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Seeking security through rubber intercropping: A case study from northeastern Thailand

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Abstract

A major constraint of smallholder farmer to plant their rubber is the sources of income for their subsistence during 6-7 years from planting until the rubber enter production. Again, it was due to price fluctuations year to year after enter production. Intercropping of rubber with cash crops will provide alternative sources of income and protect farmers from price instability. This qualitative research using household rubber growers interviews, crop and soil measurement were carried out to study aim to investigate growth of rubber and cash crops, yield of cash crops, as well as farmers' income from cash crops at Nongnangvong village, Khon Kaen province where farmers practiced intercropping of immature rubber with banana and cassava, and at Poopankham village, Nongbualampoo province, as well as Nongsaengsoi village, Udorn-Tani province where farmers practiced intercropping of mature rubber with coffee. The results indicated that intercropping of immature rubber with banana and banana combined with *Calopogonium caeruleum* tends to promote girth growth. Cassava intercropped with immature rubber gave similar girth growth of rubber compared to sole rubber. Mature rubber trees intercropped with coffee had no retarding effect on the main crop. In some cases, intercropping of mature rubber with coffee tended to improve girth growth of rubber trees compared to sole rubber. Intercropping of banana and banana combined with *Calopogonium caeruleum* with immature rubber provided net income 139 and 148 US$/ha, respectively. Cassava intercropped with immature rubber gave net income 763 US$ha^{-1} in this present study. Irrespective of coffee, intercropping coffee with mature rubber provided net income 310-845 US$ha^{-1} in this study. Therefore, intercropping immature or mature rubber with economic crops would provide assurance of securing rubber grower under price fluctuation.

Key words : *Immature rubber, mature rubber, intercropping, banana, cassava, coffee, Calopogonium caeruleum*

1. Introduction

Rubber has a long time lag about 6-7 years to provide any economic return and hence poses significant problem to resource poor farmers. However, even natural rubber provides a major source of income during latex produced at mature growth stage. Price fluctuation is a normal risk for rubber growers. Therefore, it is desirable to find different income sources in order to overcome the problems associated with the fluctuation in price. Intercropping provides a practical solution to all these problems by generating additional income from the land during the immature phase of rubber (1, 2, 3). A number of researches were carried out by investigators to identify suitable crops for intercropping with immature rubber such as upland rice (4) soybean and mungbean (5, 6) pineapple, banana and corn (7). However, the potential of profitable intercropping investigation is limited at rubber mature growth stage by the effects of increased shading. Therefore, the objective of this study was to determine growth and yield, as well as economic return of intercropped plants when grown with immature and mature rubber trees. In addition, rubber growth under intercropping and mono-cropping systems of farmer's fields was evaluated in the present study.

2. Methodologies

2.1 Site location

An economic crops banana and cassava intercropped with immature rubber of farmers' fields were purposively selected at Nongnangvong village, Nongrua district, Khon Kaen province. In case of intercropping with mature rubber, coffee intercropped were purposively selected at Poopakham village, Muang district, Nongbualumpoo province, as well as Nongsaengsoi village, Nongvuasaw district, Udorn-Tani province (Figure 1).

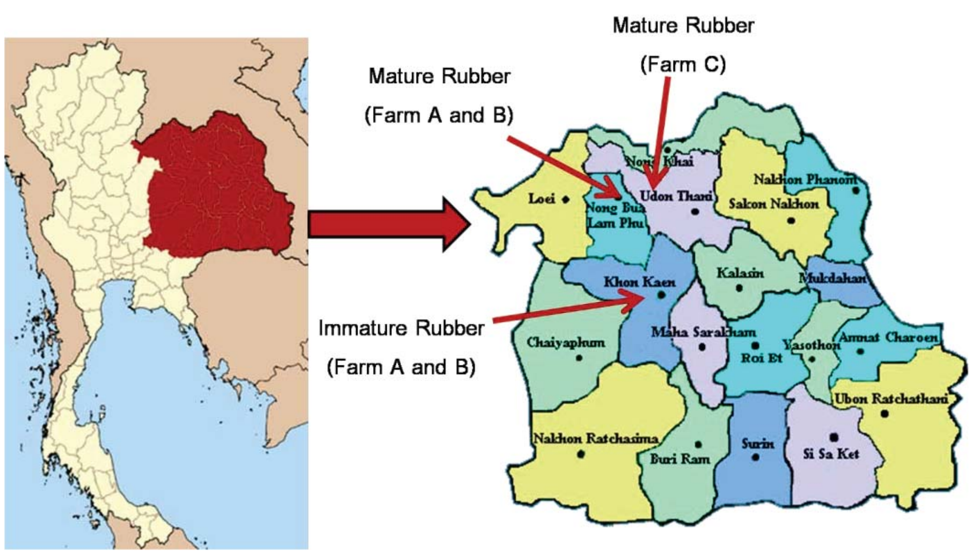

Figure 1. Site locations in northeastern, Thailand

2.2 Field survey of farmers

A survey was conducted in May and October in 2015 with five farmers who grown rubber intercropped with banana, cassava and coffee. The study methods consisted of households interview through semi-structured questionnaires, field survey and observation, as well as cash crops and rubber trees growth and yield measurement, including soil sampling for chemical properties analysis and soil moisture content determination. Household interview was focus on rubber and cash crops cultural practiced, yield, income and accessibility to marketing.

2.3 Comparison treatments of farmers farm

The study comprised of 2 farms in the immature plantations and 3 farms in mature plantations. Farm A, the treatments consisted of banana alone and banana combined with Calopogonium caeruleum intercropped with immature rubber, in comparison with sole cropped rubber. Farm B, farmer who grown cassava intercropped with immature rubber (4 years old) in comparison with sole cropped rubber. For mature rubber plantation, three farmers who grown coffee intercropped with mature rubber (7-9 years old) in comparison with sole cropped rubber.

2.4 Cultural practices

2.4.1 Intercropping cash crops with immature rubber

The rubber clone RRIM 600 grown with plant spacing 3×7 meters of both farm A and farm B. Banana planted as a single row between each row of rubber with population of 950 hole ha^{-1} (5700 stalks ha^{-1}). The fertilizer grade 20-10-17 (N, P_2O_5, K_2O) at rate of 200 gm $plant^{-1}$ was applied to rubber (4 years old) at early and late rainy season. Cattle manure applied to banana once at planting as basal in the first year. Calopogonium caeruleum were planted between banana and rubber row in the third year after rubber plantation in farm A. For farm B, cassava planted three rows between each row of rubber with population of 9525 plants ha^{-1}. The fertilizer grade 15-15-15 (N, P_2O_5, K_2O) at rate of 156 kg ha^{-1} was applied to cassava at 1 month after planting.

2.4.2 Intercropping cash crops with mature rubber

The rubber clone RRIM 600 grown with plant spacing 3×7 meter all farm A, B and C in study sites. Coffee planted as a single row (population 950 plants ha^{-1}) in farm A and C, and double rows in farm B (population 1900 plants ha^{-1}) between each row of rubber, The fertilizer grade 15-15-15 at rate of 468 kg ha^{-1} applied to the coffee crop in farm A and C, while similar fertilizer grade applied to coffee at rate of 312 kg ha^{-1} in farm B. Supplementing irrigation was practiced by the farmer during the dry season in farm C.

2.5 Soil chemical properties and soil moisture content measurement

Soil samples at depth 0-30 cm were randomly collected from studied fields on May 26, 2015 of intercropping cash crops with immature rubber, and on October 10, 2015 of intercropping cash crops with mature rubber. The soil were analyzed for pH (1:1 H_2O, pH meter), organic matter (8), total nitrogen (Micro-Kjedahl method, 9), available P (Bray II method, 10) and exchangeable K (1 N ammonium acetate, 11) both in immature and mature rubber fields (Table 1 and 2).

Soil moisture content was determined gravimetrically at two depths (0-15 and 15-30 cm) on May 26, 2015 in early rainy season and on October 10, 2015 in late rainy season. Soil samples were collected where located at 50 cm apart from rubber trees and intercropped plants, and middle row between rubber trees and intercropped plants with two replications. Soil moisture content was calculated to percent by weight (% w) according to the following formular:

$$\text{Percent soil moisture by weight (\% w)} \quad \frac{\text{Wet weight-Oven dry weight x 100}}{\text{Oven dry weight}}$$

Then, soil moisture content was calculated to percent by volume (% v) as (% w) multiply by (Bulk density).

2.6. Rubber and cash crops growth and yields measurement

The girth of twenty rubber trees of sole rubber and rubber intercropping were measured at 150 cm above soil surface. The stalk per hole of twenty banana crops were recorded in rubber/banana and rubber/banana/*Calopogonium caeruleum* intercropping systems. Banana fruit yield was collected from the individual household interview.

For cassava, ten plants were randomly selected in the farmers' field; the number of storage roots and fresh root weight were recorded and calculated as fresh root yield per hectare. Regardless of coffee, plant height and canopy width of twenty coffee plants in intercropping and ten coffee plants in sole cropping were measured all locations. Dry grain yield of coffee was collected from individual household interview.

2.7. SPAD chlorophyll meter reading (SCMR) measurement

Three reading using the SPAD chlorophyll meter (Minolta SPAD-502 meter, Tokyo, Japan) were recorded by randomly selected four plants from immature rubber fields farm A and B, as well as mature rubber fields farm A, B and C at the 6^{th}, 7^{th} and 8^{th} leaves from the top of branching rubber trees where located in lower canopy. For coffee, randomly selected ten plants and four SCMR were recorded of the 5^{th} fully expanded from the top of branching where located in upper, middle and lower canopy.

2.8. Light intensity measurement

Four sunlight intensity reading using the light meter (DIGICON-LX-72) were recorded outside and inside of the rubber fields. The shading percentage of full sun was calculated according to the following formular:

$$\text{Shading (\%)} = \frac{\text{Light intensity outside - Light intensity inside} \times 100}{\text{Light intensity outside}}$$

2.9. Economic return evaluation

Gross income of intercropped cash crops; banana, cassava and coffee were calculated based on average yield multiply by price. Then, net income was evaluated using gross income (yield kg ha^{-1}×price kg^{-1}) subtracted with fertilizer application cost (kg ha^{-1}×price kg^{-1}).

3. Results and discussion

3.1 Soil properties

Soil pH at two immature rubber farms was acidic (Table 1). Soil organic matter and total nitrogen were very poor at two sites. Phosphorus availability in the top soil was higher in farm B than those of farm A (Table 1). Potassium exchangeable in the top soil was higher in farm A than those of farm B (Table 1).

For mature rubber farms, soil pH at all sites was acidic to very acidic (Table 2). Soil organic matter and total nitrogen were very poor at all sites. Phosphorus availability in top soil was higher in farm A than those of farm B and farm C (Table 2). Potassium exchangeable in the top soil was higher in farm B than those of farm C and farm A.

3.2 Soil moisture content in immature rubber fields

Intercropping rubber with banana and banana combined with *Calopogonium caeruleum* showed higher soil moisture content than those of sole rubber, especially in early rainy season (Table 3). This was probably due to rubber intercropping reduced runoff and erosion, then increasing soil infiltration rate (12). In addition, water content of banana tissue is high (13), and since it must come from the soil in the rainy season. Then, it may be released water to the dry soil through the roots during rainless period.

Table 1. Soil chemical properties of different cropping systems from immature rubber fields

Cropping systems	Soil chemical properties				
	pH (1 : 1 H_2O)	OM (%)	Total N (%)	Avail.P (mg/kg)	Exch.K (mg/kg)
Farm A					
Sole Rubber	5.7	0.519	0.025	9.88	39.19
Rubber + Banana	5.1	0.564	0.028	16.13	55.10
Rubber + Banana + *Calopogonium caeruleum*	5.5	0.447	0.022	4.41	99.21
Farm B					
Sole Rubber	5.6	0.430	0.021	32.80	65.98
Rubber + Cassava	5.5	0.542	0.027	18.61	47.13

Table 2. Soil chemical properties of intercropping rubber with coffee from mature rubber fields

Soil chemical properties	Farm A	Farm B	Farm C
pH (1 : 1 H_2O)	4.46	5.87	4.49
Organic matter (%)	0.728	0.900	0.761
Total N (%)	0.034	0.043	0.037
Available P (mg/kg)	144.29	25.59	13.97
Exchangeable K (mg/kg)	51.68	110.24	73.33

Table 3. Soil moisture content (% by volume) at 0-15 and 15-30 cm soil depth from different cropping systems at early rainy season (May) and late rainy season (October)

Cropping systems	Early rainy season		Late rainy season	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Farm A				
Sole Rubber	5.98	6.11	13.13	14.56
Rubber + Banana	11.57	10.66	15.45	16.77
Rubber + Banana + *Calopogonium caeruleum*	10.53	8.84	14.95	16.12
Farm B				
Sole Rubber	6.37	7.15	14.69	16.38
Rubber + Cassava	8.45	7.93	15.86	17.55

Table 4. SPAD chlorophyll meter reading of rubber leaf at different cropping systems from immature rubber fields.

Cropping systems	SPAD chlorophyll meter reading		
	Rubber	Banana	Cassava
Farm A			
Sole Rubber	55.8	-	-
Rubber + Banana	63.1	31.6	-
Rubber + Banana + *Calopogonium caeruleum*	66.4	40.4	-
Farm B			
Sole Rubber	55.2	-	-
Rubber + Cassava	55.9	-	46.9

3.3 SPAD chlorophyll meter reading (SCMR) in immature rubber fields

Intercropping rubber with banana and banana combined with *Calopogonium caeruleum* exhibited higher SCMR in leaf than those of sole rubber (Table 4). This was probably due to *Calopogonium caeruleum*, providing nitrogen to rubber trees and increasing chlorophyll content in leaf. The SCMR is an indicator of the photo-synthetically active light-transmittance characteristics of the leaf. Significant and positive correlations between SCMR and chlorophyll content (14) and chlorophyll density (15) have been reported elsewhere.

Table 5. Light intensity and SPAD chlorophyll meter reading of intercropped coffee (IC) and sole cropped (SC) coffee of farm A, B and C of study sites

Items	Farm A		Farm B		Farm C	
	SC (full sun)	IC (95% shading)	SC (full sun)	IC (76% shading)	SC (full sun)	IC (80% shading)
Light intensity (*Lux)	31,250	1,717	4,420	1,041	16,170	3,115
SPAD chlorophyll meter reading						
- Upper leaf canopy	43.6	62.1	50.6	60.2	57.2	63.1
- Middle leaf canopy	49.1	63.2	53.5	60.6	57.6	60.7
- Lower leaf canopy	41.7	62.7	57.4	62.9	55.7	61.8
Average	44.8	62.7	53.8	61.2	56.8	61.9

*Light intensity values among farm A, B and C are unable to comparison, because of measurement at different time

Table 6. Girth of rubber, stalk number of banana, storage root number of cassava, yield and net income of banana and cassava intercropped with immature rubber

Cropping systems	Girth (cm)	Stalk (number/hole)	Storage root (number/plant)	Yield (t/ha)	Net income (US$/ha/year)
Farm A					
Sole Rubber	25.1	-	-	-	-
Rubber + Banana	26.6	6.5	-	0.56	139
Rubber + Banana + *Calopogonium caeruleum*	29.1	6.8	-	0.61	148
Farm B					
Sole Rubber	21.6	-	-	-	-
Rubber + Cassava	20.4	-	10.2	24.1	763

3.4 Light intensity and SPAD chlorophyll meter reading of intercropped coffee and sole cropped coffee with mature rubber

In this study, rubber age was 7, 8 and 9 years old where planted in farm A, B and C respectively. Shading level was about 95, 76 and 80 percent of full sun presented in farm A, B and C respectively, depending on rubber canopy development covered the land (Table 5). Girth of rubber tree was greater in farm A than those of farm C and farm B respectively (data not presented).

Regardless of SPAD chlorophyll meter reading (SCMR), average SCMR value of coffee leaf exhibited greater in shaded plant than those at plant in direct sun light all three farms study sites. The SCMR is an indicator amount of chlorophyll per unit leaf area (16). The darker green color of coffee leaves developed in the shade was most likely associated with the larger amount of chlorophyll content. Leaves having such dark green color absorb more light, have chloroplast with improved light-capturing capacity under lower light intensity and utilize them efficiently to increase their photosynthetic rate (17).This indicates that coffee is a well adapted shade plant which does not suffer less from environmental stress due to low light intensity. Barlett and Remphrey (18) indicated that there are no significant reductions in photosynthetic rate and growth of coffee plants grown under shade unless the level of shade exceeds 90%.

3.5 Growth, yield and economic return of immature rubber and intercropped cash crops

Girth of intercropped rubber with banana and banana combined with *Calopogonium caeruleum* illustrated greater values than those of sole rubber (Table 6). Similar girth values was observed between intercropped rubber with cassava and sole cropped rubber (Table 5). This was probably due to *Calopogonium caeruleum* contributed nutrients to intercropped rubber, *Calopogonium caeruleum* returned nutrients to the soil through above ground biomass were 506, 37, 155, 54 and 398 kg ha^{1} for N, P, K, Mg and Ca, respectively (19). In addition, intercropping protects the soil surface from the evapotranspiration and the root system can help to hold the water content. This agreement was obtained with the previous investigation by Rodrigo et al. (3). Rubber was grown either as a sole crop, or intercropped for the first four years with banana. The girth and height were greater in the intercropped rubber than those of sole cropped rubber. This was due to mutual shading in the presence of banana would help to alleviate of light-induced depression of photosynthesis of intercropped rubber on clean sunny days, radiation levels incident at the top of the rubber canopy exceed the light-saturation point for photosynthesis (20). Shade conditions have been shown to promote leaf production in rubber (21) and were associated with an increase in leaf area per plant (3). The present study, the farmer seems to manage poorly the intercropped banana as previous mention, manure fertilizer applied only once at first year planting. Therefore, fruit yields were quite low (average 45 bunchs per year). However, the farmer earned net benefit of 139 and 148 US$ ha^{-1} year^{-1} in intercropped banana alone and intercropped banana combined with *Calopogonium caeruleum*, respectively (Table 6). Laosuwan et al. (7) reported that banana intercropped with rubber gave the highest net benefit of 707 US$ ha^{-1} year^{-1} as compared to pineapple (368 US$ ha^{-1} year^{-1}) intercropped with rubber.

For intercropped cassava, tuber yields obtained 24 tones ha^{-1} by crop sampled in the 4th year of intercropping with rubber. This generates continuous cash income of cassava from the first year of rubber plantation. Polthanee and Promsena (22) reported that cassava intercropped with rubber generate cash income 571 US$ ha^{-1} in the fourth year of intercropping. The present study shows that intercropped banana provides not only an additional income, but also a benefits in terms of rubber growth during the long immature period. Cassava intercropped, provides the highest cash income as compared to banana, however intercropped cassava has not impact on rubber growth during long immature period.

Table 7. Growth yield and net income of intercropped coffee (IC) and sole cropped coffee (SC) at farm A, B and C of study sites

Items	Farm A		Farm B		Farm C	
	SC1_/	IC	SC2_/	IC	SC3_/	IC
Plant height (cm)	59.7	218.9	118.2	212.2	163.4	181.1
Canopy width (cm)	53.1	166.6	98.3	172.1	131.2	148.6
Yield (kg ha^{-1})*	-	1,519	-	3,800	-	2,344
Net income (US$ ha^{-1})**	-	310	-	845	-	517

*,**Yield and net income over material cost derived in 2014 by interviewing farmer
1 and 2 = Sole cropped coffee growth recorded from outside nearby rubber fields
3 = Sole cropped coffee growth measured from inside rubber fields with absence of rubber trees

3.6 Growth, yield and economic return of intercropped coffee and sole cropped coffee with mature rubber

The plant height and canopy width of intercropped coffee were higher than those of sole cropped coffee for all farm study sites (Table 7). Baliza et al. (23) reported that coffee shaded at 35, 50 and 65% of full sun increased plant height. This was probably induced by low light intensity due to shade conditions, promoting plants taller and leaf area increase per plant. In addition, higher soil moisture of shaded system increase water and nutrient uptake over time (23). Coffee intercropped with mature rubber produced yield 1,519, 3,800 and 2,344 kg ha^{1} in farm A, B and C respectively (Table 7). The highest yield was obtained in farm B mainly due probably to double plants population of intercropped coffee and thelower shading affected by mature trees (Table 6). Bote and struik (17) reported that greater yields were obtained from coffee grown in direct sun than from shaded plants (53% shading), although, this difference was also not statically significant. Coffee production decreased under shade cover greater than 50% was reported by Soto-Pinto et al. (24). The sole cropped coffee yields are unable to gathering from individual household interview in the present study. However, this study shows that intercropping provides additional/improved income 310, 845 and 517 US$ ha^{-1} of smallholder farmer A, B and C respectively.

4. Conclusion

Intercropping immature rubber with economic cash crops such as banana and cassava practiced by the smallholder farmers provided additional/improved income. In some cases, growth of rubber is improved by intercropping because of the complementary between crops such as banana. Coffee intercropped with mature rubber also generates income for rubber grower. Coffee plants grown in the shade suffer less from low light intensity stress, due to crops adaptation. Intercropping rubber with economic crops would provide assurance of securing rubber plantation under price fluctuation.

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