Detecting Trajectories in Rubber Farms in Southern Thailand

Chaiya Kongmanee, Ferdoushi Ahmed

Abstract: ***For the past 30 years, Thailand experienced important changes in the agricultural sector. This study aims to identify rubber farm trajectories and analyze consequences of the trajectories in southern Thailand. A household survey was carried out in four representative villages in Southern Thailand to collect the data for the period of 1990 to 2010. Purposive sampling method was employed to select the samples. The core sample size for the study was 220 rubber farmers. Principal Component Analysis (PCA) and Cluster Analysis (CA) were carried out to analyze the data. The findings revealed six significant farm trajectories. Two farm trajectories showed a decline in landholding or hired labor, namely farms with high structural change ๖(10.5%) and declining very size small farms (25%). In contrast, three farm trajectories showed expansion, which included growing medium family farm enterprise (14.5%), growing large family farm enterprise (4.1%) and towards patronal enterprise (7.7%). One trajectory showed a stability with no change in farm size and labor structure (38.2%). However, these are small farms and provide a notion of risk to follow the trajectories of farm decline. The study findings might be helpful for policy and decision makers to reconsider the current policies and design policies with a wider approach for small farms and family farms.***

Index Terms**:** ***Trajectory, Rubber Farm, Farm Size, Principal Component Analysis, Agricultural Sector, Thailand.***

I. INTRODUCTION

Rubber tree (*Hevea brasiliensis*) is among the most important economic crops in the world (Nualsri et al. 2015). Rubber products, from auto parts to medical supplies, are vital to the world's businesses and consumers (Palapan Kampan 2018). Latex is the major product from this species while rubber wood (lumber) is considered a secondary product (Priyadarshan et al., 2009). Synthetic rubber (SR) holds a slightly larger market share than natural rubber (NR), but NR is more resilient and longer lasting, making it irreplaceable for various products such as aircraft tires (Emspak, 2014). It was reported that the total planted area for rubber all over the world has increased from 3.88 million hectares (ha) in 1961 to 11 million ha in 2006, showing an almost three-fold increase (i.e 1.71% per annum) during the last four decades (Viswanathan, 2006). Currently, rubber is producing in more than 20 countries around the world. Among them, four countries, namely Indonesia, Malaysia, Thailand and India were the pioneers in development of commercial rubber plantation (Viswanathan, 2006). These countries also continue to dominate in planted area (77% of total planted area) and production (79% of total production) of rubber in the world (Viswanathan, 2006). Another study reported that Indonesia, Malaysia, and Thailand collectively accounted for about 70% of the world's natural rubber production in 2015 (Thailand Board of Investment, 2016). These countries have also experienced rapid structural transformation in terms of growth of the smallholding sector under various socioeconomic, political, and institutional contexts (Osman and Tan, 1988; George et al., 1988; Barlow et al., 1994; Burger et al., 1995; Hayami, 2004).

Rubber tree plantations play an important role in the socio-economic development in Thailand. About 10% of total population of the country are involved in rubber tree plantations. However, rubber farming is still a family business in Thailand. More than 90% of rubber plantations in the country are operated by smallholders whose farms are as modest as 0.3ha (Yamamoto, 2016). In the last decade, Thailand has become the largest natural rubber producer and exporter in the world (Poungchompu and Chantanop, 2015). In 2014, total area for rubber plantation was estimated to be 2.9 million hectares and production was 3.3 million tons (RRIT, 2013). In 2015, Thailand exported US$6.6 billion worth of standard Thai rubber (STR) blocks, ribbed smoked sheets (RSS), and other rubber products (Thailand Board of Investment, 2016). It can be mentioned that Southern Thailand is a traditional hub for rubber cultivation in the countruy. Most of the production areas (1.76 million ha) are in the southern part of the country, owing to humid tropical climate suitable for rubber cultivation (Nualsri et al. 2015 & Palapan Kampan 2018). The region produces more than 80.0% of the country's total rubber production (NSO, 2013). Nearly 1.0 million households are involved in rubber cultivation in this region (NSO, 2013). However, the rubber farms in Thailand are changing structurally due to a number of factors such as lack of plentiful supply of land and the decline in farm labor forces (Siamwalla, 1995, 1996, 1999; Poapongsakorn et al., 1998; Somboonsuke el at., 2008). For example, the size of rubber farms decreased continuously from 3.3 ha in 1993 to 1.68 ha in 2013 (NSO, 1993; 2013). At that same time, farm labor forces also decreased, from 3.52 people per household to below 2.0 people per household in 2012 (RRIT, 2012). Aged farms were no longer fully replaced (OID, 2011). Moreover, most of the rubber cooperatives or farmer groups are located far away from the central rubber market and lack of sufficient information on

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rubber marketing (Poungchompu and Chantanop 2015).

Therefore, the systematic study is necessary to understand the present situation and the past of the farm changes, to identify what were the main drivers, and to forecast the changes that might happen in the future (García-Martínezet al, 2009; Rueff et al 2012). Study on farm trajectory allows us to identify and assess the structural transformation of a firm (Kongmanee, 2015). However, there is lack of study on trajectories in rubber farms in Thailand, particularly in the Southern part of the country. Thus, the present study aims to identify rubber farm trajectories and analyze consequences of the trajectories in southern Thailand. Knowledge and understanding of farm trajectories (i.e. diversity of farm transformations) might be helpful in policy and decision making aimed at sustainable growth of rubber industry in Thailand.

II. OVERVIEW OF RUBBER TREE CULTIVATION AND TAPPING

Rubber is produced entirely in tropical areas a particular in Southeast East Asia where is the largest producing region. Rubber plantations should be located not higher than 600 meters above sea level. The land must be flat or hilly with slopes of less than 35 degrees. Appropriate soils have clay-loam to sandy clay-loam texture and should be fertile with top soils deeper than one meter. The favorable pH of soil varies from 4.5-5.5. Annual rainfall is to be not lower than 1,250 mm with 120-150 rainy days. Clones (budded planting material) are the key factors for the potential productivity of a rubber plantation. There are various varieties of clone which clonal recommendations are adapted according to the different locations, weather, and specific condition of farms, for such the RRIT's recommendation are RRIM600, RRIT 251 and RRIT 408. The planting density is 475 or 500 trees per hectare. Weeding between the tree lines is done 2-6 times a year during the immature stage when the frequency of weeding is high. The application of fertilizer is important for the growth of rubber trees and productivity. Most fertilizers are inorganic and may be complemented with organic fertilizers. Several factors should be considered for level of application such as soil quality, clone, age, etc. During the immature stage, pruning is done regularly and selectively in order to produce a suitable length of trunk for tapping and to increase leaf area and growth rate. It also helps to minimize wind damage (RRIT, 2012).

Rubber tree takes approximately seven years to come to the mature stage. It will have an economic period of more than twenty years. Latex harvesting is done through tapping, consisting of shaving rubber bark to allow latex to flow. Natural rubber can be produced throughout the year except during the winter when farmers usually stop tapping as well during the rainy season where production is usually lower as latex cannot be harvested when it rains. Farmers start to tap when the girth is 50 cm. at 150 cm. above ground level. The recommended tapping systems are S/2 d2, S/2 2d3, and S/3 2d3. The method for tapping rubber has not been changed for years. The "Jeak-Bong" knife is used to cut a thin layer from the intact section of the bark at an angle of 30° from the top left to the bottom right in order to expose the optimum number of latex vessels. The tapping should be performed deeply enough to cut maximum latex vessels but should not reach the wood to avoid wounds that would result in low productivity in the next renewable bark. Tapping wood should also not be too thick to prevent high bark consumption that would reduce the productive life of the plantation. Latex begins to flow into a latex cup below the cut. Tapping capacity per tapper is 500 trees per day depending on skill, location, age, biophysical properties of trees, and so forth. The skilled tapping associated with good farm maintenance, will be able to tap rubber trees up to 35 years old.

On tapping days, tappers will start to tap early morning or after midnight depending on tapping size, number of tappers, location, age of rubber tree, skill, and so on. In cases of tapping in the early morning, tapping tasks should be done from 6:00 – 7:00 am. Generally, the tappers will return a few hours later for collecting fresh latex between 9:00-11:00 am. When selling the collected latex will be brought to market, which can be middlemen, cooperatives, or farm groups. The working time will finish before 12 am. On the average, the total working time is about 6-8 hours. If the latex is transformed to unsmoked sheets, the farmers have a small building for processing the rubber sheets at home. The latex coagulates with acid in trays and then will be squeezed with small sheeting machines. The sheets are then hung outside on poles to dry. The sheeting tasks will be done in the afternoon from 12:00 pm to 14:00 pm. The average working time is about 10-12 hours per tapping day depending on the number of laborers, quantity of latex, and scale of sheeting. The dry sheets are sold after a week or a few times per month to middlemen or the cooperative.

III. MATERIALS AND METHODS

A. Study Site

The study conducted a household survey to collect the data to fulfill the objectives of the study. The survey was carried out in four representative villages in Southern Thailand, namely Ban Mai and Ban Koa Phra villages in Songkhla Province, and Ban Lohhan and Ban Kok Muang villages in Pattalung Province. Songkhla Province traditionally has been a center of rubber development and rubber industry for a long time. On the other hand, Pattalung Province is characterized by more recent change into rubber based economy. Rubber production in the selected four villages is dominant in terms of land and labor use. In other words, social and economic development of the four villages mainly depend on rubber cultivtion. There are two types of rubber cultivation available in the study areas: a) rubber plantation under the subsidized re-plantation scheme and b) rubber plantation under private investment. However, the selected four villages differ by farm size, linkages between rural and urban areas, and the social and economic development.

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B. Sample Design and Data Collection

The study used purposive sampling method to select the samples. Multiple criteria were applied to select a sample such as ownership of the rubber firm, earnings from rubber, having experience with mature plantations, living in the village, and willingness to provide information on their farm household. A total of 393 rubber farmers were selected and interviewed. However, among them, 220 respondents were able to provide the complete data set and were therefore used as the core sample for this study (Table 1). A structured questionnaire was designed and employed to collect the data for the period of 1990 to 2010. The data comprised of family structure, landholding, land use and acquisition, labor use, rubber yield, farm management, cost of production, income, household activities and so on. The survey was conducted between 2016 and 2017.

Table 1. Surveyed and core (i.e. analyzed) samples in the study areas

Village (Province)	Surveyed Sample	Core (i.e. Analyzed) Sample
Ban Mai (Songkhla)	120	68
Koa Phra (Songkhla)	90	50
Ban Lohan (Pattalung)	88	50
Ban Kok Muang (Pattalung)	95	52
Total	393	220

C. Data Analysis

Multivariate analysis was applied to establish a typology of farm trajectories. This method consists of three steps. In the first step, multivariate analysis was carried out to build a typology of farm trajectories using two sequential stages: Principal Component Analysis (PCA) and Cluster Analysis (CA). We selected a set of relevant variables of farm structure in order to implement the PCA. Each variable was assigned one value for each of the three stages: initial year 1990, intermediate year 2000, and final year 2010. Using the Kaiser-Maiser-Olkin measure and Bartlett's sphericity test, we checked that these variables were appropriate for PCA to highlight the correlations among the variables (Kobrich et al. 2003). A Kaiser-Maiser-Olkin value greater than 0.50 and the significance of Bartlett's sphericity test at a probability value of $p < 0.05$ were used as thresholds to indicate their fitness for the analysis (Kobrich et al. 2003). PCA with varimax rotation was applied on the selected variables that reduced the number of factors to the extracted factors (Kobrich et al. 2003; Iraizoz et al. 2007). Factors with eigenvalues equal or greater than 1.0 and variables with a variance greater than 0.5 were selected as factors for cluster analysis (Kobrich et al. 2003; Iraizoz et al. 2007; Cots-Folch et al. 2009).

In the second step, Cluster Analysis was applied to identify group of farm trajectories, using a combination of hierarchical and non-hierarchical methods. A hierarchical method was used to identify a preliminary number of clusters and clustering profiles and then a non-hierarchical method was performed to optimize the final cluster solution (Hair et al, 2010). We applied the hierarchical cluster analysis technique using squared Euclidean distances and Ward's aggregation method (Iraizoz et al. 2007). The agglomeration coefficient and the dendrogram were used to identify the number of clusters. Agglomeration coefficient presents the two clusters that are combined at each stage and the increase in heterogeneity (reduction in within cluster similarity) that occurs when two clusters combined. The observation in a sudden jump upwards in the agglomeration coefficient was used to identify a potential cluster solution. The graphical result is a dendrogram, which presents a graphical representation of the hierarchical tree structure solution. A cutting line on the dendrogram was established subjectively to identify the number of clusters by plotting the number of clusters against the change in the fusion coefficient. Once preliminary cluster solution was identified, a non-hierarchical clustering technique was applied which used the hierarchical results to determine the initial value of K-mean and then nonhierarchical clustering was developed until optimal cluster solution is achieved.

Thirdly, we carried out multivariate analysis of variance (MANOVA) to test the validity of the cluster solution and the resulting of cluster profiles (Hair et al, 2010).

IV. RESULTS

A. Findings of the Principal Component Analysis (PCA)

The study selected 19 variables in order to implement the Principal Component Analysis (PCA) (Table 2). Each of the 19 variables was assigned one value at each of the three stages: initial year (1990), intermediate year (2000), and final year (2010). Therefore, a total of 57 values were used for the PCA.

Table 2. The variables selected for the Principal Component Analysis

Variable Code	Description and Unit of the Variable
LHH	Landholding, i.e. land area (rai*)
RLH	Total area of rubber plantation (rai)
MRLH	Area of mature rubber plantation (harvesting areas) (rai)
OFFL	Area of off-farm (rai), i.e. rubber areas belonging to other farmers and where family labor taps as hired labor
SLH	Area of share-tapping, i.e. rubber areas tapped by hired labor (rai)
LHFL	Land area per family labor ratio
RLFL	Area of rubber per family labor ratio
MRFL	Area of mature rubber per family labor ratio
FML	Number of family labor ≥ 15 years (person)
FTP	Number of family tapper (person)
HTP	Number of hired tapper (person)

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UFL	Type of labor: 1:only family labor; 0: otherwise
UHL	Type of labor: 1:only hired labor; 0: otherwise
UFHL	Type of labor: 1: family and hired labor; 0: otherwise
UOFL	Type of labor: 1: family on farm and off farm; 0: otherwise
UFFL	Type of labor: 1: family only off farm; 0: otherwise
FAG	Household head's age (year)
FGD	Household head's gender: 1: male; 0: female
FED	Household head's education: 1: household head finished primary school; 0: otherwise

*1 rai = 0.16 ha

The principal component analysis gave eight principal factors with eigenvalue greater than 1.0, explaining 85.3% of the total variance. A five-factor solution was adopted, explaining 75.3% of total variance (Table 3). The Kaiser-Maiser-Olkin measure of sampling adequacy showed a value of 0.800 and the Bartlett's sphericity test showed significantly probability value ρ< 0.0005.

Table 3. PCA**:** the five principal factors explaining 75**.**3**%** of total variance**.** Each variable comprised three **'**sub-variable**'**, one per farm trajectory stage of 1990, 2000, and 2010

Variable	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**
Variance (%)	42.42	12.26	10.18	5.52	4.92
Cumulative variance (%)	42.42	54.68	64.86	70.38	75.3
Eigenvalue	16.54	4.78	3.97	2.15	1.92
LHH_2010	**.929**	-.017	-.102	-.060	.135
LHH_2000	**.944**	.062	-.087	-.070	.166
LHH_1990	**.876**	.068	-.074	-.086	.056
RLH_2010	**.938**	-.014	-.107	-.066	.113
RLH_2000	**.948**	.063	-.092	-.076	.147
RLH_1990	**.886**	.072	-.073	-.092	.060
SLH_2010	**.899**	.128	-.026	-.023	.001
SLH_2000	**.946**	.188	-.031	-.038	.109
SLH_1990	**.823**	.250	-.032	-.065	.091
OFFL_2010	-.145	-.090	**.800**	.429	-.102
OFFL_2000	-.132	-.072	**.804**	.446	-.079
OFFL_1990	-.084	-.037	**.691**	.459	.022
LHFL_2010	**.895**	-.014	-.039	-.024	-.171
LHFL_2000	**.854**	.115	-.095	-.057	.237
LHFL_1990	**.904**	.090	-.078	-.081	.127
RLFL_2010	**.882**	-.015	-.039	-.025	-.184
RLFL_2000	**.877**	.123	-.105	-.065	.222
RLFL_1990	**.912**	.093	-.078	-.088	.135
FML_2010	-.069	-.216	.055	.061	.116
FML_2000	.068	-.137	.007	.033	-.031
FML_1990	.066	.012	-.045	-.013	-.001
FTP_2010	-.163	**-.700**	.063	.106	.017
FTP_2000	-.112	**-.764**	.041	.101	.081
FTP_1990	-.140	**-.721**	-.059	.168	.118
HTP_2020	**.781**	.374	-.066	-.049	.291
HTP_2000	**.810**	.331	-.066	-.069	.353
HTP_1990	**.728**	.326	-.003	-.072	.247
UHL_2010	.148	**.861**	-.080	-.019	.077
UHL_2000	.117	**.883**	-.076	-.012	-.029
UHL_2010	.177	**.811**	-.045	-.024	-.173
UFHL_2010	.428	-.203	-.102	-.102	**.680**
UFHL_2000	.456	-.196	-.098	-.130	**.753**
UFHL_1990	.458	-.079	-.067	-.109	**.703**
UOFL_2010	-.108	-.082	-.106	**.783**	-.079
UOFL_2000	-.128	-.099	.274	**.813**	-.129
UOFL_1990	-.085	-.059	.229	**.794**	-.005
UFFL_2010	-.131	-.091	**.743**	.071	-.113
UFFL_2000	-.079	-.018	**.772**	-.136	-.015
UFFL_1990	-.051	.010	**.743**	-.198	.032

The first principal factor (Factor 1, Table 3) shows highly positive correlation coefficients with the variables of landholding (LHH), land use (RLH, SLH), and the use of hired labor (HTP) in 1990, 2000, and 2010. These variables have high scores above 0.700 and contribute to 42.42% of the total variance. Farms with high variance for this factor show increment in landholding and orientation towards farm enterprise.

The second principal factor (Factor 2, Table 3) is positively correlated with variables of the use of hired labor (UHL) in 1990, 2000, and 2010 and is negatively correlated with family tapper (FTP) for the same periods. These variables have a score higher than 0.700 and they explain 12.26% of total variance. The high variance of factor 2 expresses a farm orientation towards the dependence on hired labor.

The third principal factor (Factor 3, Table 3) is positively correlated with the use of family labor to tap plantations belonging to other farmers (UFFL) in 1990, 2000, and 2010 and with the size of off-farm tapping areas (OFFL) for the same periods, explaining 10.18% of total variance. This factor indicates the intensity for off-farm tapping. Farms with a high variance for this factor correspond to the ones with the highest participation to off-farm tapping for both number of laborers and off-farm areas.

The fourth principal factor (Factor 4, Table 3) has a high positive correlation coefficient with the use of family labor mixed on-farm and off-farm (UOFL) in the 1990, 2000, and 2010, explaining 5.52% of total variance. Farms that have the highest variance for this factor show high proportion of family labor tapping both on-farm and off-farm.

The fifth principal factor (Factor 5, Table 3) is positively correlated with the variables of the use of family labor and hired labor (UFHL) in 1990, 2000, and 2010, explaining 4.92% of total variance. Farms that have the high variance for this factor use both family labor and hired labor for their own rubber plantations, which is indicative of farm enterprise profiles.

B. Cluster analysis*:* Six Significant Farm Trajectories

The five principal factors were used for the cluster analysis. The agglomeration coefficient gave the same potential number of cluster solution with dendrogram (Figure 1). We found two large homogenous groups of pattern of change that we called PC1 and PC2, each group comprising of three differentiated clusters of farms, which represent total

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six significant farm trajectories that can be called TR1 to TR6 (Figure 2; Table 4). The hierarchical results were used to determine the value of K-mean and then nonhierarchical clustering was performed to optimize the final cluster solutions. The combined hierarchical and non-hierarchical method yielded six-cluster solutions. The MANOVA applied on the six cluster solution was statistically significant, with F (225,846) = 41.119, *p* values = 0.000, showing that a six-cluster solution was the optimum typology of farm trajectories. In figure 1, Cutting line A yielded two large homogenous groups of pattern of change PC1 and PC2. Cutting line B divided each pattern of change into homogeneity within and heterogeneity between the clusters of the farms, called farm trajectories (TR).

The first group of pattern of change PC1 concerned 26.3% of the 220 surveyed farms and consisted of three farm trajectories TR1, TR2, and TR3 (Figure 2; Table 4); overall, this PC1 group experienced an increment of landholding or hired labor. The second group of pattern of change PC2 concerned 73.7% of the farms and consisted in three farm trajectories TR4, TR5, and TR6; overall, this PC2 group characterized small farms in 2010, and which size of landholding was declining or stable at both the initial and final year of the study.

Fig. 1. Dendrogram resulted from cluster analysis (**See Appendix- A**)

The first farm trajectory **(**TR1**)** is characterized by the growth of large family farm enterprises, which comprised 4.1% of the farms. These were large farms that experienced the largest increment of land and use of hired labor. Landholding grew mainly during 1990-2000 and remained to increase in 2010. The number of family tappers decreased even if the number of family labor increased. Family labor was mainly dedicated to farm management with limited family tapping activity. Increment of landholding associated with the decrease in family labor led to employ more hired labor. This trajectory presented the highest land/labor and rubber land/labor ratios. Initial large farm size was combined with specialization and intensification in production, allowing simultaneously capital-led extensification. New technologies and modernized farm management were adopted. The farms were attempting a strong growing farm structure toward expansion of farm enterprise.

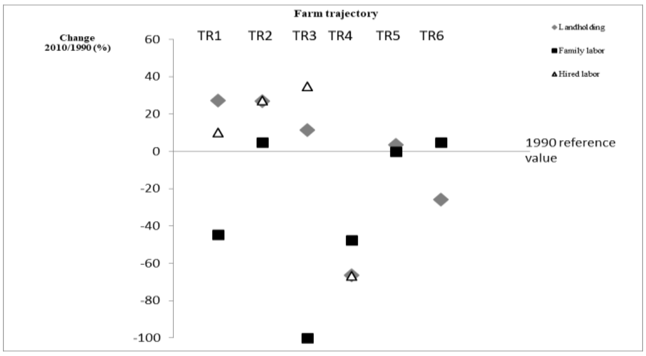

Fig. 2. Changes in rubber farm between 1990- 2010 according to the six groups of farm trajectories for landholding area, family labor, and hired labor, in percent of the reference value of 1990 for each variable in each group. (**Remark**: calculation of the change ratio 2010/1990: (2010 value – 1990 value)/1990 value, expressed in %.
Note: TR5 and TR6 hired labor are not available)

The second farm trajectory (TR2) is characterized by growth of medium family farm enterprises, which comprised 14.5% of farms. Farmers experienced moderate increase of landholding and an increase of the use of hired labor. Farms in this trajectory were the second largest for landholding and the use of hired labors. The increment of land holding was high during 1990-2000 and shown an increasing trend thereafter. Family labor also increased and farm labor forces remained stable in the past 20 years. Family labors worked for tapping activities and farm business management. Hired laborers were employed to complete insufficient family labor for all mature rubber plantations. These farms were the same as the farms in TR1 in term of specialization, intensification, technological use, and their farming performances and maintaining productive farm enterprise. These farms were attempting an enlargement of farm structure and expansion of farm enterprise.

The third farm trajectory **(**TR3**)** is characterized by patron farms, which comprised 7.7% of farms. Farms experienced moderate increase in the size during 1990-2000 and then increased in 2010. Size of landholding was lower than TR2. Family farm labors gradually decreased until there was no more family labor engaged fulltime farm in 2010, and hired labors are fully employed to substitute. Number of hired labors had increased. This is the only trajectory where all the rubber holders have now only non-farm activities. Then, they were dedicated part-time to farm management. The farms were found to be low specialization and intensification in production comparing with TR1 and TR2. These farms pursued expansion of the size and would be farming in the line with small farm enterprise.

The fourth farm trajectory **(**TR4**)** is characterized by farms with high structural change, and comprised 10.5% of farms. Farmers experienced the largest decrease of landholding and labor throughout the study period. Rubber land, mature rubber land, and share-tapping area substantially decreased. The number of hired-labors also sharply decreased consistent with the decreasing landholding size. This size is adapted and oriented to available family farm labor. The number of family tappers decreased. Specialization and intensification were limited. New technologies were rare. These farms had attempted to survive solely through income generated from sold land, which appeared to maintain livelihood consumption.

The fifth farm trajectory **(**TR5**)** is characterized by small family farms and comprised 38.2% of farms. These farms experienced stability of landholding and use of family labor since 1990. Landholding size was small for the whole period of study. Family labor increased but the labor involved in tapping work had no changed since 1990. They

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engaged full-time on their owned plantations and did not need to employ hired labor. It was the only trajectory where the size of mature rubber land was in line with the tapping capacity of family labor. Land per labor therefore was the second lowest of all trajectories. The number of family laborers, especially young labor engaged in the non-farm sector has increased. Because of small size and household income depending on rubber, high frequency tapping system adapted for more exploitation of production. These farms expressed a limiting capital investment for maintaining productive production leading to intensive latex harvesting.

The sixth farm trajectory **(**TR6**)** is characterized by declining very small farms and comprised 25.0% of farms. These farms owned very small landholding and used only family labor. Landholding was already very small since 1990, and experienced a decrease throughout the period of study. At the same time, family labor increased and then farm laborers were available. These farms had skilled labor specialized in latex harvesting techniques allowing the adoption of off-farm activities under share-tapping employment. It was the only trajectory where the farms were involved in off-farm tapping activities. Size of off-farm tapping areas increased, as a result in 2010, it was larger than their owned plantations. Workforces and farming were adapted in accordance with share-tapping employment. These farms had the lowest land per labor ratio. Technological use and a limiting capital investment were similar as the TR5 farms. TR6 farms are currently in process of farm decline.

Table 4. The six selected clusters of farms characterizing the six farm trajectories.

Variable	**Cluster (farm trajectory)**						**Cluster Mean**	**Univariate *F* (df = 5,213)**	**P-Value**
	TR 1	**TR 2**	**TR 3**	**TR 4**	**TR 5**	**TR 6**			
	n=9 4.1 %	**n=32 14.5%**	**n=23 10.5%**	**n=17 7.7 %**	**n=84 38.2%**	**n=55 25.0%**			
LHH_2010	151.8	45.0	28.4	24.9	14.6	7.5	25.0	116.0	0.000
LHH_2000	150.4	44.4	28.1	50.3	14.6	8.6	27.7	91.0	0.000
LHH_1990	119.4	35.5	25.5	74.3	14.1	10.1	27.7	61.5	0.000
RLH_2010	137.3	44.1	28.0	23.7	14.0	6.9	23.7	97.2	0.000
RLH_2000	136.0	43.5	27.8	48.4	14.1	7.9	26.5	76.7	0.000
RLH_1990	116.1	35.0	25.0	71.5	13.5	9.4	26.8	63.6	0.000
MRLH_2010	116.0	35.8	22.3	21.1	12.1	3.1	19.3	67.6	0.000
MRLH_2000	130.6	42.8	26.6	46.7	13.4	7.3	25.5	79.7	0.000
MRLH_1990	100.7	34.1	25.0	65.7	13.1	8.6	25.1	72.8	0.000
SLH_2010	106.0	20.8	22.3	13.6	0	0	10.5	61.0	0.000
SLH_2000	122.1	27.2	24.7	35.3	0	0	14.5	75.6	0.000
SLH_1990	90.4	17.5	23.1	57.3	0	0	14.0	66.9	0.000
OFFL_2010	0	0	0	0	0	13.4	3.5	83.2	0.000
OFFL_2000	0	0	0	0	0	11.4	2.9	54.5	0.000
OFFL_1990	0	0	0	0	0	5.4	1.3	13.7	0.000
LHFL_2010	50.6	13.4	13.0	12.4	5.2	2.4	11.3	26.0	0.000
LHFL_2000	52.1	16.3	13.7	16.3	5.5	3.3	11.3	59.0	0.000
LHFL_1990	51.2	15.6	11.7	20.6	6.1	4.6	11.2	63.5	0.000
RLFL_2010	45.8	13.2	12.9	11.8	5.0	2.3	10.9	22.7	0.000
RLFL_2000	47.1	16	13.5	15.7	5.3	3.0	10.7	55.4	0.000
RLFL_1990	49.8	15.3	11.6	19.8	5.9	4.2	10.8	65.6	0.000
MRFL_2010	38.7	10.7	10.2	10.5	4.3	1	8.9	19.0	0.000
MRFL_2000	45.2	15.8	12.9	15.1	5.1	2.8	10.4	53.7	0.000
MRFL_1990	43.1	14.9	12.2	18.2	5.7	3.9	10.3	61.8	0.000
FML_2010	3.0	3.2	2.2	2.0	2.8	3.1	2.8	5.0	0.000
FML_2000	2.9	2.7	2.1	3.1	2.6	2.6	2.7	2.9	0.015
FML_1990	2.3	2.3	2.2	3.6	2.3	2.2	2.4	23.4	0.000
FTP_2010	1.0	2.2	0	1.1	2.1	2.3	1.9	31.4	0.000
FTP_2000	1.4	2.2	0.4	1.9	2.1	2.2	2.0	14.9	0.000
FTP_1990	1.8	2.1	1.2	2.1	2.1	2.1	2.0	5.9	0.000
HTP_2010	8.7	2.8	3.1	1.8	0	0	1.2	122.6	0.000
HTP_2000	9.7	3.3	3.1	3.3	0	0	1.4	125.2	0.000
HTP_1990	7.9	2.2	2.3	5.4	0	0	1.4	62.6	0.000
UHL_2010	0.2	0	1	0.5	0	0	0.1	108.6	0.000
UHL_2000	0.2	0	0.8	0.3	0	0	0.1	55.9	0.000
UHL_1990	0.1	0	0.5	0.2	0	0	0.1	19.2	0.000
UFHL_2010	0.8	1	0	0	0	0	0.2	487.4	0.000
UFHL_2000	0.8	1	0.2	0.4	0	0	0.2	113.9	0.000

UFHL_1990	0.9	0.7	0.2	0.8	0	0	0.2	72.1	0.000
UOFL_2010	0	0	0	0	0	0.4	0.1	20.4	0.000
UOFL_2000	0	0	0	0	0	0.7	0.1	64.2	0.000
UOFL_1990	0	0	0	0	0	0.3	0.1	17.4	0.000
UFFL_2010	0	0	0	0	0	0.6	0.2	42.9	0.000
UFFL_2000	0	0	0	0	0	0.3	0.1	8.2	0.000
UFFL_1990	0	0	0	0	0	0.1	0.1	1.9	0.098

Note: n = number of farms; % = of the total samples (220 farms); see Table 2 for the description of the variables

Table 4 shows the six selected clusters of farms characterizing the six farm trajectories. It can be seen that the average value of variables belonging to each trajectory and the individual univariate *F*-statistics are statistically significant (*p* values equal to 0.0005).

C. Interpretation of Farm Trajectory Outcomes

Five farm trajectories were used to interpret the observation of increasingly bimodal farm structure. The concept of polarization proposed by Esteban and Ray (1994) appeared relevant to analyze agrarian change in southern Thailand. Society is polarized when a population of individuals may be grouped according to some vector of characteristics into cluster that each cluster are very similar, and different cluster are different relative to a given set of attributes or characteristics. Index of landholding was developed to measure the simplified polarization, using data of landholding size in 1990, 2000 and 2010 (Fig. 3).

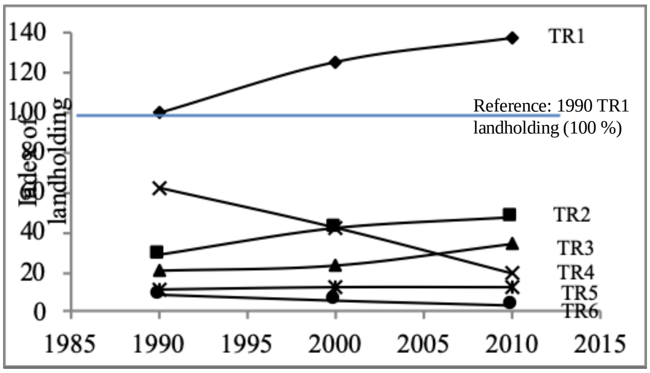

Fig. 3. Landholding Index of the six farm trajectories
Note: Calculation of the ratio: TR landholding area for a given stage / 1990 TR1 landholding area, expressed in %

We found that two groups of the better-off and worse-off in change of landholding at the end of the polar were identified. This provides important finding to identify the consequences of six farm trajectories as polarization occurred in the study areas. Figure 2 shows that polarization can be increased as the greater the distance in index of landholding. The greater in the distribution of landholding between two groups, the greater polarization (Azomahou T and Diene M, 2012). The first group gathers the farms with increasing land accumulation leading to land concentration, which is characterized by trajectory of farm growth (TR1, TR2 and TR3). They have significantly increased their landholding: index of landholding was increasing over time. The second group is made of smallholding with decreasing landholding size, corresponding to farms downsizing into farm decline (TR4 and TR6). For these farms, index of landholding was decreasing. Index of landholding was stable for TR5 and well supported unequal distribution of landholding. The significant six farm trajectories revealed a farm polarization.

V. DISCUSSIONS

Our results show that six types of farm trajectories reveals co-evolution of land and labor and farm characteristics driving the observation in structural changes in the rubber economy over the past 20 years. Structural characteristics of the farms moving belong trajectory of farm growth were significantly different from those of trajectory of farm decline or stable farms. We found that such farm trajectory consists of a series of farm stages, pattern of changes and deterministic patterns related to major periods in the farm life cycle or in the history of the farm household.

Undergoing TR1 and TR2, some farms were already large and highly capitalized in 1990 and thereby continued to grow between 2000 and 2010. These farms historically received large landholding from unoccupied or inherited land and consequently achieved the establishment of family farm enterprise before 1990. Large landholding coupled with intensification in production led to increase profitability and capital accumulation, and then stimulated land consolidation continually. Then, the significant increase of land could be interpreted as a process of capital-led expansion, of which help explains continuation in land consolidation of the farms. This resulted to be actively pursuing expansion of farm enterprise as they said that focusing attention on land accumulation will be the only way to sustain the farm.

In the trajectory of toward patron farms (TR3), they were new type of farms entering into rubber growers, derived from a broad group of landowners such as governors, businessmen, traders and self-employments. New holdings were created on the prevalence of inherited land or the purchased land pursuing a desire earning additional income and economic opportunities from rubber holding. The rate of increase in the number of patron farms briefly accelerated during the last two decade. These households were increasingly earning their income from rubber production more than non-farm activities in the period of price boom. Because of high income generated from non-farm activities associated with credit accessibility, these farms can be expected to continue expansion. The best relative expansion measuring by farm consolidation were achieved by TR1, TR2 and TR3. This implies that the trajectories of farm growth provide evidence to support the bimodalisation theory of "the strong getting stronger" (Iraizoz et al, 2007).

Regarding trajectory of farm decline, the farms fallen into trajectory of farm decline which were divided into TR4 and TR6 mainly accordance with decrease in landholding and the change in labor. Many farms from TR4 had shown the large farms downsizing into small farms, which we called "the larger getting small". There were wide array patterns of farm changes regarding constraints and barriers they were facing especially financial stress and hardships to deal with compound socioeconomic pressures. The farms had chosen for a better option of sold land regardless negative impacts of size reduction. These farms were currently in the process of downsizing at the study period and operated farming as family farms.

TR6 included farms who received a small size of inherited land before experiencing a continuous decrease in the landholding through the sold land, which is considered as farm strategy coping with debt stress and socioeconomic pressure. They were small and getting smaller. Landholding size did not meet structural requirements for their livelihood in local conditions of changes. Regarding available labor and the labor qualification allowing employment opportunity for share tapping contracts, off-farm tapping was always adopted and was a good option when the farm size was below economic scale. This was an alternative farm strategy rather leaving the farm sector. The opportunity of off-farm tapping employment allowed them continued long-term farming existence. And on the other hand, these farmers provided supply of skilled labor to be employed by TR1, TR2 and TR3. The rate of increase in number of farm decline seems to have accelerated in the last two decade. This trend indicates that the small farms have yet to adjust to the new incentive structure and local condition of the changes over the last two decade.

The analyses of TR5 found that most farms accessed to a small size of inherited land before 1990 and it was operated by family labor over the study period. The small size was an outcome of intergenerational land transfer, because when a parent died, landholding was divided in equal among many family members. Thus, the size of landholding for each individual farms has decreased substantially between intergenerational transfer, depending on the initial size of the holding. Size of land and characteristics of farmers have influence on carried out farm transfer and farming continuity. The share of farms belonging to stability of family farms in the total number has decreased more strongly since 1990 even through this trajectory still presented the majority of farms in the study areas. All farms have specialized in rubber planting and modernized plantation practices thought collaborating with the replanting scheme before the 1990s and so on remained until 2010. Consequently, these farms were dependent on rubber income generation which was sufficient to improve their family livelihood. This implies that they were under financial stress and potentially more vulnerable to adverse uncertainty and the global changes. Due to the small size and the limited potential of improvement in efficiency, many farms risk falling into trajectory of farm decline.

Agrarian structure moving toward a raising land concentration were observed, which one should take into consideration the fact that land passed from small farms to be held by medium or large farms. Small farms have options farm existing intensively or leaving farms out. This evidence supports that polarization was increasingly developed during 1990-2010. The change in agrarian structure resulted in a growing polarization, which might cause negative impacts on economic growth and social conflicts (Keefer and Knack, 2002; Cárdenas, 2011).

VI. CONCLUSION

This study attempts to identify rubber farm trajectories and analyze consequences of the trajectories in Southern Thailand. The study identified six significant farm trajectories between 1990- 2010. Two trajectories showed a decline in landholding or hired labor. On the other hand, three trajectories showed increasing landholding size or use of hired labor. One trajectory showed a stability with no change in farm size and labor structure. The six trajectories give the indication of a continuing polarization in rubber economy in Southern Thailand. However, these are small farms and provide a notion of risk to follow the trajectories of farm decline. The changes in the landholding size and the use of labor appeared as discriminant factors to identify different patterns of farm trajectories. There has been a structural adjustment and a wide variety of farm transformation in the rubber economy in Southern Thailand over the period of study.

Looking forward to the future of rubber farms ithe study area, if the government does not implement an appropriate policy, it can be foreseen that family farms will largely move into very small farms which will increase off-farm tapping when possible, highly increase non-farm activities and finally will be moving out of the rubber farm sector. Moreover, there are likely to be fundamental problems with decreasing number of small size farms and concentration in landholding by medium and large farms. The findings of the study might be helpful for policy and decision makers to reconsider the current policies and design policies with a wider approach for small farms and family farms. The future of rubber economy in Southern Thailand depends on the choice of policy makers and their willingness to continue polarization or to reverse/ limit polarization.

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APPENDIX - A

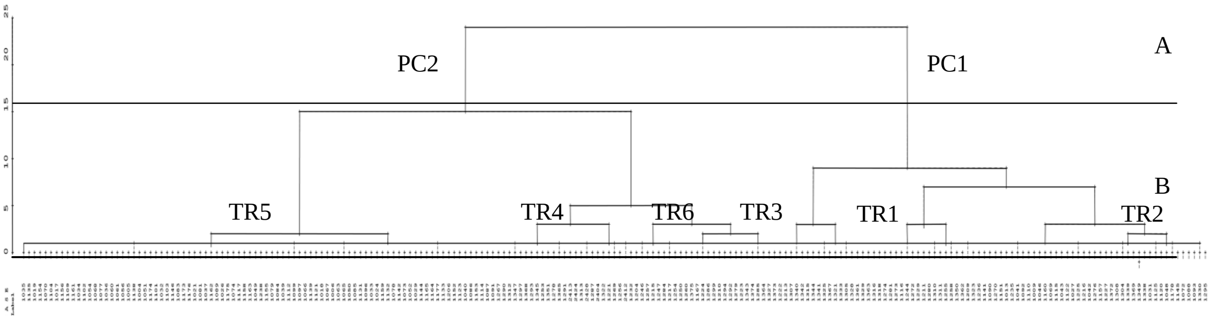

Fig. 1. Dendrogram resulted from cluster analysis.