of this paper, focusing on the three primary rubber-based farming systems, are to: (a) examine their current economic performance, (b) run economic simulation models of income and expenditure for the three systems and examine and compare the results, and (c) suggest appropriate strategies for their development and sustainability.

### Framework of the Rubber Farming System

Both endogenous and exogenous factors affect rubber productivity (Somboonsuke et al., 2002). The endogenous, or controllable, factors comprise biological and some physical components that directly affect planning and implementation strategies for smallholder farms. These include the breed of rubber, decision-making, empowerment (skill, knowledge, and attitude), soil fertility management, and farm management (farm capital investment, labor, and fertilizer). Exogenous, or uncontrollable, factors include physical and socioeconomic components that indirectly affect farm planning and implementation strategies. These include the climate, rainfall, resource profile, and marketing system. The framework below shows how these various factors interact to affect smallholder farm decision-making and farm management (Figure 1).



**Figure 1.** Framework of rubber farming system

Source: Somboonsuke et al., 2002

In the context of the framework above, Thai rubber farmers use a variety of agricultural activities and inputs—including appropriate tech-

nology, local environmental resources, material financial resources, and management practices—to achieve economic sustainability.

### **Characteristics of Rubber Smallholding System**

The rubber smallholding system in Southeast Asia involves more than 10 million farmers with average farm size varying across countries—Thailand (0.3-8.0 hectare), Malaysia (1-3 hectares), and Indonesia (1-4 hectares). The final stand planting on smallholding farms is usually very dense, with 500-900 trees per hectare. Rubber farming requires little labor. Smallholders prefer to tap when time permits or when cash is needed, although irregular tapping may lower average returns. Smallholders can employ family labor at low cost. In some cases, smallholders tap the rubber only when school is closed or on weekends and vacations. Smallholders do not receive maximum yields because of poor cleaning, product leaking, poor management, irregular tapping, and/or over-tapping. Some smallholders often use wasteful tapping techniques. Smallholders are, however, low-cost producers. As such, they can remain competitive with large estate producers and returns per hour of work compare favorably with arable crops. Estates are hit severely by falling prices. In contrast, smallholders may cultivate other crops more intensively or engage in animal husbandry during times of low prices, allowing the rubber trees time to rejuvenate in order to produce larger yields when rubber prices rise (Barlow, 1978; Ruthenberg, 1980).

### **Rubber Production in Thailand**

#### **From rice cultivation to rubber production.**

*Overall economic context.* Thailand has recovered from the 1997-2002 economic crisis and become one of the most efficient countries in Asia with high GDP growth mainly due to an increase in consumption, investment, and exports. Since the start of the 1980s, agriculture has declined slowly as a percentage of GDP. Thailand is moving from an agrarian to an industrialised society. This is causing a reduction in agricultural land use. Deforestation is a pressing environmental issue.

*Agriculture oriented towards rubber production.* In the early 1960s, rice dominated agricultural exchanges and local consumption. In 1961, government implemented the first national plan to emphasize diversification of Thai agriculture (corn, sugar, fruits, livestock, and fish). Consequently, smallholders moved towards high-value products such as rubber, thus increasing their revenue. In 2001, average smallholder farm size was 3.2 hectares. Rubber production in Thailand amounted to 2.88

million tonnes in 2004, which represented one-third of world production. However, the prospect for further rubber area increase is limited, at least in its traditional production zone in southern Thailand.

**Characteristics of the rubber-based agricultural systems in southern Thailand.** In Thailand, rubber trees are grown on about two million hectares. This land is characterised by three main rubber production systems: (a) the “jungle rubber” system (<10% of total rubber area), which is gradually being phased out by farmers in preference for monoculture; (b) the intensive agro-forestry system (5%), based on an association with various crops (fruits, vegetables, cereals); and (c) the monoculture system (85%), the most common. Farmers are cultivating mainly clones, RRIM600 and GT1. Office of Rubber Replanting Aid Funds (ORRAF) plays an important role in the development of this technology. ORRAF is a special state body that aims to increase rubber productivity within Thailand by enacting government policies through its replanting scheme. The main objectives of ORRAF are to assist rubber smallholders in replacing low-yielding plantations with high-yielding rubber clones or with perennial crops through providing technical information.

**Smallholders, actors of a remarkable growth in rubber.** The particularly high price in 2005 for unsmoked rubber sheet grade 3 (RRS3) is favoring producers. As a result, the margin for firms and traders is low (less than 15%). Several factors explain this unique situation (Sainte Beuve, 2005): (a) the relatively low cost of labor; (b) competition among firms, bringing them closer to producers; (c) Thai rubber is used in tire manufacturing by several companies (Michelin and Bridgestone) due to its relatively good quality; (d) the influence of social unrest in the three southern provinces (Narathiwat, Pattani, and Yala); and (e) speculation among traders. In addition, the international rubber market is favoring worldwide high prices. In 2005, Thailand did not achieve the expected production and Indonesia was unable to compensate for the decrease, causing a slight reduction in supply. However, demand is still increasing, with China and India the largest importers due to their booming economies and increasing demand. The rising cost of oil is causing synthetic rubber to become less competitive when compared with natural rubber. Thai smallholders and traders can bargain harder to have better prices according to the quality of natural rubber and strong speculation.

### Typology of Smallholding Rubber Farming System in Thailand

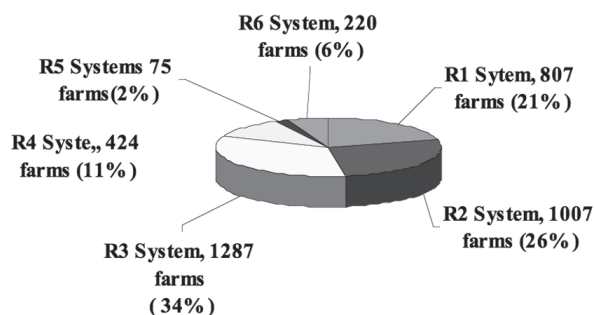
Rubber holdings in Thailand can be classified into three different sizes of farms: small, medium, and large. In 2004, small-scale farms with an area between 0.3-8.0 hectares comprised 941,160 farms, or 93.0% of total rubber holdings in the country, with an average farm size of 2.08 hectares. Medium-size farms, with an area between 8.1-40.0 hectares, included 73,000 farms, or 6.7 % of total rubber holdings in the country, with an average farm size of 9.6 hectares. Large-scale farms comprised 3,000 farms, or 0.3 % of total rubber holdings, with an average farm size of 63.2 hectares (RRIT, 2004). In addition, smallholding rubber-based farming systems can be further classified by a variety of typologies.

Thungwa (1998) classified the types of smallholding rubber-based farming systems based on the number of associated crops with rubber as follows: (a) rubber plantation with associated one cash-crop production and (b) rubber plantation with two other cash crops grown in various patterns between the trunks and/or rows of rubber trees.

Kjonchaikun (1995) classified smallholding rubber-based farming systems based on the type of crop used to supplement household income as follows: (a) rubber-intercropping system, (b) rubber-orchid system, and (c) rubber-multiple cropping system.

Nissapa et al. (1994) classified the types of smallholding rubber-based farming systems in the south of Thailand as follows: (a) jungle rubber community, (b) traditional jungle rubber, (c) economic rubber system, and (d) rubber monoculture system.

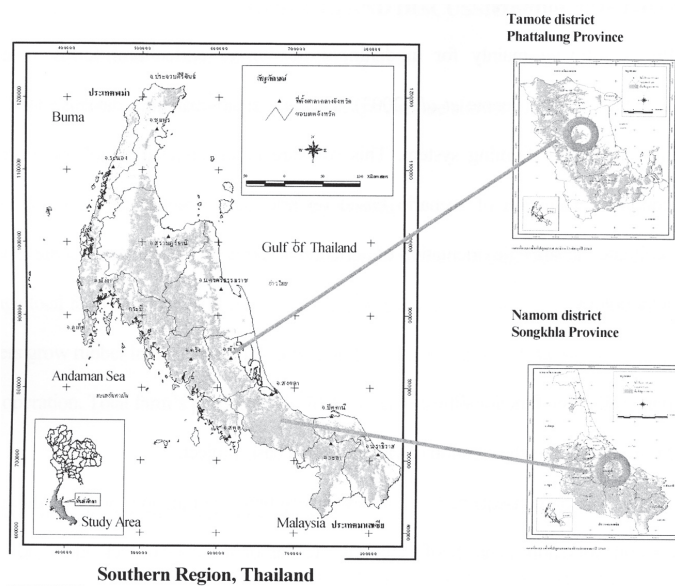
Somboonsuke and Shivakoti (2001) classified the six current main types of smallholding rubber-based farming systems (R) in the south of Thailand based on the criteria of an individual farm's agricultural production activity, socio-economic structure, and agro-ecozone as follows: (a) smallholding rubber monoculture farming system ( $R_1$ ), (b) smallholding rubber-intercrop farming system ( $R_2$ ), (c) smallholding rubber-rice farming system ( $R_3$ ), (d) smallholding rubber-fruit farming system ( $R_4$ ), (e) smallholding rubber-livestock farming system ( $R_5$ ), and (f) smallholding rubber-integrated farming system (or rubber-integrated activity farming system) ( $R_6$ ) (Figure 2).



**Figure 2.** Classification of smallholding rubber-based farming systems in Thailand  
Source: Somboonsuke and Shivakoti, 2001

### Methodology

Three types of smallholding rubber-based farming systems represented by 28 farms were selected from Tamote District of Phatthalung Province and Namom District of Songkhla Province in southern Thailand. Figure 3 shows: (a) rubber monoculture (7 farms); (b) rubber-fruit trees (16 farms) such as rubber-durian, rubber-longkong-rambutan, rubber-durian-longkong-rambutan, and rubber-longkong-rambutan-durian-mangosteen; and (c) rubber-rice (5 farms).



**Figure 3.** Study areas in two southern provinces of Thailand  
Source: Research and Development Office, Princes of Songkla University, 2004

The data collection was conducted by means of a structured interview. Secondary data were obtained through the review of publications (Somboonsuke et al., 2002). The analysis was concentrated on the description of the current demographic data of the selected systems, current agricultural production, current constraints, current net farm income and other measurements, simulations of decision-making, and suggestions for improving economic performance.

For simulation modelling, the study analyzed incomes and expenditures over a period of ten years (2005-14) using OLYMPE software. The study also compared the different types of farms in relation to their economic returns.

### **OLYMPE Software**

OLYMPE is software mainly for modelling/simulation of agricultural farms created by INRA/CIRAD/IAMM (France) (Penote et al., 2003). It provides a socio-economic database for farming systems. This software provides prospective analyses and economic evaluations of scenarios based on price and quantity variations. OLYMPE software helps facilitate the strategic orientation of agricultural farms, both individually and collectively.

1. Creation of a variant from a baseline project, the most important,
2. Evaluation of the consequences of new investment, elimination or addition of a production workshop, change of a cultural calendar, or change of technique, and
3. Integration in the simulation of risk and the evaluation of consequences of possible events known as "production hazards," which are internal or external to the firm, on the project results (such as fluctuation in price, climatic hazard, and evolution of the market).

The results of the simulation study will be helpful for rubber farmers to make strategic decisions either on an individual scale or regionally. The structure of the data encompasses socio-economic data at three different levels (systematic approach).

1. The cropping system: The study needs to know all the inputs required (name and price) for each farm's production and the characteristics of the outputs (type of product and price sold).
2. An activity system: This takes into account the repartition of the labor force throughout the year, all the costs of production (structural charges), and the quantity of inputs and outputs.



3. A production system: This includes information on structural costs, non-operational costs (family expenditure, off-farm income, etc.), and characteristics of the farm (surfaces of each production, age of plantation, etc).

The software can also indicate the financial status of the farm (subventions, debts, and loan).

## Results and Discussion

### Demographics of Three Rubber-based Farming Systems

The demographic data of the three different systems are shown in Table 1.

**Smallholding rubber monoculture farming system.** Rubber production is the major occupation of farmers in the study area. The table shows that the average total farm area is 2.21 hectares and the average total production area is 1.76 hectares. The total farm labor averages 1.34 people, which is sufficient for farm operation. Total farm production is 70.4 kg/ha/yr.

**Smallholding rubber-rice farming system.** There are two patterns of this system: (a) rice is grown between immature rubber rows, and (b) rice is grown in a different plot from the rubber plantation. Normally, the experience of smallholders in rice cultivation is passed on from ancestors. Smallholders have used both high-yielding and indigenous rice strains. The rice harvested is used only for family consumption. In the future, this type of farming system may decline due to many constraints such as a shortage of family labor, high cost of input factors, uncertain price, and high rubber product price.

**Smallholding rubber-fruit tree farming system.** Intercropped fruits are economically valuable fruits in the south of Thailand, including durian, rambutan, longkong, and champada. Normally, two patterns of this system exist.

1. Fruit trees are cultivated in the same plot as rubber. The purpose of this pattern is to increase income. In addition, some farmers postpone the rubber harvest if the price of fruit is higher than rubber.
2. Fruit trees are grown in a different plot from the rubber plantation. These farmers normally have more experience and skill in fruit tree cultivation than farmers in the previous pattern. However, this



second type requires higher capital investment and family labor. The constraints of this type include the shortage of water, the management required, and deficiency of capital investment.

**Table 1.** Demographic data of smallholding rubber-based farming systems

Characteristics	Smallholding rubber-based farming systems		
	Rubber monoculture n=7	Rubber-rice n=5	Rubber-fruit tree <sup>1</sup> n=16
1. Land holding characteristics			
1.1 Total farm area (ha)	2.21	2.88	8.80
1.2 Total production area (ha)	1.76	1.02	4.70
1.3 Topography	unfolded plain area	unfolded plain area	unfolded plain area and upland plain area
2. Total farm labor (persons)	1.34	2.17	3.67
3. Total farm production (kg/ha/yr)	2750	2585 (for rubber) 2026.50 (for rice)	3250
4. Total farm experience (yr)	23.67	20.93	18.25
5. Farmer age (yr)	50.3	47.3	48.0
6. Farmer education (yr)	7.33	7.47	7.82
7. Farm debt (THB/yr)	60,000	52,000	70,000
8. Farm saving (THB/yr)	13,000	-	109,672
9. Farm income (THB/ha/yr)	48,828	61,477	200,448

Note: <sup>1</sup>Average characteristics of four representative systems; (a) rubber-durian (b) rubber-longkong-rambutan, (c) rubber-durian-longkong-rambutan, and (d) rubber-longkong-rambutan-durian-mangosteen.

### Analysis of the Current Agricultural Production System

The current agricultural production systems of the three intercropping types were analyzed in terms of farm purposes, strategic farm implementation, and farm constraints (Table 2).

**Farm purposes.** All three systems have one major objective, that is, increasing productivity. However, increased yield and biodiversity are also important objectives in rubber-fruit operations. Such objectives are aided by the use of new farming practices and technology to improve the living standards of rubber farmers by means of increasing economic viability and

sustainability.

**Strategic farm implementation.** Normally, rubber farmers use 15-15-15 formula fertilizer. In addition, rubber farmers use this same formula fertilizer for fruit trees, rice, and vegetables. The rubber farmers use a high-yielding breed of rubber (RRIM 600). However, for rice, the indigenous breed is used because it is appropriate for the local area due to its disease resistance. All systems use natural sources of water such as rain or underground water since irrigation is not available in the area. In the smallholding rubber-fruit tree farming system, the mixed fruit tree crop is most commonly found in the study area since farmers can harvest the crops all year. This system is more profitable than other systems (Somboonsuke and Shivakoti, 2002). In the smallholding rubber-rice farming system, especially where the rice is planted in different plots from the rubber area, there are two patterns of planting-transplanting of paddy seedlings and broadcasting of seed.

**Farm constraints.** All smallholding farms faced the main constraints of low quality of production, disease, and pests due to the use of vulnerable breeds (i.e., RRIM 600); a shortage of family labor; and insufficient capital for farm investment. In addition, the smallholding rubber-fruit tree farming system faced more constraints than other smallholding farms.

**Table 2.** Current agricultural production of the three intercropping systems: rubber monoculture, rubber-rice, and rubber-fruit tree in the study area

Rubber farming system	Purpose	Implementation strategies	Constraints
Rubber mono-culture farming system	<ul style="list-style-type: none"> <li>•Increase farm income and maximize farm production</li> </ul>	<ul style="list-style-type: none"> <li>•Use fertilizer formula 15-15-15 two times/year</li> <li>•Membership in farmer's group for bargaining price in local market</li> <li>•Use chemicals for weed control</li> </ul>	<ul style="list-style-type: none"> <li>•Low quality of production</li> <li>•Insufficient capital for farm investment</li> <li>•Disease and pests (non-resistant rubber breed such as RRIM600 GT1)</li> </ul>

Table 2. (Continued)

Rubber farming system	Purpose	Implementation strategies	Constraints
Rubber-rice farming system	<ul style="list-style-type: none"> <li>•Increase farm income and maximize farm product toward sufficient standard of living</li> </ul>	<ul style="list-style-type: none"> <li>•Fertilizer of formula 15-15-15 for rubber and 16-20-0 for rice</li> <li>•Two patterns of rice plantation: transplanting of paddy seedlings and seeds sown without transplanting</li> <li>•Fertilization: two times/year for rice plantation</li> <li>•No chemical is used</li> <li>•Use indigenous breed such as rice</li> </ul>	<ul style="list-style-type: none"> <li>•Disease and weeds</li> <li>•Shortage of family labor</li> <li>•High cost of input factor</li> <li>•Low product price (rice)</li> <li>•Insufficient water resource and inappropriate soil (low soil fertility)</li> </ul>
Rubber-fruit tree farming system	<ul style="list-style-type: none"> <li>•Increase farm income, use high technology in farming, increase for more activity, increase product and yield</li> </ul>	<ul style="list-style-type: none"> <li>•Mixed fruit tree crop for decreasing risk and disease</li> <li>•Use same fertilizer, 15-15-15 formula, for both rubber and fruit tree</li> <li>•With pond in fruit tree area</li> <li>•Use equipment and method in harvest</li> </ul>	<ul style="list-style-type: none"> <li>•Shortage of water resources</li> <li>•Deficiency in capital for input factor</li> <li>•Inefficient extension system and management</li> <li>•Inconvenient communication</li> <li>•Low quality and quantity of product and price fluctuation</li> <li>•Much disease and natural predators</li> <li>•Little agricultural knowledge</li> <li>•Family labor shortage</li> </ul>

### Current Constraints of the Rubber Farming Systems

Low product price is the most serious constraint faced by all types of farmers. In addition, inefficient production knowledge, diseases and pests, insufficient capital for farm investment, and the poor market system are also important constraints for all types of farms and farmers (Table 3). Like other primary commodities, rubber price fluctuation depends on both supply and demand factors in the market and external factors. During the last twenty years, the rubber price fluctuated greatly, and directly affected smallholding farms in Thailand. For example, the world's rubber production was in excess of consumption and the rubber price dropped in 1995. This had adverse effects on smallholders and was a major reason for small farmers leaving their farms in search of off-farm employment. This led to the under utilization of land and productivity decreases in Thailand as well as Malaysia and Indonesia. A low level of education, lack of accessibility to credit, and low adoption of new agricultural practices and innovations worsened the problem. The market constraints, which included low quality, also reflect the inefficiency, complexity, and constraints of the industry. In addition, smallholders received an unfair price in the local market. Marketing became difficult and complicated for these smallholders to comprehend. Moreover, individual smallholders were unable to cope with the situation. Normally, the market structure and rubber prices are complementary to each other in determining the final price paid to smallholders who are the original producers of raw material. The price paid to the producers in the local market is a residue of the free on board (FOB) price after deductions for export, other taxes, and marketing margins. The low farm-gate price is also a cause of insufficient capital for investment.

**Table 3.** Constraints faced by the three smallholding rubber-based farming systems

Constraints	Rubber monoculture	Rubber- rice	Rubber- fruit tree
1. Deficiency of water resources		X	X
2. Non-appropriate soil (low fertility)		X	
3. Natural harm and climate			X
4. Inconvenient infrastructure			X
5. Disease/pests and weeds	X	X	X
6. Low yielding breed (crop/livestock)			
7. Deficiency of input factors (i.e., fertilizer)		X	

Table 3. (Continued)

Constraints	Rubber monoculture	Rubber- rice	Rubber- fruit tree
8. Inefficient local farmers' groups or organizations		X	
9. Inefficient local extension system and management	X	X	
10. Deficient production system knowledge			X
11. Deficiency of capital for investment	X	X	X
12. Low product price and quality			X
13. Inefficient local marketing system		X	X
14. Deficiency of family labor and equipment			

### Current Economic Performance

Based on the report of Agricultural Economics of Thailand in 2004, the current economic performance in the form of net farm income (NFI) and the cost of production in terms of baht per hectare per year and the average price for 10 years of cultivation (1993-2003) is used as a prototype (Table 4). The calculation of the relative measurements of economic performance includes net farm income (NI), return to family labor (NFL), return to fixed cost (RFC), and return to variable cost (RVC). Table 4 shows that rubber monoculture cultivation has the lowest benefit while rubber cultivation associated with other activities has more benefits. This was confirmed in rubber-rice and rubber-fruit tree systems. The results indicated that the rubber-fruit tree farming system showed excellent economic performance in terms of net farm income, gross margin (GM), return to family labor (RFL), return to fixed cost and return to variable cost. The study found that the rubber-durian, rubber-longkong-rambutan, and rubber-longkong-rambutan-durian-magosteen farming systems had excellent net farm income with 43,828, 74,489 and 71,479 THB/ha/yr, respectively. However, the systems require high investment. As seen in the table, the rubber-fruit tree system had a high value of RFL. The abilities of labor in this system, especially the rubber-durian system with the highest RFL of 10.40 units, are higher than those in other systems. Per one unit input of labor used in farm operation, smallholders get 10.40 units of output. The R1 system has a lower value of return to fixed cost (RFC (6.40 unit)) and return to variable cost (RVC (2.06 unit)). The results showed that the rubber-rice system had the highest value of RFC because the small farmer used little equipment and few buildings in its

operations. This was confirmed by the low value of RVC due to the high variable cost of production.

**Table 4.** Net farm income and relative measurements of the three rubber-based farming systems

Items	Rubber monoculture	Rubber-rice	Rubber-fruit tree			
			R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>
1. Total cost (THB/ha/yr)	26,513	38,464	51,117	57,610	62,136	60,327
2. Total variable cost (THB/ha/yr)	20,064	35,409	42,383	47,722	52,341	50,532
2.1 Cash	15,188	26,805	32,084	36,126	39,622	38,253
2.2 Non-cash	4,875	8,604	10,299	11,596	12,718	12,279
3. Total gross output (THB/ha/yr)	41,300	40,141	86,211	122,211	78,670	122,011
4. Net farm income (THB/ha/yr)	21,236	4,731	43,827	74,488	26,328	71,479
5. Gross margin (THB/ha/yr)	26,111	13,336	54,127	86,085	39,047	83,758
6. Return to family labor	8.94	2.92	10.40	9.00	8.60	8.22
7. Return to fixed cost	6.4	13.1	9.9	12.4	8.0	12.5
8. Return to variable cost	2.06	1.13	2.03	2.56	1.50	2.41

Note: R<sub>1</sub>: rubber-durian, R<sub>2</sub>: rubber-long kong-rambutan, R<sub>3</sub>: rubber-durian-long kong-rambutan, R<sub>4</sub>: rubber-long kong-rambutan-durian-magosteen.

### Economic Simulation of the Three Rubber-based Farming Systems Income and Net Income

**Rubber-fruit tree farming system.** The study found that the smallholding rubber-based farm income was correlated with farm size, but independent of the type of tree cultivated. In this case, the higher incomes were obtained by the biggest farm (16.7 ha) with four different kinds of fruit trees. The two best economic results were achieved by durian growing farms. However, the results showed that income changed year-to-year because the production of perennial crops varies along the lifespan of the tree (Figure 4).

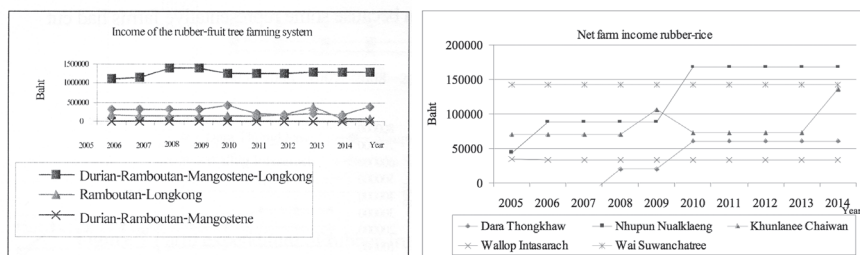


Figure 4. Income and net income of the rubber-fruit tree farming system

**Rubber-rice farming system.** The study found from the comparison of income and net income among five representative rubber-rice farms that the incomes were correlated with the proportion of rubber in the farm. The more rubber grown, the higher the income received. The result showed that the net income this system would generate in the future justifies the investment required. However, rice activity will decrease in the future due to the high price of rubber product. Dara's farm needs a few years to see her income grow to a satisfactory level. In 2014, apart from Dara's farm, the NFI seems to be in agreement with the size of the farm and the proportion of rubber (Figure 5).

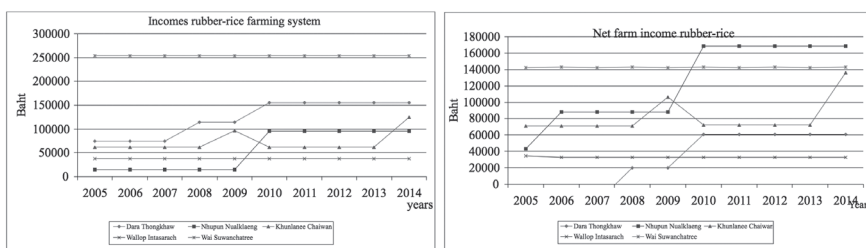


Figure 5. Income and net income of the rubber-rice farming system

**Rubber monoculture farming system.** For rubber monoculture, the study simulated income and net income of seven representative farms. The results showed that income was generally constant throughout the years of the simulation. The small variations came from the stage of the rubber production because some representative farms had cut rubber trees for replanting (Figure 6).



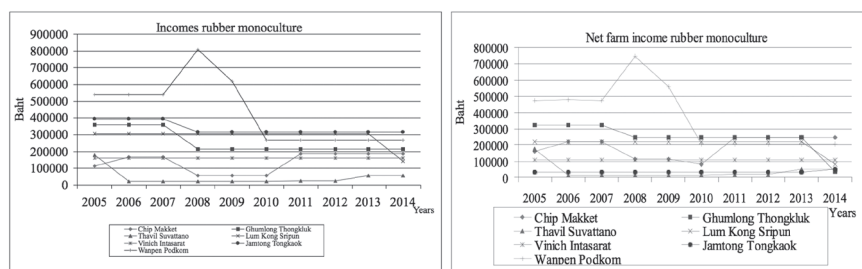


Figure 6. Income and net income of rubber monoculture farming system

### Farm Expenditure

**Rubber-fruit tree farming system.** Farm expenditures were linked with both farm size and income. Consequently, the net farm income, which represents the capacity of the farm to invest, followed the same trend as income. At the end of production, rubber wood provides substantial income to the farmers and can be used for re-planting the plot (Figure 7).

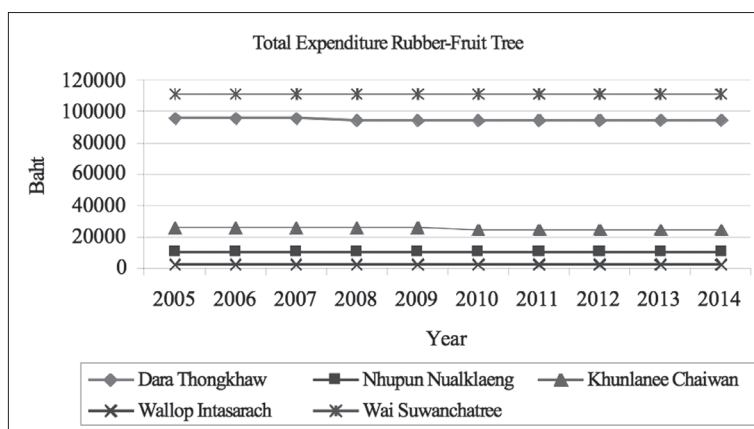


Figure 7. Farm expenditure of rubber-fruit tree farming system

**Rubber-rice farming system.** The study found that farm expenditures followed the same hierarchy. However, the family expenditures influencing the NFI were not exactly of the same trends as general income because of the farm's high expenditures (Figure 8).

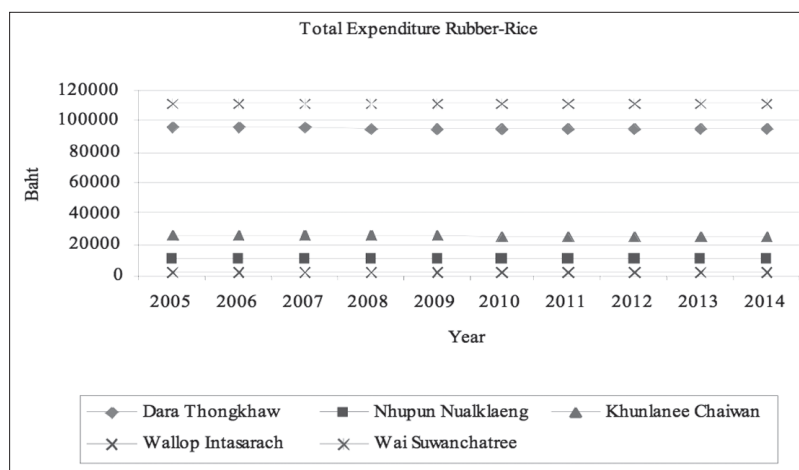


Figure 8. Farm expenditure of rubber-rice farming system

**Rubber monoculture farming system.** Every farm had similar expenditures (especially those involving inputs), no matter the size of farm. The rubber monoculture farms were quite small (seven out of eight were less than two hectares) (Figure 9).

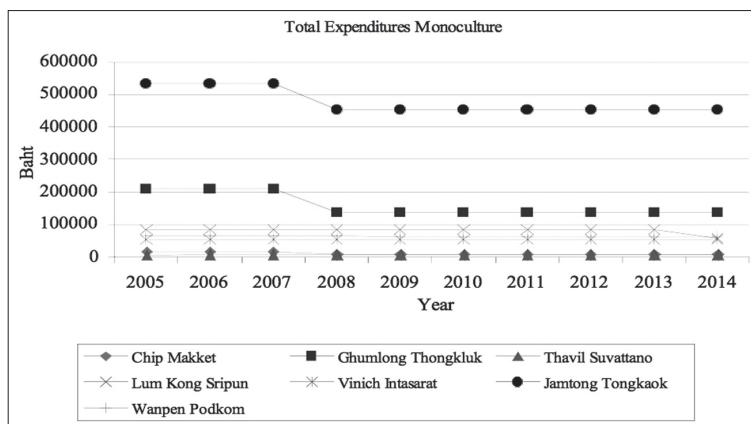


Figure 9. Farm expenditure of rubber monoculture farming system

### Comparison of Income and Expenditure

The comparison of income and net income of the three rubber-based farming systems is shown in Figure 10 below. The results showed that the rubber-fruit tree system is the best system from an economic point of view (highest incomes and NFI) and required the highest expenditure while the rubber-rice system has the lowest income since rice activity is

not currently an economic crop. Consequently, many farmers tended to change from rice to rubber activity in this area (Figure 10).

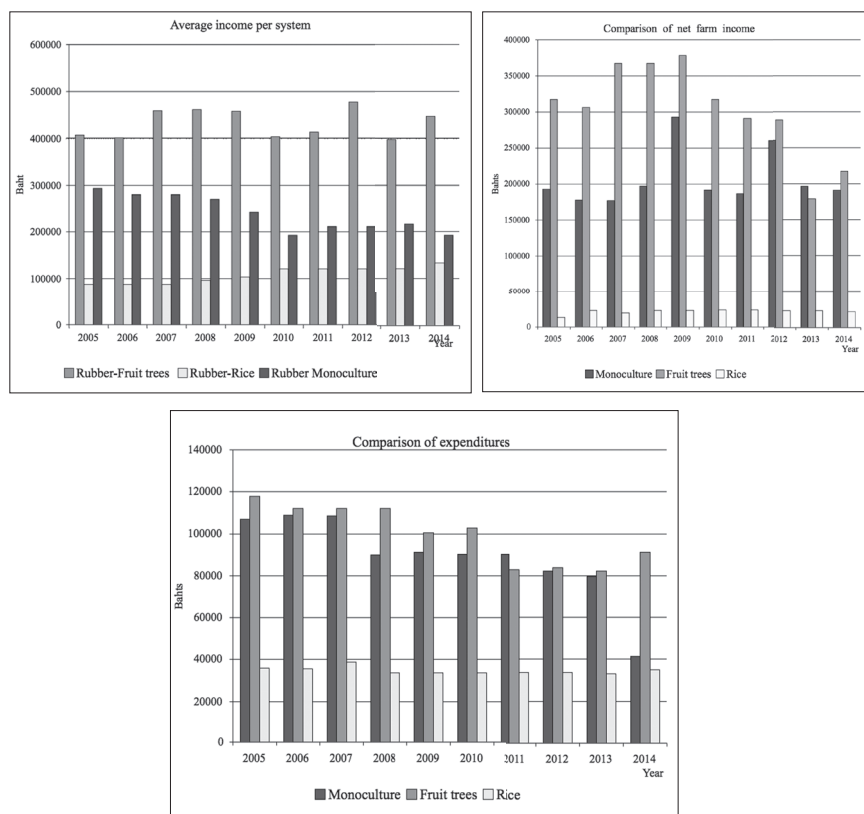


Figure 10. Comparison of income and expenditure of the three farming systems

### Conclusion and Recommendations

The rubber-fruit tree system requires higher capital investment and family labor than the other two systems. However, this system showed the best economic performance when compared with the rubber monoculture and rubber-rice systems. The result showed that the three systems had similar objectives of increasing productivity and biodiversity. Low product quality, disease, and pests have been important farm constraints. For simulation, the study found that the rubber-fruit tree system was the best system from an economic point of view in the 10-year simulation. In addition, this system showed the highest expenditures when compared with other systems.

Recommendations to improve the three systems for sustainability are as follows:

1. *Optimum for a multi-activity system.* As previously mentioned, one of the best systems seems to be R4 (rubber-longkong-rambutan-durian-mangosteen). Growing both fruit trees and rubber makes it possible to diversify the farmer's source of income. Moreover, this system provides more flexibility when confronting an economic crisis. If farmers do not want to give up part of their rubber production, they can utilize an intercropping system. In Phatthalung Province, many farmers grow rubber with intercrops such as fruit trees or vegetables. Sometimes, this association can bring mutual profit to the growing system for the reason that the fertilizers used for the fruit trees are also beneficial to the rubber trees. The study advised the farmer to carefully choose the intercrop.
2. *Decrease the expenditure on labor.* In some farms, farmers use more labor than actually required. Sometimes the farmers hire labor from outside although using only family labor would be sufficient. The study has revealed that labor is the main production input. Using family resources more efficiently could permit farmers to generate more income.
3. *Investment for high-yielding rice species.* The study noticed that the farmers were not willing to continue with rice cultivation because the resulting income generated was too low. Some farmers producing both rice and rubber wanted to change to rubber monoculture. Farmers should select better species of rice to generate more income. It is also important to conserve biodiversity on the farm. Producing more than one crop would enhance a farmer's security.

**Table 5.** Recommendations for improvement in productivity of the three different systems

System	Opportunities	Constraints	Recommendations
Rubber monoculture	•Need only inputs for rubber production	•Vulnerability when prices and quantities drop •No diversity in sources of income	•Opt for intercropping, maximizing land use efficiency •Change the time of planting between the different plots to have continuity in income throughout the year
Rubber-fruit trees	•Diversity in the source of income •Lower risk at time of crisis	•Need more labor, especially at harvest	•Diversify the kind of trees to generate more income
Rubber-rice	•Low cost of inputs	•Requires many laborers during harvest •Low income of smaller farms	•Change to more productive species

Suggestions for possible strategic development of the three different systems are as follows:

*Rubber monoculture system*

1. Improving local information systems such as establishing Village Information Centers (VIC) and improving sources of information in the community.
2. Increasing educational experience such as providing formal education for new generations through agricultural programs, offering Friday Agricultural School Programs, and organizing training courses.
3. Looking for supplementary activities on rubber plantations for increasing income and cultivating of multi-crops with rubber.

*Rubber-rice system*

1. Providing for extension programs, decision-making help, and solutions to problems. Encouraging members to sell their products through Group Information Centers (GIC) and providing the community with a silo for rice storage.
2. Promoting bio-fertilizer use and optimizing chemical fertilizer use through provision of training courses, exploring locally-available

materials, and using local materials for making bio-fertilizer within the community.

3. Changing to more productive rice species.

#### *Rubber-fruit tree system*

1. Enhancing the product-processing plants.
2. Establishing a village marketing committee (VMC).
3. Trying to lower the cost of production.
4. Strengthening fruit tree group activity and encouraging participation.
5. Providing low cost inputs through local farmer groups.
6. Improving the available sources of information in the community.
7. Improving local farmer group activity and participation.
8. Providing high-yielding varieties of rice through extension workers and ORRAF officers.
9. Initiating Friday Agricultural School Programs.

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