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REGULAR RESEARCH ARTICLE

The Livelihood Adjustment of Smallholding Rubber Farming Systems (SRFS) in Southwestern Thailand: Case Study in Ranong, Krabi, Phangnga, and Phuket Provinces

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ABSTRACT

This study aimed to examine the livelihood adjustment, to analyze factors affecting, and to synthesize the relationships between production and livelihood adjustment in model of SRFS for Ranong, Krabi, Phangnga, and Phuket provinces, in Southwestern Thailand. A sample group of 399 rubber farmers was involved in data collection and 60 key informants were selected as a subsample. A structured interview form and a semi-structured interview form were the tools for data collection. In data analysis, descriptive statistics, linear regression and technical- economic simulation were applied, as well as synthesized model of connections between the production system and livelihood under SRFS was analyzed. The results indicate that rubber farming could be classified into four types: smallholding rubber monoculture farming system (S1) (40.9%), smallholding rubber with fruit tree farming system (S2) (35.8%), smallholding rubber with oil-palm farming system (S3) (49.8%), and smallholding rubber with livestock farming system (S4) (5.9%). These were different in livelihood assets and livelihood outcomes. Smallholding rubber with livestock farming system (S4) was better for livelihood outcomes than the other systems. The social capitals were quite high while the economic capitals were quite low. Livelihood strategies give importance to increasing productivity, reducing costs, financial management, and changes in food consumption. All farms relied on government support and received welfare. For the 10-year economic model (2017- 2026), S4 had the highest margin value. This study synthesized the relationships of production and livelihood adjustment model, showing that the model was composed of four sub-models: production system, support system, strategy, and livelihood adjustment system, and the resulting sustainable livelihood system will be useful for analyzing livelihood adjustments.

KEYWORDS
Rubber Livelihood; Rubber adaptation; Livelihood adjustment; Smallholding rubber farm; Southwestern Thailand

1. INTRODUCTION

Rubber is an economic crop cultivated in Southern Thailand. In 2019, these rubber plantations were covering 2.2 million hectares with a total production of 3.1 million tons, yielding 1,543.8 kg/hectare equivalent and representing 64.6% of the total amount in the southern region of Thailand. The major growing rubber areas were Surat Thani province (0.4 million hectares), Songkhla province (0.3 million hectares), Yala province (0.2 million hectares), Nakhon Si Thammarat province (0.3 million hectares), and Trang province (0.2 million hectares). These growing areas produced rubber for more than 3.33 million tons, equivalent to 42.5%of the whole nation, and 65.4% of the whole southern Thailand (RAOT, 2019). The circumstances of low rubber prices in Thailand have affected household livelihoods and livelihoods of rubber farmers, many

of which rely on the rubber plantations. With people in the Southern Thailand deriving their major incomes from rubber plantations, a significant recent study found that livelihood of farmers still displayed both a high vulnerability and a weak viability because of the evident poverty problems (Office of the National Economic and Social Development Board, 2019). These also have a connection with the structure of the production system, the management of production, and utilization of selected technologies that may not have ample productivity. For the future, rubber farmers need to have a direction for the right production type, a fitting farming system, and for a proper household livelihood create sustainable income levels.

In Southwestern Thailand in 2019, Ranong province had rubber growing area of 0.05 million hectares, and an average production of 1,587.5 kilograms/hectare, Krabi province had rubber growing area of 0.09 million hectares with an average production of 1,675 kilograms/hectare, Phangnga province had rubber growing area of 0.10 million hectares, with an average production of 1,650 kilograms/hectare, and Phuket province had rubber growing area of 0.01 million hectares, with an average production of 1,225 kilograms/hectare (Office of Agricultural Economic, 2019). While the rubber price was fluctuating in Thailand, farmers in these four provinces had to adapt to survive and attempted to increase their household incomes despite the low rubber price. One pattern of such adaptation by the rubber farmers was taking up a secondary occupation alongside the rubber plantation activities. However, farmers did not have a clear pattern or even a development direction that would answer questions regarding production issues, livelihood, as well as sustainable livelihoods going forward. Accordingly , the objective of this study was to study, classify, and analyze the present rubber production system of SRFS, to examine the adjustment patterns of livelihoods and the relevant components in households under SRFS, to analyze factors affecting the livelihood of SRFS, to compare technical economic simulations for respective sub-systems amongst rubber farming systems, and finally to synthesize a suitable model of relationships between the production system and livelihood under SRFS.

1.1 The concept of rubber farming system

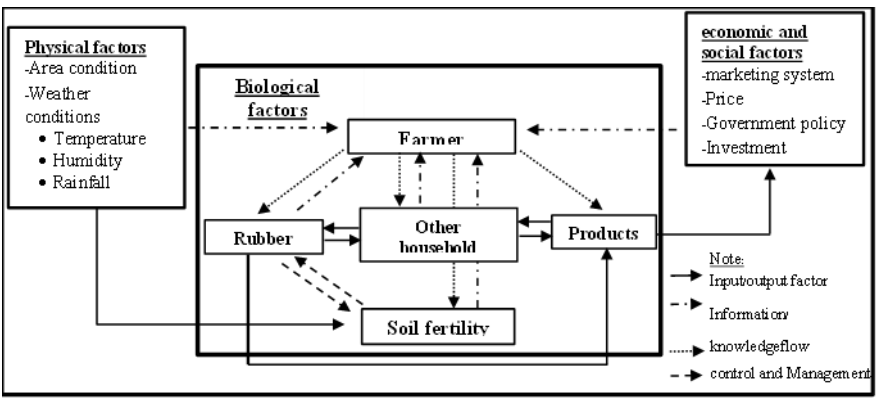


Figure 1. The concept of rubber farming system

[Sources: Adapted from Somboonsuke et al. (2002) and Cherdchom et al. (2009)]

A concept relevant to the rubber farming industry and connected society is the concept of rubber farming system, which is one pattern of the farming systems (Cherdchom et al., 2009). And also, this is the farming system that pays attention to

factors relevant to the production process such aseconomic factors, social factors, physical factors, and biological factors which (Somboonsuke et al., 2002) are described in some more detail as follows: 1) Economic and social factors such as the respective marketing system, prices, government policies, investment, actual and potential farmers, and management; 2) Physical factors such as an area's conditions (e.g., soil), its climatic and weather conditions (temperature, humidity, and rainfall); and 3) biological factors such as farming and other household activities, and soil fertility management. All these factors have respective relations that constitute important parts of production systems and require rubber plantation management (Figure 1).

1.2 The Agricultural Production System Model (APSM)

The APSM model[1] can be utilized the explain the smallholding rubber production system. Futhermore, it is useful for understanding the components of rubber production system and their interdependence linkages. However, this model does little to explain the social and empowerment components, which are important for the acceleration and motivation of smallholding rubber production.

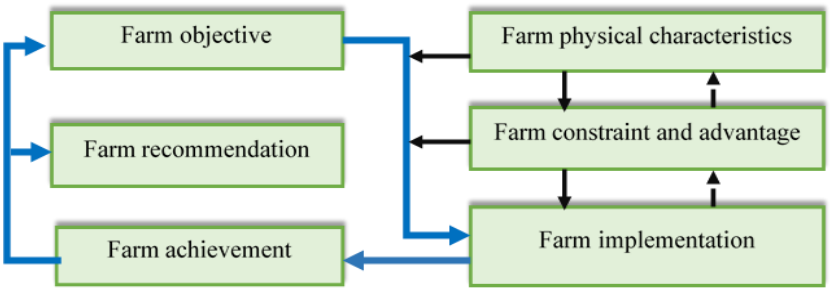


Figure 2. The Agricultural Production System Model (APSM)
[Source: Adaptation from Somboonsuke et al. (2002) and Conway (1985)]

1.3 The Concept of Sustainable Livelihood Framework (SLF)

The concept of Sustainable Livelihood Framework (SLF) is for the study of relationships of the five different but inter-related components that determine the level of livelihood of the target group, as follows (DFID, 2001): 1) The context of weakness and uncertainty which relates to the condition that suddenly occurs and has a severe effect with a tendency, and a tendency condition of mobility factors that affect the livelihood and seasonal changes; 2) Assets or capital for livelihood is the major component, or in other words, it is the capital that the target group uses for livelihood process. This has a positive relationship with the results that affect the optional opportunity of the respective livelihood way being influenced directly by the context of weakness and changes of structure and institutions, such as human capital, natural capital, financial capital, physical capital, and social capital; 3) Structure and process that are due to changes relate to components that directly affect and cause weakness in the process. This component affects the choosing of the respective livelihood way. This component is composed of two sub-components, namely structure and process; 4)

[1] The Agricultural Production System Model (APSM) is a dynamic system comprising six interlinked components as follows: a farm's objective is the most important component which determines a farm's implementation together with the other components, such as farm's physical characteristics, farm's constraints and advantages. All of these components effect the farm achievement.

Livelihood strategy is the component related to an optional opportunity that the target group uses as the strategy for livelihood and which has diversity depending on the features of topography of the holding and the period in the feature of moving, scattering across places, and linking, and; 5) Livelihood achievement is the consequence resulting from choosing a way or strategy of livelihood that expresses sustainable livelihood by obtaining an income, living better, reducing weakness, having food security, using sustainable natural resources, etc (Figure 3).

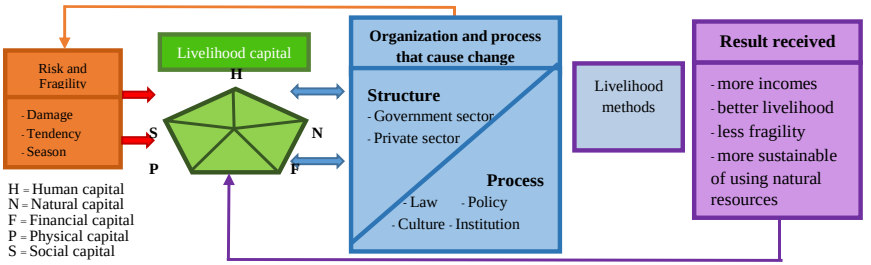


Figure 3. The Concept of Sustainable Livelihood Framework (SLF)
[Source: The Department for International Development (DFID), (2001)]

2. MATERIALS AND METHODS

The studied locations were Khabi, Ranong, Phangnga, and Phuket provinces in Southwestern Thailand.The population of the area covered in this study, in terms of rubber farmer households was 159,600 households (ROAT, 2019) in the four provinces overall, and broken down by province there were: Krabi (71,200 households), Ranong (42,100 households), Phangnga (36,400 households), and Phuket (9,900 households). The sample group for this study consisted of 399 farmer households.

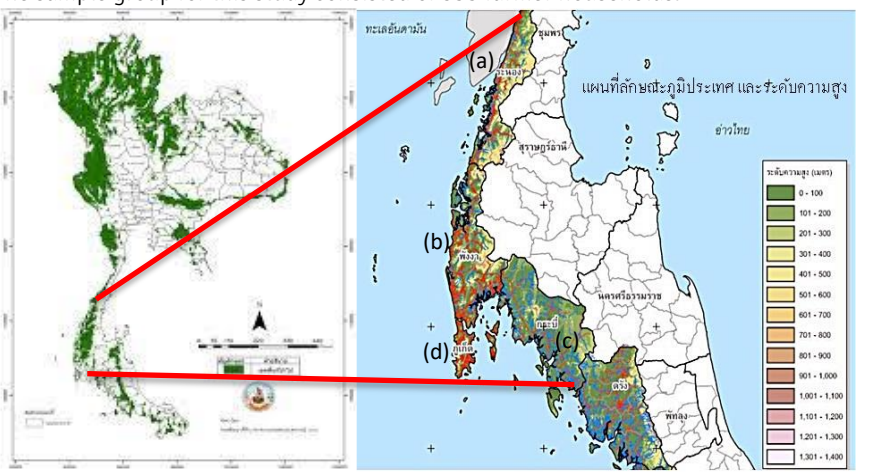


Figure 4. Studied areas of Ranong province (a), Phangnga province (b), Krabi province (c), and Phuket province (d)
[Source: OSM Adaman, 2018]

The sampling method was multi-stage sampling applied to the rubber plantations in four provinces; namely in Krabi 178 households were sampled, in Ranong 105 households, in Phangnga 91 households, and in Phuket 24 households for the quantity

method. The instruments used for this study were a structured interview form as well as a semi-structured interview form. Furthermore, 60 key informants were selected as a sample group for in-depth interviews. In data analysis, descriptive statistics such as percentage, frequency distribution, average, and standard deviation were assessed. Referential statistics such as multiple linear regression analysis was calculated for data analysis. Furthermore, the analysis focused on factors affecting the livelihood of SRFS, and to compare the respective technical economic simulation among rubber farming systems with the application of the OLYMPE Software and to synthesize the model of connection between the production system and livelihood under SRFS.

3. RESULTS

3.1 The classification of smallholding rubber farming systems (SRFS)

The classification criteria of SRFS in the study areas used here were: 1) mixed principle composed of household agricultural activities, 2) socio-economic and rubber management, and 3) agricultural land utilization. The study found that the surveyed sampled SRFSs can be classified into four main types of systems (Figure 5), namely: 1) A smallholding rubber monoculture farming system (S1) in Ranong (33.3%), Krabi (24.7%), Phangnga (26.4%), or Phuket (79.2%) with the total share of this system being (40.9%); 2) Smallholding rubber with fruit tree farming system (S2) in Ranong (38.1%), Phangnga (18.7%), and Phuket (12.5%) with the total average share of this system being 17.3%; 3) Smallholding rubber with oil palm farming system (S3) in Ranong (25.7%), Krabi (75.3%), and Phangnga (48.3%) with the total average share ofthis system being (37.3%); 4) Smallholding rubber with livestock farming system (S4) in Ranong (2.9%), Phangnga (6.6%), and Phuket (8.3%) with the total average share of this system being (4.6%).

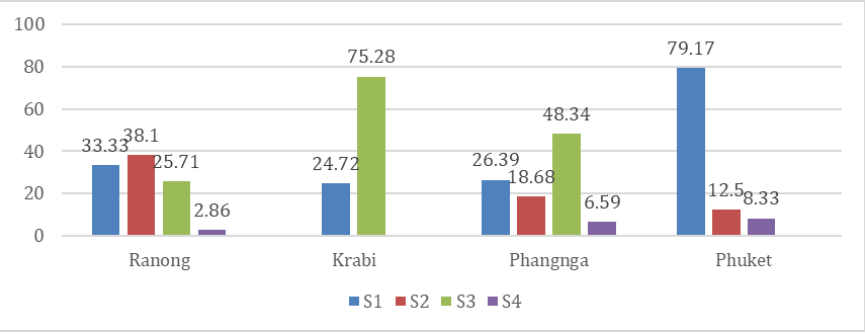


Figure 5. The classification of SRFS the four studied provinces of Ranong, Krabi, Phangga and Phuket in percentage contributions of the total for each respective study region. [Remark: S1: smallholding rubber monoculture farming system, S2: smallholding rubber with fruit tree farming system, S3: smallholding rubber with oil palm farming system, and S4: smallholding rubber with livestock farming system].

3.2 Agricultural production system model (APSM) of SRFS types

All the farmers had practiced their respective four systems by following the principles of household agricultural activities, socio-economic and rubber management, as well as agricultural land utilization. Moreover, the study indicated that farmers practiced their farming by different systems as summarized Table 1. The study

concluded that the objectives of all production systems aimed at similar targets that were to increase household income, with an average land holding at 1.92 hectare/household. All production systems used similar production technology. The major problems of production were a low rubber price, high price of input factors and labor shortages that would affect all production systems. However, farmers of all production systems had experiences of working with rubber plantations. Then farmers could adjust themselves quite easily. In evalating the success of the production by comparing amongst the four systems, the study found the two systems S2 and S3 had the highest net values at 298,106.2 and 235,242.5 baht/year, respectively. These indicate that these systems would be the best options for farmers financially.

3.3 Sustainable Livelihood Framework (SLF) of SRFS types

Concerning the livelihood of farmers under the four systems (Table 2), the study concluded with regard to capital that the human capital had the largest proportion in S1, financial capital in S2, natural capital in S3, and physical capital in S4. These reflected that rubber farmers under these four systems for potential and capability of production. However, there were some major barriers for livelihood such as price, market, climatic variations, unsuitable area, deficient investment fund, and labor shortage, which affected production and income sufficiency of households. Regarding success of livelihood in the four systems, the study found that food security was rated not at a high level, and asset holding of farmers was rated at a low level. However, the social relationship in the community was still considered to be at a high level even though other social capitals were not rated at those high levels. The study concluded that livelihoods of rubber farmers under all four systems were at the middle level with having high potential farmers which would be able to address the major factors for the development of production for households under four systems.

3.4 The Decision making and condition for transformation among SRFS types

In Figure 6, the study's results are shown regarding decision making and condition for transformation among SRFS types in study areas as follows: S1 system can change to S2 under the conditions of having fruit tree cultivation experience, high fruit tree price, as well as an existing government policy; S1 can also change to S3 under the conditions of having oil palm experience, low rubber price, an unsuitable area for rubber cultivation and a market for rice production. The S1 system can also change to S4 under the conditions of having livestock experience, sufficient investment fund and food security need. S2 system can change to S1 system under the conditions of deficient investment fund, deficient water resource, and low fruit tree price; S2 system can change to S3 under the conditions of a deficient investment fund, an unsuitable area for fruit trees, having oil palm cultivation experience, and having market for rice production; the S2 system can also change to S4 under the conditions of high livestock price, an unsuitable area for fruit trees, supporting government policy and having livestock knowledge. The S3 system can change to S2 system under the condition of sufficiently large investment fund, a high fruit produce price, and having fruit tree cultivation experience; the S3 system can also change to S1 system under the conditions of high rubber price and labor input shortage; and it can change to S4 under the conditions of sufficient labor availability, having an investment fund, having livestock experience, and the existence of supportive government policies. The S4 system can change to S3 under the conditions of having an investment fund, suitable area for rice cultivation as well as the existence of supportive government policies; it

can change to S2 under the conditions of a high fruit price, a suitable area for fruit tree cultivation, and having enough labor availability, and it can change to S1 under the conditions of an unsuitable area for raising animals, having an investment fund, and a high rubber price.

3.5 Factors affecting the livelihood of the SRFS.

From the results summarized in Figure 7, it can be inferred that for the S4 system capital assets, transformation structure and process, as well as livelihood achievement can explain the vulnerability context with the highest R2 value when compared to the other systems. Accordingly, a supportive government policy, food security, and physical capital should be considered and addressed in S4 system development in the future. In the S2 system, a livelihood strategy can explain the livelihood achievement. Hence, the adaptation of fruit tree technology and management practice should be considered in the future. Furthermore, the results indicate that receiving support from related government sectors, especially RAOT, is important. Moreover, the surveyed rubber farmer sample were members of cooperatives. Therefore, the impacts of external shocks, e.g., floods and storms, became less severe. In addition, more than half of the rubber farmers in all smallholding rubber farming systems changed their production system to satisfy consumer needs. They attempted to reduce the cost of agricultural production and to increase diversity in their rubber plantation area. These strategies help cushion against possible adversities in livelihood achievement.

Table 1. Agricultural production systems model (APSM) of SRFS types in studied areas

APS's Component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
1. Farm's production Purpose	- household income - have ample income for good livelihood - carry on a farming career from an ancestor	- be the major household income - have more enough income - have fruits for household consumption - have a good household livelihood	- be the major household income - have more enough income - expand production to new economic crop for risk reduction - have a wellbeing toward sustainable livelihood	- be the major household income - have more inadditional income - have more consumption, selling and food security - have a wellbeing toward sustainable livelihood
2. Farm's physical facors for production	- the average land holding 2.2 hectares/ household - soil texture: sandy loam - topography: plain/low plain (41.7%) folded/undulating area (38.8%) high land /mountain (19.5%) - water source: natural water	- the average land holding 2.5 hectares/ household - soil texture: sandy loam - topography: plain/low plain (60.0%) folded /undulating area (35.7%) high land /mountain (4.4%) - water source: rain and pond	- the average land holding 2.9 hectares/ household - soil texture: clay loam - water source: rain and natural water	- the average land holding 1.98 hectares/ household - soil texture: clay loam - water source: rain and natural water
3. Farm's socio-economic factors of production	- average age 52.6 years - gender: male (83.1%) female (16.9%) - educational level: primary education (40.9%), secondary education (27.3%), high school (13.6%) and other educational levels (18.2) - total average income 136,818.2 baht/year	- average age 55.5 years - gender male (92.3%) female (7.7%) - educational level primary education (52.2%) secondary education (24.7%), high school (22.1%) and other educational levels (1.0%) - marriage status married (92.5%) - Buddhist (100.0%) - total average income 251,724.7 baht/year - average debt: 145,320.1	- average age 57.1 years - gender male (100.0%) - educational level primary education (41.9%) secondary education (11.1%), high school (33.9%) and other educational levels (13.2%) - total average income 208,143.3 baht/year	- average age of 58.6 years - gender male (75.4%) female (24.6%) - educational level primary education (52.0%) secondary education (22.7%) and other educational levels (25.3%) - total average income 190,209.4 baht/year

Kongmanee et al. (2022)

APS's Component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
	- average debt: 168,022.7 baht/household - receive farm's investment fund from ROAT. 58.2% - total houshold's membership: 3.6 persons - total houshold's labor: 2.7 persons	baht/household - receive farm's investment fund from ROAT. 43.3% - total houshold's membership: 4.4 persons - total houshold's labor: 2.2 persons	- average debt: 125,007.8 baht/household - receive farm's investment fund from ROAT. 43.3% - total houshold's membership: 4.0 persons - total houshold's labor: 3.6 persons male (3.6)	- average debt: 102,087.3 baht/household - receive farm's investment fund from ROAT. 56.1% - total houshold's membership: 4.4 persons - total houshold's labor: 3.0 persons male (1.87) female (1.2)
4.Farm production weakness	- rubber is vulnerable to disease - rubber price is inconsistent have rubber land ownership - high input factor e.g high price of chemical fertiliser - use high frequency tapping effect on rubber tree - labor shortage	- Low rubber price effect on lowincome - Low fruit price - high input factor e.g high price of chemical fertilizer - labor shortage	- Have a lot of dept impact on investment is limited. - Uncertain price of rubber and oil palm fruit - high price factor of product - lack knowledge of production oil palm management	- Unsuitable areae for animal husbandry - Lack knowledge of animal husbandry - more alternative occupation due to low rubber price - lack of financial investment support
5.Farm production advantage	- have experience and skill in rubber production - proper area for rubber farming - have rubber land owner - receive the support from government project	- have rubber land owner - have experience and skill inrubber production more than 20 years that receivefrom their ancestors	- have rubber land owner - have experience and skill in rubber production - receive the support oil palm from government project	- have long experience and skill of livestock - have rubber land owner - more enlargement livestock market in the future
6.Farm's production implementation and Technology	Rubber - the average rubber farming labor 2.5 workers	Rubber - the average rubber area 2.1 hectares	- Rubber - the average rubber area 2.0 hectares	Rubber - the average rubber area 1.98 hectares

Kongmanee et al. (2022)

APS's Component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
management	/household - rubber variety: RRIM600 (62.2%), RRIT 251 (13.6%), other rubber breed (10.6%) - rubber age: 18.3 years - growing space: 3x7 meters (73.6%), 4x6 meters (17.7%), other space (8.7%) - average number of rubber trees: 465 trees/hectare - chemical fertilizer applying: 4,640kg/hectare, frequency: 1.3 times/yr - organic fertilizer applying: 1,982 kg/hectare, frequency: 0.7 times/yr - weed control: lawn mower (96.1%), chemicals (3.9%) - frequency of weed control: 1.2 times/yr -tapping system: 1/3S3d4 (56.8%), 1/3Sd2(24.5%), other tapping systems (18.7%) - average selling price: cuplamp 24.3 baht/kg, latex 47.2 baht/kg, rubber sheet 41.3 baht/kg	- the average rubber farming labor 2.0 workers/household - rubber variety: RRIM600 (74.3%), RRIT 251 (14.4%), other rubber breed (1.4%) - rubber age: 15.5 years - growing space: 3x7 meters (68.8%), 4x6 meters (16.7%), other space (14.5%) - average number of rubber trees:465 trees/hectare - chemical fertilizer applying: 4,253.1kg/hectare, frequency: 1.1 times/yr - organic fertilizer applying: 991.9kg/hectare, frequency: 1.0 times/yr - weed control: lawn mower (98.3%), chemicals (1.7%) - frequency of weed control: 2.2 times/yr - tapping system: 1/3S3d4 (74.5%), 1/3S2d3(13.7%), other tapping systems (11.8%) - average selling price: cuplamp 23.3 baht/kg, latex 45.3baht/kg, rubber sheet 44.9 baht/kg - production type: cup lamp (43.4%), latex (40.8%), raw rubber sheet (15.8%)	- average rubber farming labor 2.1 workers/household - rubber variety: RRIM600 (84.1%), RRIT 251 (10.7%), other rubber breed (5.2%) - rubber age: 17.4 years - growing space: 3x7 meters (82.5%), 4x6 meters (13.6%), other space (3.9%) - average number of rubber trees: 473.1 trees/hectare - chemical fertilizer applying: 4,446.9kg/hectare, frequency: 1.7 times/yr - weed control: lawn mower (100.0%), the frequency of weed control: 1.3 times/yr - tapping system: 1/3S3d4(87.6%), 1/2Sd2(12.4%) - rubber product type: cup lump (57.4%), latex (40.0%), raw rubber sheet (2.6%)	- average rubber farming labor 2.7 workers/household - rubber variety: RRIM600 (98.1%), other rubber breed (1.9%) - rubber age: 17.0 years - growing space: 3x7 meters (92.2%), 4x6 meters (7.8%) - average number of rubber trees: 4,839.4 trees/hectare--chemical fertilizer applying: 4,327.5kg/hectare, frequency: 1.4 times/yr - weed control: lawn mower (100.0%), the frequency of weed control: 1.5 times/yr - tapping system: - tapping system: 1/3S3d4(77.3%), 1/2Sd2(22.7%) - rubber product type: cup lump (37.4%), latex (50.0%), raw rubber sheet (12.6%) - average selling price: cup lump 24.1 baht/kg., latex

APS's Component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
	- production type: cuplamp (24.3%), latex (0.7%), raw rubber sheet (14.4%) - source of selling production: local buyer (97.3%), farmer group (2.7%), - benefit ratio: 50:50 (64.5%), 60:40 (34.2%)	- source of selling production: local buyer (97.31%), farmer group (2.7%), - benefit ratio: 50:50 (60.0%), 60:40 (35.2%), other benefits (4.7%) Fruit tree - the average size of fruit tree farming 0.3 hectares/household - fruit tree labor 2.6 persons/household - Rubber-fruit tree system type: Rubber agro-forestry system (intercrop and multicrop forms) (7.8%), Rubber-based system (different plot from rubber) (90.2%) - model of rubber-fruit tree farming system: rubber with one associate fruit tree (82.5%), rubber with two associate fruit trees (14.9%), and rubber with more than two associate fruit trees (2.7%) - Fruitree type: Durain, Banana, mangostene - the nuber of fruit tree per rai: Durian (40), banana (20), mangosteen (45) - chemical fertilizer applying: 312 kg/hectare - frequency 1.8 times/yr - age of fruit tree that gives yield 7.7	- average selling price: cup lump 23.3 baht/kg, latex 44.3 baht/kg, raw rubber sheet 43.7 baht/kg. - source of selling production: local buyer (80.1%), farmer group (12.9%), - benefit ratio: 50:50(30.1%), 60:401(16.3%), other benefit (53.6%) Oil palm - the average size of oil palm land: 0.85 hectares-/household (grow different plot of Rubber plantation area) - labor: 2.2 workers - breeds: tenera (80.0%). Other oil palm breeds (20.0%) - age of oil palm that gives yield 4.5 years - growing space: 9x9 meter (100.0%) - average number of oil palm trees: 142.5-trees/hectare-	44.3 baht/kg, raw rubber sheet 45.0 baht/kg. - source of selling production: local buyer (68.4%), farmer group (12.9%), and cooperative (17.6%) Animal raising - raising methods: inform of both raising in rubber plantation area (71.7%) and and raising in grass field (28.3%) - labor: 1.2 workers - breeds: native cow, goat and backyard chickens - number of animal raising: native cow 3.4 heads/houshold and backyard chickens 32.2 heads/household and goat 8.2 haeds/houshold - feed for backyard chickens: 4,000 bath/yr, for cow: 8500 bath/yr. and goat 6700 bath/houshold - production type: head form

APS's Component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
		years - recent age of fruit tree 18.6 years - labor 2.5 workers - disease and weed control: mechanical method (92.3%) chemicals (7.7%) - source of selling fruit: Huait market (Nakhon Si Thammarat)/middlemen/ local markets - average rubber tree 112 trees/hectare - chemical fertilizer applying: 1,470.6 kg/heactare and frequency 1.6 times/yr - organic fertilizer applying 481.9kg/hectare and frequency 1.1 times/yr - disease and weed control: 1.6 times/yr - average fruit tree price: Durain 43.0 baht/kg., banana 32.7 baht/comb. And mangostene 32.0 baht/kg. - source of selling fruit: local trader (83.5%), local market (16.5%)	- chemicals fertilizer applying: 1,253.1 kg/yr, frequency 3.7 times/yr and no use bio-fertilizer or organic fertilizer - weed control: lawn mower (100.0%), the frequency of weed control: 1.5 times/yr - average selling price: 5.7 bath/kg. - source of selling: palm courtyard	- average selling price: native cow 15,000 baht/head, backyard chickens 150 baht/kg, and goat 400 baht/head - source of selling: middlemen, local markets
7.Farm's succestion of production	- average rubber production 18,864.4 kg/hectare/yr - total incomes of rubber 73,261.1 baht/yr - current saving fund	- average rubber production19,045.6 kg/hectare/yr - fruit production 18,877.5 kg/hectare/yr - total incomes of rubber 61,125.0	- average of rubber production: 3,011.3 kg/yr - average of oil palm production: 5,080 kg/yr - total income of rubber:	- average of rubber production quantity: 2,842.1 kg/yr - average of total rubber income: 65,263.3 bath/yr

APS's Component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
	43,124.4 baht/yr.	baht/yr - total incomes of fruits tree 287,563 baht/yr - net income 298,106.2 baht/yr - saving fund 61,570.3 baht/yr	54,756 baht/yr - total income of oil palm: 230,486.3 baht/yr - Net income 235,242.5 baht/year - saving fund 45,061.1 baht/yr	- total animal raising income: 57,500 bath/yr (native cow 2 head/yr, backyard chickens 30 head/yr and goat 12 heads) - saving fund 20,907.5bath/yr.
8.Farm's Suggestion and recommendation for future Improvement from farmers	- Government units should give promotion and support continually such as fertilizer at low cost - There should have more management to create networking or grouping to reduce underselling problem caused by the middleman. - There should have the training to create a secondary career for smallholding rubber farmers. - There should be promote growing additional plant for improving income	- government should be fruit tree price insurance - provide low cost of production input - promote more organic fertilizer and bio-fertilizer used for decreasing cost of production - support fruit tree group for bargaining price - improving the research and development of fruit tree for receiving high breed of fruit tree and suitable area for growing fruit tree - have fruit tree and rubber price stabilization policy	- Government units should be rubber and oil palm price insurance continually - Government units should support production input such as fertilizer and Pesticide - Government units should transfer and training course of oil palm plantation knowledge - government should be support and provide the irrigation system for oil palm	- Government units should support and extend of animal raising associate with rubber plantation - There should have the - provide training, field trip and transfer knowledge of animal raising and marketing - Government should be rubber price insurance Government units should support production input such as fertilizer and feed - Government should provide area for forage grass cultivation

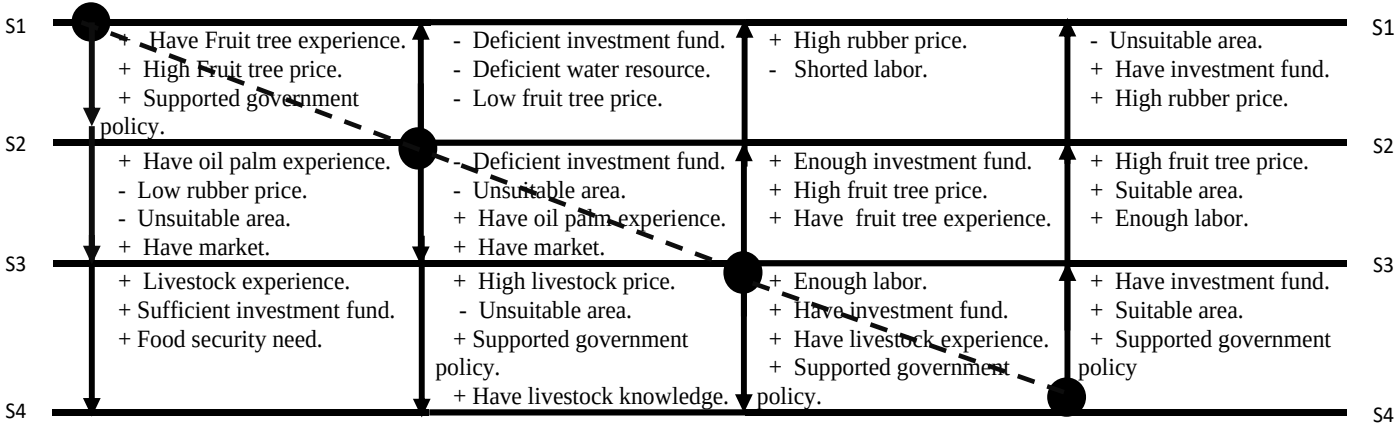
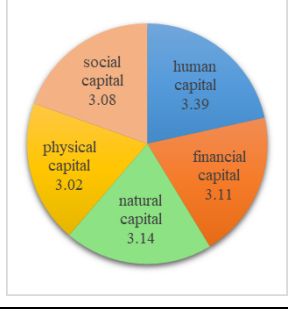
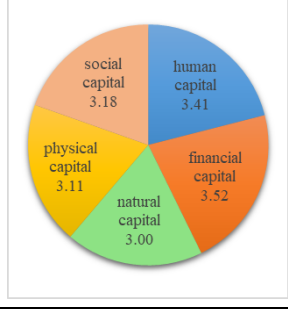
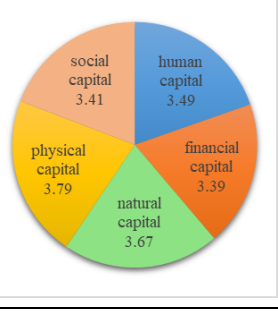
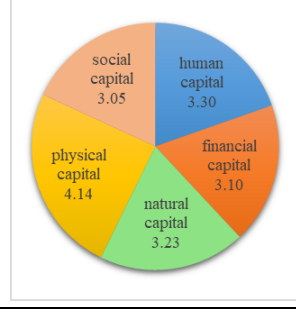


Figure 6. The decision making and condition for transformation among SRFS types in study areas
[Source: from survey of 399 houshold in four provinces]

Table 2. Sustainable Livelihoods by SRFS type in studied areas

Livelihood component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
1. Vulnerability context	- Natural Disasters (average at 1.4 times/yr, side effects average at 22.0% - The flood 0.8 times/yr side effects average at 47.0% - the drought 0.3 times/yr side effects average at 32.7% - The storm 0.5 times/yr side effects average 20.4%	- Natural Disasters (average at 1.0 times/yr, side effects average at 22.4% - The flood 0.44 times/yr side effects average at 22.7 % - the drought 0.1 times/yr side effects average at 13.0% - The storm 0.1 times/yr side effects average 9.2%	- Natural Disasters (average at 1.1 times/yr, side effects average at 12.7%) - The floo 0.2 times/yr side effects average at 23.2% - the drought 0.1 times/yr side effects average at 8.1 % - The storm 1.0 times/yr side effects average 1.0 %	- Natural Disasters (average at 0.7 times/yr, side effects average at 0.1%) - The flood 0.1 times/yr side effects average 3.1% - the drought 0.3 times/yr side effects average at 3.5% - The storm 0.9 times/yr side effects average 8.6 %

Livelihood component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
	- The Diseases and pests 0.2 times/yr side effects average a 11.4% - The tendency of change 63.7% - Price product and factor of product 77.5% - human capital had an average at 76.5% - natural capital had an average at 82.0% - Technology capital had an average at 34.0% - Occupations 45.0% - financial capital had an average at 63.5% - social capital had an average at 67.5%	- The Diseases and pests 1.2 times/yr side effects average a 31.1% - - The tendency of change 43.9% - Price product and factor of product 75.3% - human capital had an average at 46.0% - natural capital had an average at 45.3% - Technology capital had an average at 22.3% - Occupations 45.9% - financial capital had an average at 45.1% - social capital had an average at 29.2%	- The Diseases and pests 1.1 times/yr side effects average a 20.1% - The tendency of change 37.5% - Price product and factor of product 71.6% - human capital had an average at 31.8% - natural capital had an average at 41.9% - Technology capital had an average at 21.0% - Occupations 27.7% - financial capital had an average at 37.8% - social capital had an average at 30.4%	- The Diseases and pests 1.0 times/yr side effects average 5.1% - The tendency of change 54.0% - Price product and factor of product 83.3% - human capital had an average at 61.1% - natural capital had an average at 50.0% - Technology capital had an average - at 33.3% - Occupations 33.3% - financial capital had an average at 77.8% - social capital had an average at 38.9%
2. Livelihood assets (criteria: average 1.00-1.80: non, 1.81-2.50: little, 2.51-3.25: moderate, 3.26-4.20: much, 4.21-5.00: very much)				

Livelihood component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
3. Transforming structure and process	- Participating in activities and Received help from the government sector 82.2% have a good household livelihood 80.2%. - Participating in activities and Receiving Welfare/Social Policy form the Government - 25.8% have a good household livelihood 82.2%	- Participating in activities and Received help from the government sector 74.4% have a good household livelihood 90.1% - Participating in activities and Receiving Welfare/Social Policy form the Government - 25.6% have a good household livelihood 68.9%	- Participating in activities and Received help from the government sector 82.7% have a good household livelihood 96.1% - Participating in activities and Receiving Welfare/Social Policy form the Government 17.3% have a good household livelihood 73.1%	- Participating in activities and Received help from the government sector 94.8% have a good household livelihood 80.9% - Participating in activities and Receiving Welfare/Social Policy form the Government 17.7% have a good household livelihood 97.8%
4. Livelihood strategies	- Changed production pattern that served the need of market (12.5) - Increase productivity (24.5%) - Reduce production cost (25.0%) - Expand production (27.3%) - Increased diversity in Production (25.0%) - change labor productivity (27.0%) - Work Outside the Agricultural Sector (23.5%) - Financial Management (34.6%) - Behavioral of food consumtion Change (21.0%) - Marketing adjustments (10.6%) - social relation (33.3%)	- Changed production pattern that served the need of market (22.3) - Increase productivity (24.0%) - Reduce production cost (39.5%) - Expand production (18.0%) - Increased diversity in Production (12.0%) - change labor productivity (16.0%) - Work Outside the Agricultural Sector (12.0%) - Financial Management (30.7%) - - Behavioral of food consumtion Change (40.0%) - Marketing adjustments (40.0%) - social relation (46.7%) - associate into goverment unit/company (54.0%)	- Changed production pattern that served the need of market (19.4) - Increase productivity (19.6%) - Reduce production cost (30.3%) - Expand production (38.0%) - Increased diversity in Production (28.0%) - change labor productivity (10.0%) - Work Outside the Agricultural Sector (14.0%) - Financial Management (38.0%) - Behavioral of food consumtion Change (53.3%) - Marketing adjustments (19.0%) - social relation (46.0%) - associate into goverment unit/company (69.0%)	- Changed production pattern that served the need of market (10.2%) - Increase productivity (5.9%) - Reduce production cost (10.2%) - Expand production (10.2%) - Increased diversity in Production (5.1%) - change labor productivity (2.5%) - Work Outside the Agricultural Sector (12.7%) - Financial Management (10.7%) - Behavioral of food consumtion Change (8.9%) - Marketing adjustments (7.6%) - social relation (11.0%) - associate into goverment unit/company (13.4%)

Livelihood component	SRFS type S1 (Rubber Monoculture)	SRFS type S2 (Rubber with Fruit tree)	SRFS type S3 (Rubber with Oil palm)	SRFS type S4 (Rubber with livestock)
	- associate into goverment unit/company (12.5%)			
5. Livelihood Achievement	- financial status households (average at 2.4 low level) - Food Security and facilities (average at 2.4 low level) - asset possession (average at 2.7 medium level) - productive resources (average at 2.3 low level) - Relationship with community and society (average at 2.2 low level) - sanitation (average at 2.3 low level)	- financial status households (average at 3.4 medium level) - Food Security and facilities (average at 4.0 high level) - asset possession (average at 4.0 high level) - productive resources (average at 4.0 high level) - Relationship with community and society (average at 3.4 high level) - sanitation (average at 4.0 high level)	- financial status households (average at 3.1 medium level) - Food Security and facilities (average at 3.7 high level) - asset possession (average at 3.8 high level) - sanitation (average at 3.7 high level) - productive resources (average at 3.9 high level) - Relationship with community and society (average at 4.0 high level)	- financial status households (average at 3.7 high level) - Food Security and facilities (average at 3.9 high level) - asset possession (average at 3.7 high level) - sanitation (average at 3.6 high level) - productive resources (average at 4.1 high level) - Relationship with community and society (average at 3.8 high level)

[Source: from survey research 399 houshold in studied area]

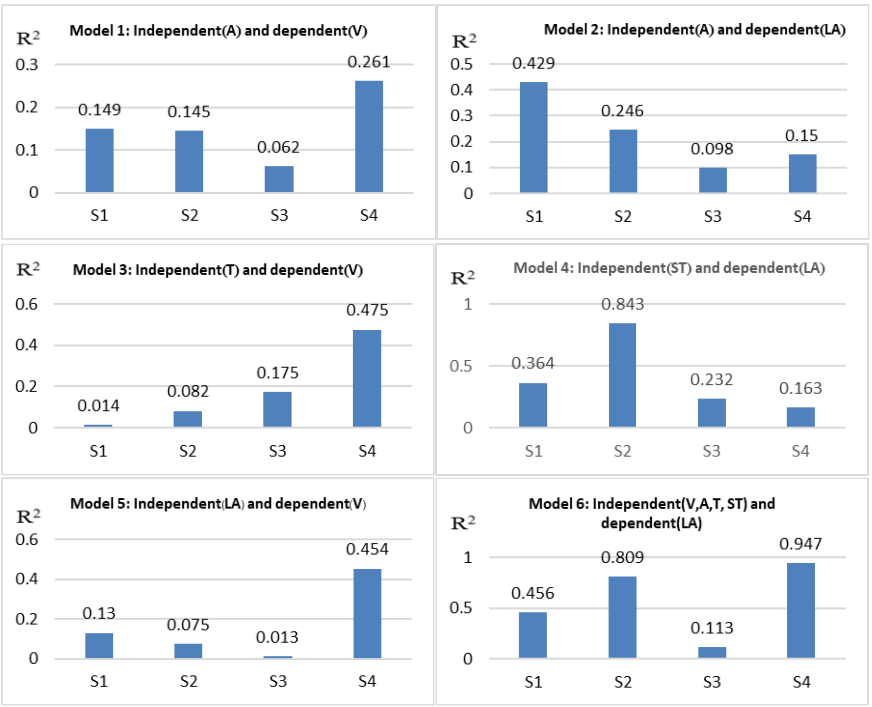


Figure 7. **(Models 1-6)** Factors affecting the livelihood of SRFS. [Remarks: Variables; A: Livelihood assets, V: Vulunarbility context, T: Transforming Strucrure and process, LA: Livelihood achievement, ST: Livelihood Strategy]

Model 1: S1; F-sig (0.032*), Std.Error of Estimation (1.094). S2; F-sig (0.158), Std.Error of Estimation (0.844). S3; F-sig (0.169), Std.Error of Estimation (1.088). S4; F-sig (0.222), Std.Error of Estimation (0.903).

Model 2: S1; F-sig (0.000***), Std.Error of Estimation (0.659). S2; F-sig (0.061), Std.Error of Estimation (0.971). S3; F-sig (0.088) Std.Error of Estimation (0.805), S4; F-sig (0.648) Std.Error of Estimation (1.578)

Model 3: S1; F-sig (0.269) Std.Error of Estimation (1.016), S2; F-sig (0.150), Std.Error of Estimation (0.875), S3; F-sig (0.004**), Std.Error of Estimation (1.020), S4; F-sig (0.0016*), Std.Error of Estimation (0.761).

Model 4: S1; F-sig (0.002***) Std.Error of Estimation (0.695), S2; F-sig (0.000***), Std.Error of Estimation (0.442). S3; F-sig (0.031*), Std.Error of Estimation (0.743). S4; F-sig (0.2321), Std.Error of Estimation (0.564).

Model 5: S1; F-sig (0.080), Std.Error of Estimation (1.122, S2; F-sig (0.272), Std.Error of Estimation (0.878). S3; F-sig (0.054), Std.Error of Estimation (1.130). S4; F-sig (0.926) Std.Error of Estimation (1.266).

Model 6: S1; F-sig (0.000***) Std.Error of Estimation (0.643). S2; F-sig (0.000***), Std.Error of Estimation (0.489). S3; F-sig (0.109), Std.Error of Estimation (0.799). S4; F-sig (0.003**), Std.Error of Estimation (0.257).

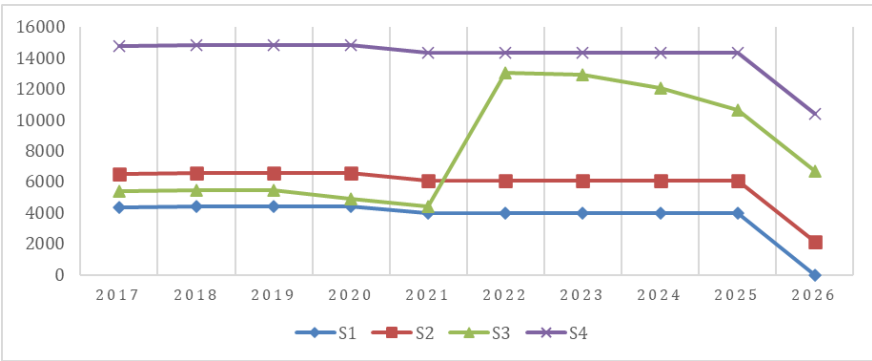


Figure 8. The technical economic simulation model (marginal analysis) among SRFS types 2017-2026 using the OLMPE Solfware

3.6 The technical economic simulation model (margin analysis) among SFRS types 2017-2026.

The results shown in Figure 8 on the comparison margins simulation analysis software amongst the four systems by using the OLYMPE indicates that the farms of type S1 had the lowest margin while those in S3, S4 and S2 had a high margin; especially the S4 system had the highest margin value when compared with the other systems.

3.7 The relationship between production and livelihood adjustment model of SRFS

1) Economic features with livelihood: According to the economic data, household incomes and household expenses have interrelation with the saving level and debt situation which are affected by the fluctuations in price of rubber and unfair marketing situation. Those would affect the risk of the production process that would make a difference to household capital level and the fragility of the production system. Then farmers have to adapt themselves to respond to the economic needs (Nusang, 2006). For example, farmers need to have secondary income for their households in order to be able to manage the household income with high efficiency; 2) Social features with livelihood: The study data indicate that social features such as knowledge, educational level, experience, being a group member, having a relevant production policy all had effects on the decision process. Furthermore, the participating process relevant to the production process and marketing process would affect the process of risk management, which relates to human capital and social capital. Farmers have to select strategies for the adaptation by building the concept and creating innovation to increase value in order to increase both household incomes and livelihood strength. These would result in obtaining a good livelihood by having food security, convenient facilities, and community interaction (Boonchu, 1990). In short, these are increasing the potential of human capital and social capital for even more potential of the production process; 3) Rubber production with livelihood: The proper technique of the production process would affect the efficiency of the production process. Nevertheless, the production process would need to have both proper physical and biological factors (Athipanan, 1999). These factors would lead to the selection of the production process that harmonizes the location situation. The aforementioned factors will relate to the process of risk management, which aims for a good quantity and quality of the production. However, physical factors and biological factors have interaction with

fragility caused by the natural capital in the component of the weakness of livelihood that directly affects the success of livelihoods such as production resources, food security, and farmers' good sanitation. In short, economic features, social features, and the production process would have interaction among themselves and by employing proper policy and production plan that would contribute to the selection of livelihood strategies for the production process. These would lead to the success of livelihood by having increased incomes, food security, ample assets for livelihood, sufficient production resources, good sanitation conditions, good participation, and good interaction with people in the community.

3.8 Synthesizing the relationship between production and livelihood adjustment model of SRFS

This model shows the connection between the production system and livelihood of four systems. Such a model can be classified into four sub-models as follows (Figure 9). 1) Sub-model: Production System is a systematic concept composed of four production factors, namely physical factors, biological factors, economic factors, and social factors. These factors have relations among themselves and conjunctively perform their duties to reduce the risk of production that will lead to target or propose of production under the recent situation. Such production factors also have relations with livelihood factors; 2) Sub-model: Support System is a sub-model composed of livelihood component in terms of assets that will have relation with weakness component and fragility. Both systems will help strengthen to promote and support the production system and move forward efficiently. In addition, there will be a relation with strategies and livelihood adaptation. 3) Sub-model: Strategic and Livelihood Adjustment System is a sub-model that has relation with a decision support system by changing structure and institution that will strengthen the components of livelihood, weakness, fragility, and assets and will lead to the strategies and adaptation for proper livelihood, and 4) Sub-model: Strategies and Adaptation of Livelihood is a sub-model which should lead to the results or success of livelihood of practicing rubber farming alongside another agricultural activity system that has indicators such as recent economic (financial) status, food security, asset holding, production resources, community interaction, and sanitation (Choengsa-at, 1991).

4. DISCUSSION AND CONCLUSION

The four types of smallholding rubber farming systems (SRFS) indicated that the smallholding rubber monoculture farming system (S1) and smallholding rubber with fruit tree farming system (S2) were the dominant farming systems which were similar plantation technology of RAOT. The farming system of S1 had the lowest income at 73,261.1 Baht/yr while the S2 and S3 had the highest incomes at 298,106.2 and 235,242.5 baht/yr. This result is similar to previous research on the current evolution of smallholder rubber–based farming systems in Southern Thailand which showed that the rubber monoculture system contributed more than 50% of cases (Simien and Penot, 2010). As well, household incomes of mixed farming system had high incomes (Cherdchom et al., 2009; Stroesser et al.,2016; and Warren et al., 2019).

Regarding livelihood assesments, the S1 showed that human capital was quite high while the physical capitals were quite low, while the S3 and S4 showed that the physical capitals were quite high but the social capitals were quite low. The S3 showed higher household assets and productive resources on an average than the others. By

the farm performance's projections until 2026, the S1 expects to earn the lowest margin while the S3, S4 and S2 may earn higher margins, especially S4 may be able to earn the highest margin. Thus, the adjustment of S1 to diversify farming systems (S2, S3, S4) depends on several factors such as experience, rubber price, resource availability, sufficient investment, food security, farm technologies, and promotion policy. The livelihood assets of the four systems were at the middle level with increasing the exposure and vulnerability by many risks such as climate change, natural disaster, economic viability, technological changes, and policy risks. Consequently, the livelihood achievement of the four systems was medium level. The study indicated that food security and facility, asset possession, and productive resources under the S4 system had higher average values than in the other systems. As a sustainable development, the study identified three features contributed to farming system change, 1) the economic features, household incomes and expenses have interrelation with the savings level and debt affected by the price fluctuation and unfair marketing systems, 2) the social features, such as knowledge, educational level, experience, farm's groups, and relevant policy had effects on the production decision and strategies, and 3) the plantation management, such as the recommened technologies by RAOT would affect the productivity and cost reduction. The study indicated that capital asset, transformation structure and process, and livelihood achievement have explained coping capability to the vulnerability context. Then, promotion policy, food security, sufficient capital should be emphasized for promoting diversification of farming systems. This study suggested the relationship between production system and livelihood adjustment models composed of 4 sub-systems that were 1) Production System, 2) Support System, 3) Strategy and Livelihood Adjustment System, and 4) Livelihood Achievments. The model can function not only as an analysis framework and policy tool promoting a holistic perspective of sustainalble livelihood development but also useful for analyzing livelihood adjustmentation (Figure 9). The model helps to focus on the process of livelihood adjustment and the systematic synergy between sub-systems and dimensions of sustainable livelihood.

Regarding the livelihood adjustment toward sustainability of SRFS, the suggestions are as follows: 1) In order to cope with price fluctuations, promoting the philosophy of sufficiency will be the solution for smallholding farms. 2) Promotion of mixed - farming systems can have a positive impact on food security, increasing household income, and risk management of production and livelihood as reflected for instance by promoting alternative economic crops and rubber intercropping. 3) Promoting the adoption of recommended technologies for increasing productivity, reducing the cost of production and supporting production factors at a low price such as fertilizers. 4) Promoting farmer's groups and improving farm knowledge relevant to strengthen farm's entrepeneurship, production, farm management, markets, cost reduction, and productivity. 5) Promoting high value- added processing of rubber products and other.

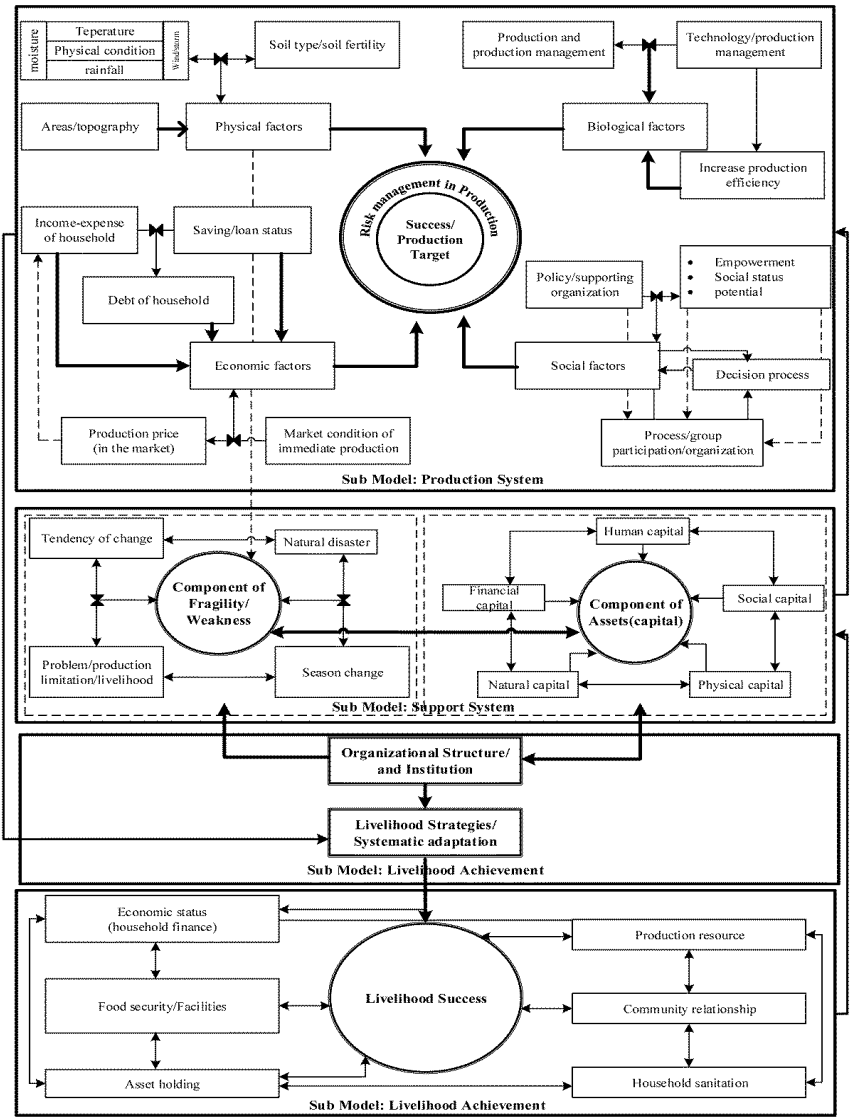


Figure 9. The relationship between production and livelihood adjustment in model of SRF

Author Contributions: Chaiya Kongmanee developed the theoretical framework, designed the study, corrected the data analysis, wrote and edited the manuscript. Buncha Somboonsuke designed and directed the project, and contributed to the interpretation of the results. Milinpat Boonkongma carried out the field survey, performed the analysis, drafted the manuscript preparation in consultation with Chaiya kongmanee and Buncha somboonsuke. Prawat Wettayaprasit, Rawee Chiarawipa, Kamonwan Sae-chong, Kanata Thatthong, Panuphan Prapatigul provide critical feedback and helps shape the manuscript.

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