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**The economics of rubber intercropping during the immature period in Buriram, Northeast Thailand**

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**Abstract**

In order to alleviate poverty in the Northeast Thailand, the Thai government has promoted rubber farming which has expanded at the expense of annual crops. Because of a long period of immaturity, planting rubber represents a loss of income for poor farmers. This paper analyzed how rubber intercropping during the immature period helps farmers to compensate this loss of income. Beside landscape observation and semi-structured interviews, a questionnaire was addressed to 35 farmers in Buriram province to estimate economic performances of different cropping systems found in smallholders’ rubber farms. A description of main farming practices and spatio-temporal dynamics of rubber plantation is followed by an economic analysis. A sub-sample of 22 farmers was further interviewed to estimate the contribution of rubber intercropping in the formation of total annual income during the immature period. Results showed that interest in rubber intercropping has gradually grown up, with cassava and rice as main associated crops. Planting rubber recently occurs in lowland against official recommendations as an adaptation to recurrent drop of annual rainfall. Rubber-cassava intercropping systems which are market-oriented generated a gross margin estimated at 11.340 THB/ha/year. As compared to a monospecific rubber plantation, rubber-cassava intercropping created a cost reduction of 59% over the whole immature period. However, the cash-income drawn from intercropping is approximately 10% of total annual income, regardless of the farmer’s livelihood assets.

**Key-words**: Northeast Thailand, rubber, intercropping, cropping systems, livelihood

1. **Introduction**

Interest in adaptation and resilience studies grows up in scientific and political arenas, and is triggered by the increasing frequency and magnitude of extreme events, with dramatic consequences on living conditions of local populations. Agriculture is worldwide one of the most exposed sector due to its dependence on natural processes. According to the United Nations Framework Convention on Climate Change (UNFCCC), adaptation to climate change in agricultural sector will cost approximately $12 billion in 2030 (Parry, 2009). Impacts of climate change on agriculture interplay with other socioeconomic realities that increasingly pressure producers. All these threats are embedded in what is now termed as ‘global changes’ that pervasively shape and modify rural life in many regions. Global change issues are very complex as they are intertwined at different geographical and time scales, involving diverse and often conflicting stakeholders. It has been found that adaptation problems cannot be treated equally, and need more insights at local level (Agrawal, 2010; Regmi et al, 2016). In fact policies and top-down interventions have better chances to succeed when they match with local contexts and bottom-up initiatives. Feola et al (2015) argued that understanding farmers’ actions in their socio-ecological context is essential to identify where intervention is needed, and how it should be oriented. As the context-dependent nature of the challenges makes it difficult to generalize findings, researchers engaged in vulnerability assessment and local responses to evolving environments in different local settings.

Farmers in Thailand are hit by negative impacts of global changes. Main threats are climate variability and commodity price volatility. In addition, poor soil conditions were identified as major constraints to agricultural production in general in Northeast Thailand (Barnaud, 2005; Rantala, 2006). As a consequence, Northeast Thailand has always been depicted as one of the poorest region in the country. For this reason, and to stop massive out-migration, government made efforts to offer economic opportunities to poor rural populations. Despite being a marginal zone of agricultural production, rubber has been promoted in the region. According to Fox and Castella, the Thai government objective was clearly to provide viable alternative to farmers locked in cassava or sugarcane mononculture. Rubber plantations rapidly expanded in the region, thanks to the Organization of Rubber Replanting Aid Fund (ORRAF). Rubber production areas are still in expansion in this region. In Northeast Thailand, rubber plantations do not expand at the expense of forest, but rather at the expense of annual crops targeted for land reconversion. Under the banner of crop diversification, peasants were encouraged to grow rubber instead of cassava and sugarcane. As a consequence, farmers who had been heavily dependent on annual cash crops had to forego part of this income during the immature period of rubber plantation. The main concern of farmers is about income generation during the immature period of rubber. As rubber tapping starts approximately 5-7 years after plantation, farmers need to secure income during the early unproductive phase which can be much longer under unfavourable growing conditions (up to 8-10 years). In Sri Lanka, Herath and Takeya (2003) observed that “after replanting or new planting, farmers face a gap income of 5-7 years during which immature rubber cannot be tapped for latex”. This is aggravated by the poor conditions of farmers in Northeast Thailand.

Intercropping appears as a potential solution to reduce the loss of income during the early stage of rubber plantations. It has been promoted by the Rubber Research Institute of Sri-Lanka since 1979. However, only 30-40% rubber farmers adopted it in Sri Lanka in 2000s (Herath and Takeya, 2003). Even recently, in their review, Langenberger et al (2016) observed that rubber plantations were usually managed as monocultures. The authors gave an historical perspective of rubber intercropping, all around the world. While cover cropping was undertaken by real estates, Balkhill (1989) and Zeng et al (2012) cited by Langenberger et al (2016) described immature rubber intercropping as a hybrid between subsistence and cash crops practised by smallholders, whether in Indonesia or China. According to Zhou (2000) and Zeng et al (2012) cited by Langenberger et al (2016), intercropping first experienced a boom around 1970s, and has later been abandoned in many places in China around 1990s. Overall, Langenberger et al (2016) observed that “despite comprehensive trials by practically all rubber research institutes as well as an ongoing promotion of intercropping, information about actual adoption rates can hardly be found”. In Northeast Thailand however, Chambon (unpublished) conducted a series of surveys from 2012 to 2014 in 7 provinces. These surveys showed that 63% of 627 plots had never been intercropped during the immature period. In spite of its economic interest for farmers in marginal agricultural zone, it is interesting to understand why intercropping during the immature period was far from being a systematic practice in rubber plantations. To do so economics of rubber intercropping systems are needed to shed light on farmer intercropping decisions.

As rubber was promoted in Northeast Thailand as an alternative to cassava monoculture, a few conditions accompanied support given by ORRAF which has later been merged with other institutions into the Rubber Authority of Thailand (RAOT). Support essentially consisted in provision of technical assistance, credit facilities and subsidizes for planting material and operating costs. Any registered household could receive up to 9,375-15,625฿/ha for a surface area less than 2.4 ha. Recently, planting materials have been provided free of charge, probably to promote the new clones (mainly RRIT 251, and RRIT 408 at a lesser extent). To be eligible for funds, farmers had to comply with RAOT technical recommendations (also reported by Thongyou, 2014). Among others, it was clearly stated that farmers could intercrop with any plant, except cassava or sugarcane which “exhausts soil by extracting too much nutrients, at the expense of rubber trees” (Watthaphon[[1]](#footnote-1), D., Personal Communication, August 2016). Another strong requirement was that rubber plantations could not be set in lowland, because “well drained soils are needed for good tree growth”. There is no special recommendation on how to grow the associated crop, implicitly suggesting that every step should be carried out like in a pure stand fashion. Materials of extension (handout and video record) in use only mentioned the possibility of intercropping, without further details. Incentives were even greater for cover crops, including provision of seeds and fertilizers free of charge.

The first aim of this study is to describe rubber intercropping practices in Northeast Thailand, in order to fill the gap of information about rubber intercropping systems during the immature period. Secondly, this paper analyzed economics of immature rubber intercropping system. Finally, the contribution of rubber intercropping to the household livelihood is assessed. Because previous studies (Ellis and Allison, 2004; Hussein and Nelson, 2016; Mumuni and Olade, 2016) posited that livelihood activities and their outcomes are framed by existing assets and mechanisms of access, the paper tested the following hypothesis: (1) the decision to intercrop depends on a farmer’s livelihood assets. Among these assets, alternative financial resources have been identified as a key determinant of decision-making about rubber intercropping. In fact, Stirling et al (2002) noticed that farmers with additional sources of income paid less attention to rubber intercropping during the immature period. Likewise, Min et al (2015) found that rubber intercropping was an important source of complementary income for poorer farmers during the early stage of plantation. Therefore, in order to analyze the importance of intercropping in household revenues. The second tested hypothesis in this study stated that (2) among rural livelihood activities, rubber intercropping provides important incomes to farmers who chose it.

Hereafter, methods of investigation are presented, followed by main results including a description of farmers’ socioeconomic characteristics, the rubber farming practices during immature period, the profitability of rubber intercropping systems and their importance in household revenue composition. The following discussion focuses on comparison of economic results with previous studies, with further perspectives on farmer decision making studies.

1. **Methods**

The study took place in Buriram province (Northeast Thailand), in two neighbouring subdistricts: Tum Yai (Khu Mueang district) and Khaendong (Khaendong district, Fig 1). Landscape observation of the study area revealed that the study area (163 km2 approximately) is situated in a large floodplain surrounded by the Khorat plateau. Elevation is comprised between 142 and 196m above sea level. As the area is very flat (average slope being less than 1%) and it was difficult to distinguish upland from lowland. Moreover, since the environment had undergone deep anthropogenic transformation, water retention and water logging could significantly vary over a 1 meter elevation. Therefore upland could be found next to lowland. Transition was either smooth or rapid depending on location, in-between situations were numerous, and formal classification might be slippery. The topsoil texture ranged from sand to loamy sand in surface (0-20cm), with some inclusions of clayey sand. The topsoil is probably formed on sedimentary bedrock with an impermeable layer beneath. Soil particle cohesion probably disappeared with repetitive use of farm machinery and rapid organic matter mineralization under favourable climatic conditions; only poorly structured soil was visible in surface (single grain structure). The weathered soil was generally white or greyish, darker colour being usually associated with continuous amendment by farmers. Some inclusions of ferralsols (according to FAO classification) were noticed higher in toposequence, outside the study area. Water retention was generally (but not systematically) expected to be poor, if no technique of conservation was provided. On small paddy fields, rainwater was directly harvested on the raised-edged plots, with low infiltration rate and almost no runoff.

Climatic data recorded at the nearest meteorological station (Satuek) over a 15 year period are provided below (Fig 2). Annual rainfall is about 1327mm. The dry season lasts 6 months, ending up with high temperatures (up to 40°C) which certainly increase the evaporative demand of the air. This usually results in water stress and mortality of rubber trees. Moreover, during the last years, the annual rainfall has steadily decreased as shown on Fig 3.

Land-use was mainly made of cultivated lands, with patches of remnant plantations of *Eucalyptus* sp. and natural forests dominated by *Dipterocarpus* spp. Settlements and water bodies (including constructed ponds) were also visible. Grasslands were mainly found on communal lands. Nearly no fallow land was seen, and monoculture was fully integrated in the agricultural customs. Sometimes, change of land-use occurred, but no rotation was predetermined. Generally, sugarcane and paddy fields occupied lowland, and cassava was mainly grown on upland. Rice was still the main crop, followed by sugarcane in lowland and cassava in upland. In fact, rice paddies occupy more than two thirds of the agricultural land, whereas cassava and sugarcane represented 6.4% and 10.6% in respective. Rubber plantations covered 6.7% of the agricultural land. According to Watthaphon, D (Personal Communication, May 2016) rubber plantations registered by RAOT are about 270,000 rai (43,200ha), of which 26% are said to be in immature stage. Other crops represented approximately 0.5% of the land-use. Despite the presence of processing factories, some homelands of sugarcane were targeted for reconversion (which was financially supported by the government). Newly promoted crops included rubber whose surface area was still increasing in the Northeast.

Rice was grown once a year, either by broadcasting or by laborious transplanting (less represented). When water was harvested in a pond, vegetables could be produced in a timely manner, in a corner of the farm, mainly for home consumption. Pipe irrigation of sugarcane was rare. Breaking the edge of a paddy often resulted in drying up the plot, allowing a land-use change. Cassava was grown for feed industry in expansion in South-East Asia. Use of organic amendments, mineral fertilizers and herbicides was widespread in this monoculture situation. Atrazine, glyphosate based formulations were the most used, but other unidentified formulations were found. Probably because of service affordability, many ploughings were performed to manage weeds before planting/sowing. Often, rice paddy bore *Cyperus* spp which was not removed mechanically, if pollarding was not done promptly.

Previous surveys conducted by Chambon (unpublished) in Buriram revealed different intercropping practices undertaken by rubber farmers who owned at least one mature plantation (Table 1). The choice of the study area was in accordance with local RAOT officers and Li and Fox (2011) who identified hotspots of rubber plantations by age all over Northeast Thailand. For this study, semi-structured interviews were held with 35 rubber farmers regardless to the age of their rubber plantations. Table 2 gives an overview of main cropping systems managed by farmers interviewed for this study. In each sub-district, a landscape observation round occurred to select villages displaying more diverse rubber agroforestry practices and showing more cooperation. Unavailability of farmers was a major constraint which resulted in a frequent change of target. Interviews were held in six (6) villages in Tum-Yai sub-district (Nong Boa18, Kum Somran, Ban Tum-Yai, Nong Pai Dong, Mai Jalon Su, Prakham Dong), and four villages in Khaendong sub-district (Ban Pa Nam, Nong Weng, Ban Nong Krathum, Non Sombun). Unbalanced stratified random sampling was done, based on different cropping systems associated with immature rubber plantations (monospecific, and different rubber intercropping systems). The sample was unbalanced since some categories of cropping systems were less represented than others. Therefore, snowball sampling was used in situations where random sampling was not practical. Statistical representativeness was not sought, but rather a diversity of cropping systems, following the judgment sampling suggested by Cochet (2015).

To gather economic data during this study, rubber farmers were individually interviewed from May to August 2016. Each interview lasted approximately 3 hours, using a questionnaire focusing on the characteristics and economics of all the cropping systems found in the farm during the immature period of rubber plantation. Labour requirements and economic performances were assessed based on estimation of family and paid labour, fixed and variables costs, yields and selling prices. Besides cropping systems, all the other sources of income were evaluated for the same period for 22 farmers (among the 35 farmers of the initial sample). As suggested by Ortiz (2005: 60), “to understand production decisions and predict the welfare of household members it is important to evaluate all household activities (production and wage-earning activities) and the pooling and distribution of food and cash”. Efforts were made to recall data over a 5 year period; however in many cases, the recall period has been extended to 20 years. When the recall-period exceeded 5 years, prices were found to be not applicable, and change of technology was silenced. For livelihood analysis, landholding, family labour availability, farm machinery, agricultural loans, and number of close friends who could help the interviewee in farming if needed were proxies used to describe natural, human, physical, financial, and social capital assets. Historic data were collected with elders included in the sample. Economic analysis is grounded on budgetary technique. As farmer practices and economic results were highly variable within cropping systems, a specific model was represented for the main system, in accordance with Giller et al (2011). Farming practices were further assessed through participant and non-participant observations to feed information gathered during interviews.

1. **Results**
	1. **Socioeconomic characteristics of rubber farmers and the decision to intercrop**

This section analyzes the main differences in rubber family livelihood assets, with a link to the choice of immature rubber cropping system (intercropping versus monospecific). Table 2 shows general characteristics of rubber farmers interviewed. Consistent with previous surveys conducted in 2014 (Chambon, unpublished), it appears that rubber farmers were relatively old (over 50 years on average), whether they owned immature, mature plantations, or both. This means that growing rubber is rather a strategy to secure living during old days. In general, households were nuclear families made of a couple raising 0-6 children or grand-children (for the elders). Few households (13%) had external dependents -mostly students- whereas 48% regularly received remittances from their children. Most of the heads of household (regarded as the sole decision-maker) attended primary school, the third quartile having achieved grade 9 (junior secondary school). Formal agricultural education was provided to only 5% of farmers. However rubber intercropping was not specifically included in the curriculum. On average, experience in rubber farming was about 14 years for farmers owning mature plantations and 4 years for farmers owning only immature plantations. General knowledge on agricultural practices was often said to be acquired from childhood, and this applied for all the crops.

It appears that an average household exploited 7.2 ha (45 rai) on a yearly basis, the third quartile being under 8.5ha. 29% of farmers rented 0.8-9.5 ha. Some farmers (e.g. marigold) expressed a more secured access to rented land than others (e.g. cassava). According to the local classification, 72.5% of farmers were considered as very smallholders (less than 8ha), while 27.5% were medium-size farmers (more than 8ha). When considering access to farm machinery, only 19% of households did not own any machinery (roto-tiller or tractor). However, this was not perceived as a constraint. In fact, all farmers had a fairly good access to mechanized farm operations, since service providers were numerous and prices affordable (e.g. 200-250฿/rai for ploughing). Even farmers who own roto-tiller preferred not using it at first hand. Access to agricultural loans was granted for any farmer. However, based on the evaluation of farmer’s capacity, claimed amounts varied from 4,000 to 625,000฿/year, the modal value being 100,000฿/year. The Coefficient of Variation (CV) over 155% showed high discrepancies between farmers who could claim less than 40,000฿/year and those who could get more than 60,000฿/year.

Despite such differences in farm endowments (especially natural and financial capital assets), Fig 4 shows that almost all farmers equally engaged in rubber intercropping during the immature period. Only one farmer never engaged in rubber intercropping system, whereas 8 farmers had both rubber intercropping systems and monospecific immature plantations. Over 81 plots surveyed during this study, 20% had never been intercropped during the immature period. A sub-sample of younger plantations (planted from 2009) revealed that there were recently even less monospecific immature plantations (11% of plots over 36 plots). Moreover, from visual observation, more than 90% of rubber plantations younger than 5 years showed visible signs of recent or current intercropping. Immature plantations older than 5 years could not always be ascertained as previously intercropped or not. A shared point of view was expressed as follows by a Sub-district Administration Officer: “It is very hard to find young rubber plantation without any intercropping in this area. Only very rich planters can do without intercropping, disregarding immediate benefits”. By contrast, the survey conducted over 196 plots in mature plantations in 2014 revealed that 42% of plots had never been intercropped. This huge difference in adoption of rubber intercropping during immature period was striking over this short period of time.

* 1. **Spatial dynamics of rubber plantations**

Hereafter, the spatial expansion of rubber plantations in the study area is explored through the lens of ecological and economic drivers. Fig 4 suggested that in the study area, rubber-cassava in lowland started 7 years ago while rubber-rice began approximately 9 years ago. The number of plantations in lowland (rubber-cassava and rubber-rice) progressively increased. Considering rubber price trends and recent climatic vagaries, it seemed that lowland had been invested to cope with drought, with further incentive provided by rubber price rise. In fact, as former rubber plantations in Buriram were set under the program of plantation led by RAOT, technical recommendations (including the need of deep soil) were strictly observed. Therefore, it was obvious that rubber plantations first only expanded on upland for several years (1990s onward). From 2000 to 2010, rubber prices steadily increased (Fig 5). As a consequence, farmers’ interest in planting rubber likely grew up. Probably, less favourable land had progressively been sought to grow rubber. However, Fig 4 also shows that occupation of lowland in the study area started later, coinciding with lower records of annual rainfall. In fact, for more than 16 years, rubber-cassava intercropping occurred on upland whereas rubber-cassava intercropping in lowland started less than 11 years ago. The first rubber-rice plantation in lowland was found in the Ban Nong Krathum village in 2007, whereas upland monospecific rubber planting had started since 1992 in the same village. Probably, dry weather favoured this first plantation in lowland against technical recommendations. Similarly, in Ban Tum Yai village, an elder farmer reported that rubber-rice intercropping only started 7 years ago, and rapidly expanded. As the following years proved to be dryer (except 2011, Fig 3), more farmers continued planting in lowland, as a response to combined effect of price rise and rainfall shortage. But the fact that no rubber-rice plot and no rubber-cassava in lowland was found before 2007 in these villages means that the first expansion of rubber plantations (1990s-2007) did not specifically target lowland whereas the later (2007 onward) did it clearly.

* 1. **Farming practices during immature period of rubber plantation**
		1. ***Dual management of the plantation during the immature period***

Many farming practices were similar in many aspects, regardless of the rubber cropping system during the immature. Only two rubber clones were in use: RRIM600 and RRIT251, with no clear preference for RRIT251 which was promoted by RAOT. Whether intercropped or not, dual management of the rubber plantation was striking: the rubber-row (1-2.5m wide proximal earth band) was treated differently from the inter-row (distal earth band). Prior to hole digging, land preparation involved one or two mechanized ploughings, depending on weed growth, biomass decay, soil bulk density, and dry spell. Straws of precedent crop were usually incorporated. First fertilization usually occurred just before planting, but not systematically. Organic and/or chemical fertilizers may be added at variable rate during planting, which occurred between late-May and early-July. Grafted plants were widely used; modal spacing was 7m\*3m, and common densities were close to 476-528 trees/ha. Mechanical weeding around young trees started approximately 2 months after planting, depending on weed abundance. Use of total herbicides (which rate depended on weed growth) on the rubber-row was observed as a preferred alternative to mechanical weeding. Weed management was continuous during wet season (up to 3 times). Fertilizer types and rates varied very much. Organic amendments included cow-dung, chicken manure, wood residues, sewage sludge, and many other formulations of commercial products from different sources such as guano and industrial by-products (mostly pure organic and granulated, sometimes in organic-mineral blend approximately 10% organic content). Zero (0) to 2,850kg/ha were the extreme rates recorded, likely depending on availability and affordability. Mineral fertilizers were even more variable as the input market expanded. At the time of data collection, N15P15K15 formulation seemed to be preferred to others included the one recommended by RAOT (N20P10K12). First application rate ranged from 600g/ha to 8.5kg/ha. Mineral fertilizer could be applied after first weeding as well. Only one farmer reported the use of bio-fertilizers (termed as ‘Efficient Micro-organism’ or EM) on rubber trees. Young plants were staked, and suckering was later completed during early growth.

From the very first year to the end of immature period, inter-row ploughing occurred and progressively took over weeding/herbicide (on the row) to effectively manage weed growth, lower bulk density and thus favour root growth. This ploughing was performed once or twice a year, regardless of the rubber cropping system (monospecific or intercropping). The plow-line stood near the rubber-row and moved outward from year to year. Often, small ridges or larger banks were raised in the inter-row to collect rainwater and receive mineral fertilizers; they were maintained every 3-5 years. Drainage canals and small ponds were created to prevent flood events, when needed. Chemical fertilizer rate was either maintained or more often increased over years to reach approximately 300kg/ha in many cases. Change of formulations from year to year was possible, but unusual. Organic fertilization continued as well, near the tree collar or under its canopy’s edge, on the rubber-row. No specific plant protection was reported, as pest attacks seemed to be extremely rare. Tree growth and development was a critical indicator to adjust most of these practices, as well as intercropping.

* + 1. ***Monospecific immature rubber plantations***

Management of the inter-row, when done without any associated crop is referred as to monospecific immature rubber plantation. This rubber cropping system included all plots (and part of plots) which had never been intercropped until tapping started. It did not include plots that had been intercropped once and abandoned for poor performance.

* + 1. ***Rubber-cassava intercropping systems***

Plantations were intercropped, regardless of the rubber clone. Differences in practices appeared only from the way of managing the inter-row. For cassava crop, upper-land was preferred as to prevent root rotting, but lower land was increasingly used during last years. Many cassava clones were found (Kasesaart and Rayong series). The day before planting, cuttings were sliced and dipped in a stimulant or urea-diluted solution that would favour root initiation. In general, one to four ridges (3 as modal value) were made by tillage with a tractor or a rototiller. Distance from the border of cassava band to the next rubber line varied from 0.6m to 2m, modal value being about 1.3m. Approximately 45-95% of the soil surface was covered by cassava in full growth stage. On each ridge, plant spacing varied from 0.6m to 1m. On average, cassava density was estimated at approximately 7,000 plants/ha. Higher densities (12-15,000plants/ha) were found, especially when farmers believed that root growth was only limited by fertilization, not density. Some farmers privileged rubber growth and squeezed the cassava band, reducing its density in the first year; others did not, depending on how they perceive potential inter-specific competition. Organic and mineral fertilizers were applied to cassava, with the same variability as for rubber trees. Organic fertilizer rates were found ranging from 0 to 6 tons/ha. Likewise, chemical fertilizers varied in NPK formulations, rates and time of application. Potassium (KCl, 60%) was applied from 5th month after planting, but the practice was not widespread. EM was more often used for cassava. In a ready-made commercial form, 6-20g of a concentrated liquid was mixed with 120-600L/ha of water and sprayed either on the topsoil (before plantation) or on plant leaves (in later growth stage). Another type of EM was an inoculum (in a powder form) mixed with food scrap, manure, vegetable waste and water, fermented or macerated over 1-1.5 month to get compost in form of sticky liquid, of which approximately 3L/ha is diluted before spraying. It was believed to improve soil physical (water holding capacity) and biological properties, activate cassava root growth, and even protect plants against potential aphid outbreak. But the most shared belief was about improving soil biological properties, as farmers argued that “soil life is improved” and its effects were expected over the following year of application. This delayed effect was cited as well as plant nutrition in the year of application (which response was found to be lower than that of mineral fertilizers). EM (in its traditional form) is likely a selection of soil bacteria strains which actively mineralize organic matter (provided by household waste) to make a compost.

Weed management was mainly done through use of total and/or pre-emergence herbicide. One to three applications could be recorded from 15 to 90 Days After Plantation (DAP), and mechanical weeding was rare (mostly once to enhance herbicide action, when few weeds persist). Mechanical harvesting was the only available modality; seasonal workers helped for loading, and usually a transporter’s service was required to deliver the product. The market was unique: merchants or buying-points which provided animal feeds to neighbouring countries. These were present in every district, and transportation costs were close in the same sub-district.

* + 1. ***Rubber-rice intercropping systems***

This system was found as rubber trees were planted on a previous paddy field, especially when rubber prices skyrocketed. Ridges surrounding paddy were broken during the first ploughing. Little earthwork was completed (less than 0.5m level rise) so as to reconcile drainage need for rubber and high water demand of rice. Rice transplanting was not very common (only found in Khaendong subdistrict), rather broadcast seeding was outright performed. Rice band was as large as possible, the rubber-row been approximately 1m to 1.5m wide. No plow-line was provided. Harrowing was systematic and served barely for levelling. However it occurred just after sowing, never before. In fact, coarse soil texture allowed easy rice seedling emergence. Seeding rate ranged from 90 to 240kg/ha. As compared to monocrop rice, organic fertilizer rate was lowered, and so was the mineral fertilizer rate. Two main formulations were used: N16P16K8 and N16P8K8. Other formulations including N15P15K15 were found. Approximately 100-150kg/ha was applied, which was on average half of that applied to monospecific paddy field. Weed management relied heavily on herbicide use. Manual weeding was almost an abandoned practice. It was also found that no weed clearing was possible (the farmer stating that there were so few weeds). In fact, repeated soil tillage with adequate timing (mechanical stale seedbed) may have greatly reduced weed seed bank; and other factors may have contributed to a faster ground cover by rice (higher seeding rate). Rice pollarding was done by one farmer who presented it as a tradition that improved yield. It was presumed to foster tillering, but it was noticed that the harvested biomass was used to feed cows as well. In all cases, harvesting was performed by family labour (with help of friends and relatives in many cases) in contrast with what was done on open paddy field. The main reasons given were that mechanical harvesters were too large to safely operate in rubber plantations, and that all the rice would not be completely harvested like in open paddies. The harvested product was equally treated as that of open field, that is for household consumption, the excess been sold whether systematically or when prices were ‘good enough’.

Upland rice was never observed in rubber plantations, though the possibility was suggested by RAOT officers. Beside rubber-cassava and rubber-rice, other rubber intercropping systems were found marginal in the landscape, but are not described in this paper.

* 1. **Profitability of rubber intercropping systems**

A comparison of economic performances of main cropping systems is used to assess the rationale of rubber intercropping. Main cropping systems found during immature period of rubber plantation are listed in Table 3. The most represented one is the rubber-cassava intercropping system, followed by rubber-rice intercropping system and monospecific immature rubber systems. Minor cropping systems included rubber-vegetables, rubber-banana, rubber-sugarcane, rubber-cover crops intercropping systems. Some of them bore entry-barriers such as irrigation, high investments, and high risk of crop failure (due to pest attack). Focus on cassava is justified by the fact that it is commercially oriented, with a wide market demand stimulated by a rapid growth of animal industry in Southeast Asia. Also, the cassava market is open to any farmer as outlets are found in each district.

In general, intercropping lasts three years, before rubber canopy closes. Table 4 compares actual operating costs and gross margins for 11 farmers during the first year of rubber-cassava intercropping, while cassava selling prices are kept standard (at 1.7฿/kg). Despite a low variability in yield (CV=24.8%), gross margins were highly variable because of differences in cost structure. A specific type of farmer (model) relying heavily on external farm machinery and herbicide with a relatively low organic and mineral fertilizer use is represented in Table 5. In a similar way, Table 6 shows economic performances of rubber-rice intercropping systems, focusing on a model farmer who also relies on herbicide with low fertilization. Further analysis is based on these models. For rubber-cassava intercropping system, the total labour was 27men.days/ha, of which harvesting represented 50%. Using the average price (1.7฿/kg), it was found that cassava production value was about 25,509฿/ha/year, while expenses were about 14,169฿/ha/year. Gross margins were 11,340 ฿/ha/year. In case of cassava price drop (0.8 ฿/kg at its lowest level over the last 5 years), gross margins would drop to -1,039 ฿/ha, provided that input prices do not change. In fact, when threatened by cassava root rotting in the rainy season, farmers were obliged to sell their products at lower prices. This usually resulted in a lower gross margin which proved to be negative in bad years for very few farmers. Overall, three years of intercropping allowed compensation and no farmer was found with cumulated negative gross margins (data not shown).

Rubber-rice intercropping was similar to rubber-cassava in that some operations were systematically performed by contractors (ploughing, harrowing). In the same way, farmers preferred carrying out specific operations (sowing, fertilizer application, herbicide spraying), even though few of them would require additional labour to complete these operations in a timely manner. As compared to cassava, rubber-rice intercropping was less input-intensive. In fact, its input consumption was far lower, whether compared to rubber-cassava or to rice monocropping (Tables 5 and 6). Total labour required per unit of surface area (23 men.days/ha/year) was similar to cassava intercropping, but harvesting was more labour consuming (80% of total labour) because it was only manually performed. According to the model, farmers spent 8,100฿/ha/year, and they were rewarded with a gross margin of 4,200฿/ha. At the average price of 10฿/kg, actual gross margins ranged from -3,750 to 14,062฿/ha (data not shown). In a worse scenario (lowest price recorded being 7฿/kg), the average gross margin would drop by 88% (data not shown). But this figure is less meaningful as farmers generally do not sell rice when prices were judged too low (except for those whose incomes are largely dependent on rice production). Because of inconsistency (small sample size and spatial heterogeneity), figures for other rubber-intercropping systems were not further analyzed.

Table 7 displays comparison of economic indicators for different cropping systems largely represented in the study area. It showed that rubber-cassava, while using approximately the same labour as for rubber-rice, bore higher operating costs. Because of its use of external labour, rubber-cassava was slightly less demanding for family members who could engage in other activities. Conversely, it was more intensive and thus operating costs were higher than for rubber-rice intercropping system. Similarly, gross margins for rubber-cassava were more interesting for farmers, and this is certainly why the system was the most preferred, when biophysical conditions allowed its implantation. Recent colonization of lowland by rubber-cassava intercropping is better understood, for economic profitability matched with recent climatic trends.

As total labour used for rubber-cassava and rubber-rice were similar, returns to labour were higher for rubber-cassava (420฿/man.day) as compared to rubber-rice (184฿/man.day). Even more, farmers tended to hire more labour for cassava harvesting, but not for rice. This slightly widened the gap, and returns to family labour were 810฿/man.day and 184฿/man.day respectively. Farmers expressed this difference by stating that cassava was an “easy-growing” crop. When compared to the flat wage of agricultural labour in the study area (200-250฿/man.day), rubber-rice intercropping was less profitable than casual off-farming. Because rubber-rice was less intensively grown, it required half of the working capital used for rubber-cassava. But rice production in the intercropping system is so low that returns on capital were lower, which means that rubber-rice intercropping bore high financial risks. Table 7 shows that rubber-cassava and rubber-rice intercropping systems bore the highest financial risks, as compared to monocropping systems (rice, cassava, sugarcane) predominant in the study area. Even more, they were the least profitable cropping systems, considering the returns to labour. Thus, by choosing rubber intercropping systems in general, especially rubber-rice intercropping system, farmers proved to be inefficient in the allocation of two resources: workforce and working capital. However, as compared to other cropping systems, rubber-cassava and rubber-rice did not require high level of investment, which is a clear advantage for poor farmers. Another economic reason can justify importance of rubber intercropping.

When engaging in rubber-cassava intercropping, a clear objective of operating cost reduction is pursued by farmers over the first years of rubber plantation. Management costs of monospecific rubber plantation include costs on the rubber-row and costs on the inter-row (Table 8). Costs on the rubber-row are the ones directly engaged to grow rubber trees. Despite variability, no structural difference was found from monospecific plantations to rubber intercropping systems, in regard with costs on the rubber-row. These costs were estimated approximately at 34,975 ฿/ha in the first year and approximately 5,353 ฿/ha in the 5 following years, including land preparation, transplanting, fertilization, weed management, and other cares given to rubber trees (stalking, suckering). Costs of the inter-row (in monospecific plantation) are shown in Table 8. For the entire immature period, managing a monospecific rubber plantation roughly cost 71,113 ฿/ha. These costs were raised to 105,806 ฿/ha in a rubber-cassava intercropping system. Gross margin of rubber-cassava intercropping system (which is only market-oriented) represented 28% of the total cost of the plantation management. Rubber intercropping with cassava eventually helped farmers to offset production costs by 59% (as compared to monospecific plantation), provided that they were able to raise their working capital by 14,000 ฿/year. Farmers certainly needed an extra-source of income to cover the initial investment cost (mostly grafted plant purchase). For this purpose, agricultural loans were appreciated. As some farmers and other actors argued that cassava may delay rubber maturity (despite the on-going controversy), a cost analysis has been sketched in Table 9. In this scenario, the immature period of the rubber-cassava intercropping system was prolonged to the 7th year, while maintained at 6 years for the monospecific plantation. It shows that cost reductions were about 50%, which is still considerable.

* 1. **Contribution of rubber intercropping system to the household livelihood**

To assess the economic importance of rubber intercropping systems for the household, the composition of the total annual income was evaluated during the intercropping period. Fig 6 shows that the rubber intercropping system gross margins represented 1 to 27% of the annual net income. On average, 10% of the annual income was derived from rubber intercropping systems. On average, other crops and husbandry made up to 37% of the income while other sources of income non-farm activities and remittances generated 56% of the income. Moreover, Fig 7 shows that the contribution of rubber intercropping system to the annual income does not depend on the level of the income. Therefore, it cannot be concluded that reliance on income derived from rubber intercropping systems is grounded on a farmer’s total annual income.

Another aspect of livelihood is the non-cash income generation for subsistence. In fact the main function of rubber-rice intercropping during the immature period is to increase rice stock. Contribution of rubber-rice intercropping system to the total rice production was low, for most farmers managed an open rice paddy which usually yields 2,706 kg/ha. The main rice production (4,236kg/household) represented more than 300% of annual household needs estimated at 1,303 kg/year on average. With an average yield of 1,238 kg/ha, rubber-rice intercropping systems provided approximately 890 kg/year, which represented 17% of the total household production.

1. **Discussion**

In Thailand, immature rubber intercropping systems received less attention than mature rubber agroforestry systems. Somboonsuke et al (2011) identified 21 rubber agroforestry systems in the country without any distinction of mature and immature periods. According to the authors, rubber-cassava, rubber-rice and rubber-banana agroforestry systems approximately generated net farm income estimated at 111,666, 116,106 and 163,200THB/year/rai or household respectively. The indicator’s unit (THB/year/rai or household) does not allow distinction between cropping system and production system. Moreover the income generated during the immature period (by growing the associated crop) could not be individualized as to allow comparisons with our data.

Many studies reported rubber intercropping and its profitability based on adoption drivers and farmers’ perceptions, without further economic valuation (Herath and Takeya, 2003, Iqbal et al, 2006, Effiong and Effiiong, 2014). Another corpus of research focused on experimental data. After 3 years of intercropping, Ogwuche et al (2012) found in Nigeria that over 1ha, various arable crops cost ₦ 193,310/ha, and generated a gross margin of ₦ 715,360/ha, with a net profit estimated at ₦ 640,020. The crop mixture included yam, yam-bean, pepper, pineapple, and banana-plantain. The returns on working capital would be as high as 3.7. *Ceteris paribus*, this return is higher than the ones recorded for all the cropping systems found in the current study. This study is of different nature, and in a different context.

Contribution of rubber intercropping to household livelihood has been estimated by Min et al (2015) in Xishuangbanna, China. It was found that on average, intercropping contributed at 16.5% of household income formation. But this proportion was clearly higher for smallholders in the low income group. They concluded that rubber intercropping was important for poorer farmers, as it provided essential complementary income. Similarly, Stirling et al (2002) and Herath and Takeya (2003) suggested that in Sri-Lanka, farmers relying more on other sources of income were less interested in intercropping. The contribution of rubber intercroppping to total household income is slightly lower in Buriram, as compared to Xishuangbanna. One major finding of the current study is that farmers equally engaged in rubber intercropping, regardless to their level of annual income or landholding. Also, it has been found that farmers in Buriram were still interested in rubber intercropping even when they relied more on non-farm sources of income. These findings challenge previous results above mentioned. Another striking finding is related to the choice of intercropping as related to efficiency in the use of farm resources.

From the comparison of economic performances of different cropping systems, the current study proved that farmers were not necessarily efficient when they chose rubber intercropping, especially rubber-rice intercropping system. Opposite to the expected rationale behaviour, rubber-rice intercropping system growers allocated financial resources and workforce to the least rewarding activity, while having better choices at hand. In fact, the opportunity cost of labour is theoretically important to consider farmers’ choices. According to Cochet (2015: 127), “… economic calculations can prove to be extremely efficient in explaining the diversity of situations and trajectories, in highlighting the real opportunity cost allocated by producers to the means of production to which they have access and to their workforce”. This case study seems to be an example of deviant economic behaviour, where inefficiency occurs for at least two main resources: labour and money. Besides, if rice production in open paddy fields is stable over years, choice of rubber-rice intercropping system may not be explained by the means of risk-avoidance theories (Umar, 2013). In fact, it appeared that farmers relied more on open paddies to meet their household needs. In case of rice crop failure due to climatic perturbations, food aid is systematically provided by the government to households in villages at risk. As rubber-rice intercropping system is a conversion of a previous paddy field into a future rubber plantation, it is clear that this change of land-use is a farmer’s strategic decision whose consequence is a potential reduction of the household rice production. Thus, rubber-rice intercropping represents a transitional stage between two regimes of rice production at the household level. Under the hypothesis of stable rice production in open paddies, it is relevant to question the importance of such a transitional stage provided that households otherwise achieved food sufficiency. If it is usually admitted that farmers deal with multiple and often contradictory goals (Taillander and Therond, 2011), there is a need to better understand how they are identified, valued and prioritized by farmers. This case-study offers a ground where socio-psychology, meets agronomy and farm economics to elicit farmers’ decision making.

Farming decisions are also known to be very reactive to changes in the environment (Shanahan et al, 2012). According to Feola et al (2015), “agricultural activities entail many decisions that are recursive and made at least partly in response to changes and pressures that are the result of previous behaviours and their consequences in the agricultural system”. In Buriram, despite RAOT recommendations, rubber farmers recently relocated their plantations lower in the toposequence in order to cope with a series of severe droughts. As a consequence, many of them chose rubber-rice intercropping systems. In line with RAOT recommendations, it is arguable that poor drainage during wetter months (August-October) can temporarily prevent deep rooting of rubber trees, thus impeding plant growth. On the other side, it is possible that shallow root development during this period expanded lateral root system, which would increase root density in soil surface layer. In fact Langerberger et al (2016) observed that despite its remarkable taproot system, rubber tree essentially feeds on a shallow dense root mat located in 0-30cm. In the study area (floodplain), as the water table lowers at the end of the rainy season, deep root development would revive during the dry season, but not at the expense of shallow roots. In the end, the total soil volume explored over a longer time period may be higher than root systems of rubber trees in upland (with regular deep roots not affected by flooding). While many farmers reported loss of rubber trees due to drought, none of them complained of tree death by inundation. However, visual observation suggested slower rubber growth and mortality in few cases. Monitoring above-ground and below-ground tree growth parameters in different toposequences, along with soil water status monitoring should ascertain the effect of this farmer practice on rubber growth and survival. It is also important to assess future performances of main rubber intercropping systems during the mature period.

1. **Conclusion**

The aim of this study was to describe farming practices and to evaluate economic performances of cropping systems during the immature period of rubber plantations in Northeast Thailand. Beside rubber monocropping system during immature period, two main other systems were found: rubber-cassava and rubber-rice intercropping systems. With strong economic and political drivers, rubber plantations expanded from 1990s until 2007. But from 2007, recurrent droughts sparked rubber planting in lowland, starting with rubber-rice intercropping systems. Later, monocropping systems and rubber-cassava intercropping systems have being planted planted in lowland. On average, rubber-cassava intercropping system which is market-oriented generated for the 3 years of intercropping a gross margin estimated at 11,300 ฿/ha/year. For rubber-rice intercropping system, the average gross margin is about 4,200 ฿/ha/year for the same period. But these cropping systems were associated with the least returns to labour and working capital in the farm system. The most important advantage related to rubber-cassava intercropping is a 50-59% reduction of operating costs during the immature period of plantation. This cost reduction has overruled the subsidies that can only be obtained for a maximum of 2.4ha, if a registered farmer grows a monocropping rubber plantation in upland as suggested by RAOT officers. Overall, rubber intercropping makes approximately 10% of the net annual income of the household, regardless to the level of this income. In contradiction with most of the results from other studies, it is shown that rubber intercropping during the immature period can be attractive for both poor and rich smallholders alike. Further investigations are needed to ascertain the real influence of toposequence and soil water status on rubber tree survival, growth, and production during the mature period of plantations.

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**Illustration**



Figure 1: Study area location

Source: petit Marico (2016)



Source: Fieldwork (May-August 2016)

Figure 2: Importance of the rubber intercropping systems in 35 farms



Source: Fieldwork (May-August 2016)

Figure 3: Composition of the annual gross income during the intercropping period

Source: Fieldwork (May-August 2016)

Figure 4: Contribution of rubber intercropping to the household’s annual net income

**Table 1: Diversity of immature rubber cropping systems in Buriram province based on a survey with 100 farmers in 2012**

|  |  |  |
| --- | --- | --- |
| Use of the inter-row | Nb of plots | % of plots |
| nothing | 82 | 41.8 |
| cassava | 82 | 41.8 |
| legume crops (bean, peanuts) | 12 | 6.1 |
| rice | 8 | 4.1 |
| corn | 3 | 1.5 |
| watermelon | 3 | 1.5 |
| jute | 1 | 0.5 |
| pumkin followed by cassava | 1 | 0.5 |
| rice followed by cassava | 1 | 0.5 |
| bean and marigold flower | 1 | 0.5 |
| vegetables and chili | 1 | 0.5 |
| Alternate cassava and peanuts | 1 | 0.5 |

Source: Chambon (unpublished)

**Table 2: General characteristics of rubber households in Buriram province in 2016**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Feature** | **Mean** | **CV\*** |  | **Minimum** | **3rd quartile** | **Maximum** |
| **Head of household’s gender (%female)** |  |  | **18** |  |  |  |
| **Age of the head of household (years)** | **56** | **24%** |  | **38** | **65** | **82** |
| **Level of formal education (years)** | **7** | **49%** |  | **3** | **9** | **15** |
| **Household’s size (adult equivalent)** | **3** | **36%** |  | **1** | **3.5** | **6** |
| **Farm worker/dependents ratio** | **0.33** | **102%** |  | **0** | **0.64** | **1** |
| **Landholding (ha)** | **7.2** | **103%** |  | **1.6** | **8.5** | **40** |
| **Rubber plantation surface area (ha)** | **3.89** | **143%** |  | **0.48** | **3.08** | **24** |
| **Immature rubber plantation surface area (ha)** | **3.1** | **131%** |  | **0.48** | **2.8** | **22.4** |
| **Value of remittances (฿/year)** | **81,000** | **165%** |  | **0** | **93,250** | **360,000** |
| **Value of non-farm income (฿/year)** | **143,183** | **313%** |  | **0** | **241,000** | **420,000** |

\* CV: Coefficient of Variation

**Table 3: Diversity of immature rubber cropping systems in Buriram province based on a survey with 35 farmers in 2016**

|  |  |  |  |
| --- | --- | --- | --- |
| Use of the inter-row | Nb of farmers | Nb of plots (frequency) | Surface area (ha) |
| Nothing | 9 | 16 (20.8%) | 17.76 |
| Cassava | 17 | 27 (35.0%) | 56.16 |
| Rice | 10 | 15 (19.5%) | 22.08 |
| Various associated crops | 10 | 11 (14.3%) | 12.08 |
| Minor crops | 5 | 8 (10.4%) | 8.8 |
|  |  |  |  |

**Table 4: Variation of cost structure and production value within rubber-cassava intercropping systems based on a sub-sample of 11 interviewed farmers**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  Farmer  | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | CV |
| Topography | Lowland | Lowland | Upland | Upland | Upland | Lowland | Upland | Upland | Upland | Upland | Upland | - |
| Surface (rai\*)  | 10 | 7 | 1 | 7 | 8 | 2 | 6 | 5 | 5 | 10 | 6 | 47% |
| Family labour (men.days/rai) | 1.5 | 1.5 | 11 | 1 | 0.25 | 3.25 | 3.5 | 1.2 | 3.1 | 1.7 | 0.67 | 114% |
| Total labour (men.days/rai) | 3 | 3.8 | 9.5 | 5.4 | 2.25 | 3 | 2 | 3.2 | 5.5 | 3.4 | 1.8 | 57% |
| Paid wage\* (฿/rai) | 930 | 1130 | 1600 | 1654.3 | 1125 | 550 | 1133.4 | 1160 | 1050 | 1390 | 250 | 38% |
| Cutting cost (฿/rai) | 0 | 0 | 0 | 0 | 300 | 280 | 150 | 0 | 0 | 0 | 0 | 180% |
| Fertiliser quantities (kg/rai) | 60 | 75 | 25 | 5 | 60 | 12.5 | 66.6 | 0 | 0 | 25 | 8.33 | 95% |
| Fertilization cost (฿/rai) | 936 | 995 | 350 | 80 | 840 | 205 | 1198.8 | 0 | 0 | 400 | 166.6 | 94% |
| Amendments (kg/rai)  | 0 | 20 | 0 | 10 | 0 | 25 | 0 | 0 | 150 | 0 | 0 | 238% |
| Amendment cost(฿/rai) | 0 | 120 | 0 | 80 | 0 | 175 | 0 | 0 | 900 | 0 | 0 | 14% |
| Manure | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1000 | 0 | 0 | 230% |
| Manure cost฿/rai) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1000 | 0 | 0 | 331% |
| Herbicide (Litre) | 2 | 2.5 | 0 | 0.85 | 1.25 | 2 | 0.17 | 0.2 | 0.12 | 0.7 | 0 | 103% |
| Herbicide cost(฿/rai) | 200 | 250 | 0 | 93.5 | 112.5 | 180 | 18.7 | 20 | 13.2 | 70 | 0 | 102% |
| EM\*\* cost(฿/rai) | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 120 | 60 | 0 | 0 | 223% |
| Fuel cost(฿/rai) | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 166.67 | 311% |
| Root promoter cost (฿/rai) | 0 | 10 | 0 | 0 | 13.75 | 0 | 20 | 50 | 0 | 25 | 16.67 | 126% |
| Rent (฿/rai) | 0 | 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2000 | 222% |
| Transportation cost(฿/rai) | 120 | 385.74 | 500 | 321 | 500 | 49.8 | 249.96 | 299 | 0 | 9.99 | 83.34 | 75% |
| Yield (kg/rai) | 3,000 | 2,143 | 2,000 | 2,140 | 4,000 | 3,000 | 2,083 | 2,300 | 2,300 | 3,000 | 2,000 | 25% |
| Price\*\*\* (฿/kg) | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 0% |
| Total cost (฿/rai) | **2186** | **4890.7** | **2450** | **2248.8** | **2891.3** | **1439.8** | **2770.9** | **1649** | **3023.2** | **1895** | **2683.3** | **36%** |
| Production value (฿/rai) | **5100** | **3643.1** | **3400** | **3638** | **6800** | **5100** | **3541.1** | **3910** | **3910** | **5100** | **3400** | **25%** |
| Gross margin (฿/rai) | **2914** | **-1247.6** | **950** | **1389.2** | **3908.7** | **3660.2** | **770.2** | **2261** | **886.8** | **3205** | **716.7** | **88%** |

**Table 5: Model specification for a rubber-cassava cropping system**

|  |  |
| --- | --- |
| Feature | Modelled Rubber-cassava intercropping system |
| Topography | **Upper land** |
| Surface area (ha) | **1** |
| Number of cycles | **3** |
| Duration of cycle | **10 months** |
| Number of ploughings (ridges included) | **2** |
| Use of root promoter | **Yes** |
| Origin of cuttings | **Bought the first year** |
| Total mineral fertilizer rate (kg/ha) | **194** |
| Farm organic fertilizer rate (kg/ha) | **0** |
| Commercial organic fertilizer rate (kg/ha) | **112** |
| Liquid herbicide rate (L/ha) | **11.25** |
| Number of hand-hoe weeding | **0** |
| Number of EM applications | **0** |
| Operations executed by family labour | **Planting, Fertilizer application, Herbicide spraying** |
| Operations executed by contractor and/or paid labour | **Ploughing, Harvesting** |
| Rent (฿/ha) | **0** |
| Yield in 1st year (ton/ha) | **15.8** |
| Yield in 2nd year (ton/ha) | **15.5** |
| Yield in 3rd year (ton/ha) | **13.6** |

**Table 6: Model specification for a rubber-rice cropping system**

|  |  |
| --- | --- |
| Feature | Modelled rubber-rice intercropping system |
| Topography | **Lowland** |
| Surface area (ha) | **1.4** |
| Number of years | **3** |
| Number of ploughings (harrowing included) | **2** |
| Origin of seeds | **Own** |
| Propagation method | **Sowing** |
| Sowing density (kg/ha) | **125** |
| Total mineral fertilizer rate (kg/ha) | **164** |
| Farm organic fertilizer rate (kg/ha) | **0** |
| Commercial organic fertilizer rate (kg/ha) | **74**  |
| Herbicide rate (L/ha) | **0.9** |
| Number of mechanical weeding | **0** |
| Number of EM applications | **0** |
| Operations executed by family labour | **Sowing, Fertilizer application, Herbicide spraying, Harvesting** |
| Operations executed by contractor or paid labour | **Ploughing** |
| Rent (฿/ha) | **0** |
| Yield in first year (ton/ha) | **1.468** |
| Yield in second year (ton/ha) | **1.237** |
| Yield in third year (ton/ha) | **1.018** |

**Table 7: Comparison of economic performances for main cropping systems found in the study area**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cropping systems\* | Total labour (man.day/ha) | Family-labour(man.day/ha) | Operating costs (฿/ha) | Gross margin/ha (฿/ha) | Returns to labour\*\* (฿/man.day) | Returns on working capital |
| Rubber-cassava | **27** | **14** | **14,169** | **11,340** | **810** | **0.80** |
| Rubber-rice | **23** | **23** | **8,181** | **4,235** | **184** | **0.52** |
| Cassava monocrop | **33** | **13** | **20,835** | **22,438** | **1,726** | **1.08** |
| Rice monocrop | **9** | **9** | **14,600** | **12,463** | **1,385** | **0.85** |
| Sugarcane | **50** | **7** | **51,156** | **31,966** | **4,567** | **0.62\*\*\*** |

\*Figures are provided as a yearly average

\*\* Only family labour has been considered

\*\*\*Input-credit is usually provided, but not deducted here.

**Table 8: Comparison of costs on monospecific rubber plantation and rubber-cassava intercropping** system

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Age (years) | Costs on rubber-rows\*(a) |  | Costs on monospecific plantations (฿/ha) |  | Costs and production value in rubber-cassava intercropping system (฿/ha) |  | Cost reduction\*\*\* (%) |
|  | **Inter-row****(b)** | **Total costs****(c=a+b)** |  | **Inter-row** **(d)** | **Total costs** **(e=a+d)** | **Production Value (f)** | **Deducted costs (g=e-f)** |  |
| 1 | **34,975** |  | **1,563** | **36,538** |  | **15,300** | **50,275** | **26,981** | **23,294** |  | **36** |
| 2 | **5,113** |  | **3,125** | **8,238** |  | **13,700** | **18,813** | **26,369** | **-7,556\*\*** |  | **100** |
| 3 | **5,425** |  | **3,125** | **8,550** |  | **13,506** | **18,931** | **23,175** | **-4,244\*\*** |  | **100** |
| 4 | **5,300** |  | **1,563** | **6,863** |  | **1,563** | **6,863** | **0** | **6,863** |  | **0** |
| 5 | **5,619** |  | **0** | **5,619** |  | **0** | **5,619** | **0** | **5,619** |  | **0** |
| 6 | **5,306** |  | **0** | **5,306** |  | **0** | **5,306** | **0** | **5,306** |  | **0** |
| Total | **61,738** |  | **9,375** | **71,113** |  | **44,069** | **105,806** | **76,525** | **29,281** |  | **59** |

\* Applies to rubber-rows on both plantations

\*\*Absolute value represents a gross profit for the farmer

\*\*\* Cost reduced by intercropping rubber with cassava from year1 to year3.

**Table 9: Economic simulation of a one-year delay of immature period of rubber-cassava intercropping system**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Age (years) | Costs on rubber-rows\*(a) |  | Costs on monospecific plantations (฿/ha) |  | Costs and production value in rubber-cassava intercropping system (฿/ha) |  | Cost reduction\*\*\* (%) |
|  | **Inter-row****(b)** | **Total costs****(c=a+b)** |  | **Inter-row** **(d)** | **Total costs** **(e=a+d)** | **Production Value (f)** | **Deducted costs (g=e-f)** |  |
| 1 | **34,975** |  | **1,563** | **36,538** |  | **15,300** | **50,275** | **26,981** | **23,294** |  | **36** |
| 2 | **5,113** |  | **3,125** | **8,238** |  | **13,700** | **18,813** | **26,369** | **-7,556\*\*** |  | **100** |
| 3 | **5,425** |  | **3,125** | **8,550** |  | **13,506** | **18,931** | **23,175** | **-4,244\*\*** |  | **100** |
| 4 | **5,300** |  | **1,563** | **6,863** |  | **1,563** | **6,863** | **0** | **6,863** |  | **0** |
| 5 | **5,619** |  | **0** | **5,619** |  | **0** | **5,619** | **0** | **5,619** |  | **0** |
| 6 | **5,306** |  | **0** | **5,306** |  | **0** | **5,306** | **0** | **5,306** |  | **0** |
| 7 | **-** |  | **-** | **-** |  | **0** | **6,250** | **0** | **6,250** |  |  |
| Total | **61,738** |  | **9,375** | **71,113** |  | **44,069** | **112,056** | **76,525** | **35,532** |  | **50** |

\* Applies to rubber-rows on both plantations

\*\*Absolute value represents a gross profit for the farmer

\*\*\* Cost reduced by intercropping rubber with cassava from year1 to year3.

1. Director of RAOT provincial office in Buriram at time of fieldwork [↑](#footnote-ref-1)