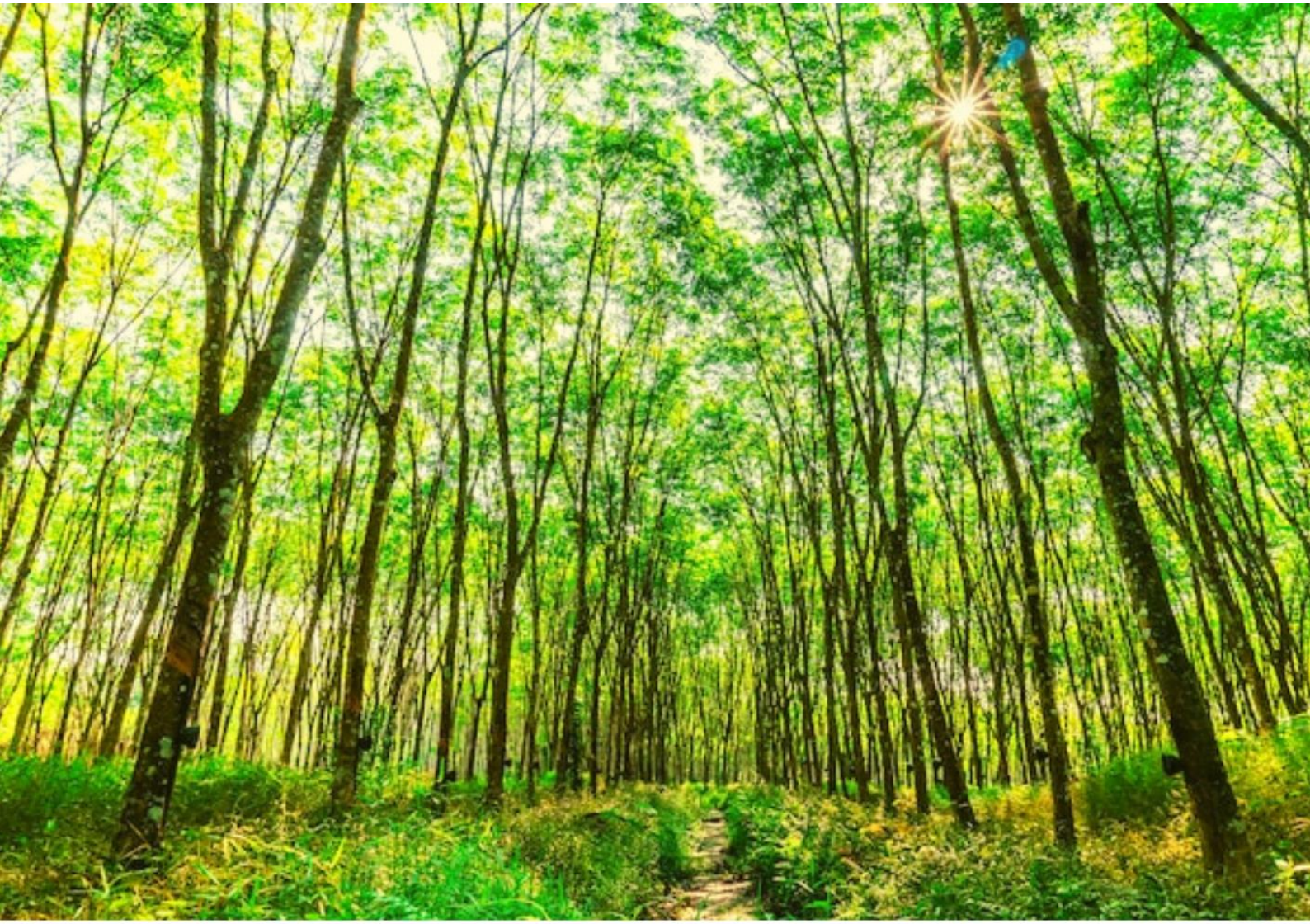

Final Report

Study on intercropping in rubber cultivation in the Moneragala and Ampara regions of Sri Lanka

JULY 2022

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STUDY ON INTERCROPPING IN RUBBER CULTIVATION

IN THE MONERAGALA AND AMPARA REGIONS OF SRI LANKA

2022

YAPI Expertise, ISTOM, Ksapa, CIRAD, CAMSO

The views expressed in this report are those of the authors of the document and do not necessarily reflect the views of the sponsor or project partners.

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LIST OF ABBREVIATIONS

%: percent

DS: Divisional Secretarial

Etc.: etcétera

ha: hectare

HCPC: Hierarchical Clustering on Principal Components

km: kilometre

LOAM: Lanka Organic Agronomic Movement

m: metre

MCA: Multiple Correspondence Analysis

mm: millimetre

NGO: non-governmental organisation

RDD: Rubber Development Department

RRISL: Rubber Research Institute of Sri Lanka

SUTTI: Scale Up Training Traceability Impact

WTO: World Trade Organisation

YEP: Youth Expertise Project

ABSTRACT

Latex is considered a strategic material for the development of the country by the Ministry of Plantation of Sri Lanka. In response to the climate change, the country has adopted a policy focused on resilience and sustainable development. It is in this context that Ksapa initiated in 2022 the RIVER project which will develop a program to strengthen agricultural capacity in Sri Lanka through a digital suite, SUTTI. To carry out this project, the company commissioned YAPI Expertise to provide intercropping models based on rubber trees that are agronomically "performant" and economically interesting for producers to diversify their income.

The RIVER project takes place in two districts in south-eastern Sri Lanka: Moneragala and Ampara. This study was based on literature searches which enabled to select crops that could be intercropped with rubber. In parallel, 80 interviews, prepared by YAPI Expertise, were conducted on the field by a local organisation, LOAM. The aim of these interviews was to identify rubber intercrops models already implemented in the study areas and to understand the reasons why farmers adopted these intercrop models. The interviews were analysed statistically by MCA and Chi².

Combined with the literature review, the study established 5 models (Pineapple model, Cocoa model, Banana model, Passion fruit model, Soursop model) proposing several intercrops that could be planted with rubber. Finally, choice criteria have been established for each model, presenting their strong and weak points.

Le latex est une matière considérée comme stratégique pour le développement du pays par le Ministère des Plantations du Sri Lanka. En réponse au changement climatique, le pays a adopté une politique axée sur la résilience et le développement durable. C'est dans ce contexte que Ksapa a initié, en 2022, le projet RIVER induisant le développement d'un programme de renforcement des capacités agricoles au Sri Lanka à travers une suite numérique, SUTTI. Pour mener à bien ce projet, l'entreprise a mandaté YAPI Expertise afin d'obtenir des modèles de cultures associées à l'hévéa, agronomiquement " performants" et économiquement intéressants pour les producteurs afin de diversifier leurs revenus.

Le projet RIVER se déroule dans deux districts du sud-est du Sri Lanka : Moneragala et Ampara. Cette étude s'est basée sur des recherches documentaires permettant de sélectionner des cultures pouvant être associées à l'hévéa. En parallèle, 80 entretiens, préparés par YAPI Expertise, ont été menés sur le terrain par une organisation locale, LOAM. L'objectif de ces entretiens était d'identifier les modèles de cultures intercalaires d'hévéa déjà mis en place dans les zones d'étude et de comprendre les raisons pour lesquelles les agriculteurs adoptent ces systèmes de cultures intercalaires. Les entretiens ont été analysés statistiquement par ACM et Chi².

Combinée à la revue bibliographique, l'étude a permis d'établir 5 modèles (Pineapple model, Cocoa model, Banana model, Passion fruit model, Soursop model) proposant plusieurs cultures intercalaires pouvant être mise en place avec l'hévéa. Enfin, des critères de choix ont été établis pour chaque modèle présentant leurs points forts et leurs points faibles.

INTRODUCTION

What is a Youth Expertise Project?

Fourth year ISTOM students carry out a Youth Expertise Project (YEP) on behalf of a sponsor (public, private, association, NGO, etc.) working in tropical agricultural and rural development. This exercise is being completed in groups of 8 to 10 students. During the first 6 months of the exercise, the students must find a sponsor and draw up a preliminary project that will be examined and validated by ISTOM. They must, then, write a methodological proposal adapted to the sponsor's request and to the field context. If necessary, they also must find fundings. At the end of the 4 to 8 weeks of fieldwork, the students analyse their results and write the deliverable expected by the sponsor and by ISTOM. Eventually, ISTOM organises a final presentation of the study's conclusions in the presence of the sponsor and a jury.

Specific situation of YAPI Expertise

YAPI Expertise signed an agreement with the sponsor Ksapa in April 2022 to realise an expertise on rubber cultivation in Sri Lanka. YAPI Expertise worked on a field survey methodology. The team was ready to realise the field data collection when an important economic crisis arose in Sri Lanka. Since the end of March 2022, there have been large-scale demonstrations, leading to violence, resulting in the government’s overthrow. The country has been placed under a state of emergency on several occasions since April 2022 and curfews are regularly imposed for all, or part of the day and night throughout the country (France diplomatie, 2022). In this context of high tension, YAPI Expertise’s field phase mission was cancelled on the 06/05/2022 by the project partners for security reasons. As a result, the whole methodology was adapted to a desk study relying on agronomy experts: Alexis Thoumazeau and Eric Penot. Finally, it has been possible for a local partner of the project, LOAM, to conduct a field survey using a methodology designed by YAPI Expertise.

Sri Lanka and its rubber industry

Sri Lanka is a country whose economy is highly dependent on agriculture, both food and cash crops. Rubber as a major cash crop in the country and therefore plays an important role in its economy, with more than 80 000 small-scale producers within the island. In the past few years, the government has classified rubber as a major strategic resource and is therefore encouraging the development of the sector, with the help of scientific institutions and private companies such as Camso Loadstar.

The aim is to establish a more agronomically, economically and socially sustainable cultivation system. It has been shown that the implementation of inter-row cultivation is more than interesting in rubber plots. The RIVER project set up by Ksapa is part of this process of implementing innovative practices among rubber smallholders. One of the hindrances to the development of inter-row cultivation is the difficulty of understanding and implementing it by the rubber farmers. YAPI Expertise has therefore worked in two districts considered as new areas for rubber cultivation. In order to understand the limits of the implementation of these systems, and understand how to facilitate the development of this agroforestry practice, different approaches (social science, agronomy, etc.) will be carried out.

1. PART 1: CONTEXT

1.1. The sponsor: Ksapa

Ksapa is a French consulting company created in 2019. It provides services and assistance in order to promote the development of a performant economic model based on social and environmental improvements with the support of a community of experts. Ksapa works mainly on agricultural and development project throughout the world.

Since 2020, Ksapa is working on the development of a digital suite called SUTTI (Scale Up Training Traceability Impact): an application that provides access to education and digital technologies to farmers and businesses working in the agricultural sector. The main objective of this tool is to include women and young adults in agricultural value chains, to increase producer's income and to improve the resilience of the ecosystems and communities. It has the advantage of being suitable for illiterate people and of being usable offline on different electronic media. It started with the CASCADE Project in Indonesia which involves 1000 rubber smallholders benefiting from the application. The end of the project is planned for 2025.

In 2022, Ksapa initiates a similar project called the RIVER project, which will develop a program to strengthen agricultural capacity in South-East Sri Lanka. This project will mainly focus on rubber farming systems that are developed by the farmers of the region. The overall objective is to allow 6000 rubber smallholders to benefit from this program. The specific objective is to develop the technical and management skills and know-how of participants, in order to increase the farmers' income, control their expenses, improve social inclusion, and improve environmental practices.

The RIVER Project is funded, amongst other, by the French Ministry of Economy, Finance and Recovery (Ministère de l'Economie, des Finances et de la Relance) and the Michelin Group. The main implementing organisation are Camso Loadstar (Michelin subsidiary in Sri Lanka) and LOAM (Lanka Organic Agronomic Movement), a local NGO promoting organic farming in Sri Lanka. The French research centre CIRAD is also a partner of the project. Alexis Thoumazeau and Eric Gohet will, among other things, carry out an agronomic diagnosis (Annex 1: Diagram of the main partners of the RIVER project).

1.2. Terms of Reference of the study

Ksapa commissioned YAPI Expertise for the initial diagnosis phase once the RIVER project starts. Their mission aims to identify potential intercrops in rubber cultivation, during the immature and mature phases of the tree, in the selected study areas. Indeed, during the first 7 years of the rubber tree, farmers cannot exploit it for latex. It is called the immature phase. Thus, farmers have no income from rubber cultivation during this period. Intercrops should allow farmers to have a higher income than in a monoculture system, allowing them to better cope with the very high volatility of natural rubber prices (Stroesser et.al 2018) while having more environmentally friendly and productive production system. The objective of the expertise is to provide "models of cultivation" that are agronomically "performant" and economically interesting for farmers. Finally, YAPI Expertise will also analyse the possibility of adoption of these innovations by farmers. The results of this study will be used to design training courses available on the SUTTI application. YAPI Expertise's work will enable the selection of the definitive study areas for the rest of the project thanks to a grid built in collaboration with Ksapa, LOAM and Camso Loadstar.

1.3. The rubber sector in Sri Lanka

Sri Lanka is an island with a population of 22 million located in the South-East of India. Its surface area is 65 000 km² (Population data, 2022). Agriculture in Sri Lanka is divided into two main sectors:

- National food production: rice accounted for 11% of total agricultural production and over 27% of cultivated land in 2011. It employed about half of the total agricultural labour force of the country (Department of agriculture Sri Lanka, 2011).
- Export-oriented farming: In 2020, the export of crops such as coffee, tea and spices accounted 15,6%, i.e., $1,6 billion, of the country's total export value. Rubber by itself accounted for 8,1% ($870 million) (Workman D., 2022).

The rubber industry is a pillar of Sri Lanka's economy accounting for around 10% of agricultural exports together with processed agricultural products (Sri Lanka export development board, 2022) (Annex 2: Contribution of rubber products to Sri Lanka's exports). In 2020, rubber cultivation represented 136 300 ha in Sri Lanka, which corresponds to 2% of the total land area (Sankalpa, 2020) with an average yield of 642 kg/ha/year (Rubber Research Institute of Sri Lanka, 2020) (Annex 3: Map of the area occupied by rubber cultivation in Sri Lanka). Thus, latex is considered a strategic material for the development of the country by the Ministry of Plantation.

In Sri Lanka, 81% of rubber production comes from smallholders (Dissanayake D. M. P. *et al.*, 2016). Hence, and in response to the climate change that is particularly affecting Sri Lanka (drought, floods, soil erosion, etc.), the country has adopted a policy focused on resilient and more sustainable development. Therefore, in the context of the revitalisation of some agricultural export sectors, rubber is at the centre of governmental concerns. Indeed, the Ministry of Plantation Industries in Sri Lanka has launched the Sri Lanka Rubber Industry Master Plan, which began in 2017. Its main objective is to improve productivity, control production costs and develop knowledge through technical and technological improvements in rubber cultivation (Rubber Research Institute of Sri Lanka, 2020).

The institutional framework of the Sri Lankan rubber sector is organized around 3 main governmental organisations. The first one is the **Rubber Research Institute of Sri Lanka** (RRISL) which oversees all the scientific research on the rubber clone, seedlings, farming technical, intercropping etc. This institute works with universities and substations in every district where natural latex is produced. Secondly, there is the **Rubber Development Department** (RDD) which focuses on the development of the sector with projects on crop selection or the material of primary transformation. The RDD is a branch of the Ministry of Plantation and was created for the "Enforcement of legal provisions and supply of Financial Subsidies, Agricultural Inputs and Extension Services for the Qualitative and Quantitative Development of the Rubber Sector specially in the Smallholdings" (RDD, 2022). Finally, the farmers-based organisation who grow rubber are supported by the **Thurusaviya Fund** which is a governmental fund raised and its functioning have been integrated to the Constitution of Sri Lanka since 2000. It aims *"to uplift the living standards of rubber smallholders by facilitating the production and marketing of quality rubber sheets and ensuring a fair price for their products through the establishment of Farmer Based Organizations"* (Act No.23 from Sri Lanka constitution, Ministry of Justice).

At the village scale, smallholders are organised in "societies" which can be compared to the functioning of cooperatives. There is a significant variation of the activity of the societies depending on the district or even the village in which they are located. Each village's society elects a Management Unit composed of 11 volunteers' members. Societies have several roles:

- Distribution of subsidies;

- Developing marketing facilities;
- Training programs;
- Rubber processing facilities.

Field officers hired by the RDD oversee the coordination between societies and governmental institutes. Societies face some issues mainly due to the lack of leadership. In Moneragala district, there are only 43 societies out of 85 that are considered as active. Altogether, 65% of the smallholders are members of a societies in Moneragala (Gunarathne, P.K.K.S *et al.*, 2020).

1.4. The study areas

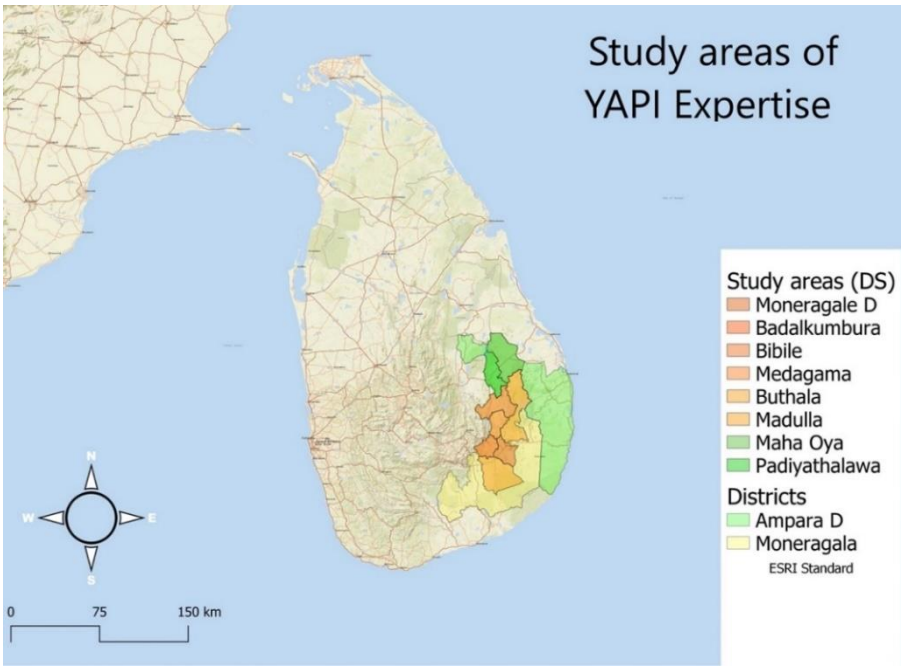


Figure 1:Study area of YAPI Expertise's study areas

The study is conducted in two areas in the south-east of Sri Lanka (Figure 1: YAPI Expertise's study areas): Moneragala and Ampara. These two districts are not historical rubber cultivation areas. Indeed, they are: Kegalle, Rathnapura, Kalutara and Colombo. However, the government has decided to develop new rubber plantation areas in intermediate and dry climate regions due to the lack of available cultivable land in the historical rubber cultivation areas. The expertise requested by Ksapa to YAPI Expertise is precisely focusing on these two districts nowadays considered as very promising areas for rubber cultivation in Sri Lanka.

1.4.1. Moneragala

Moneragala is located in the province of Uva and is the second largest district in the country with an area of approximately 5,639 km². It is also one of the least densely populated regions in the country with almost 90 inhabitants/km² and its population is mostly rural. It is a transition zone between the highlands in the middle of the country and the plains in the eastern part of Sri Lanka. Three different types of land can be identified within the district:

- The mountainous areas, rather located in the east of the district with altitudes between 550 m and 1 400 m above sea level;
- The hilly areas, transition zones between the mountainous parts of the centre and the wide plains of the east. Their altitude ranges from 160 m to 550 m;

- The lowland areas are the most widespread zones in the district since they represent almost 75% of its area. They are generally below 160 m in altitude (Annex 4: Topographic map of Sri Lanka).

The district has seven catchment areas with most of the rivers originating outside the district to the west. These rivers generally flow east or south-east to the Indian Ocean. The mountainous area in the north of Moneragala has a rainfall that tends to be around 1 000 mm/year. The southern part of the region has a higher rainfall which varies between 1 500 and 2 000 mm/year on average (Annex 5: Rainfall map of Sri Lanka).

Throughout the year, the district experiences two alternating dry and rainy seasons. The first rainy season is called Maha and is the longest and most intense. It usually begins in early October and ends during January. The second rainy season, Yala, is shorter and usually starts in late March and ends in late May. Thus, 84% of the annual rainfall is concentrated in the seven months of the rainy seasons (Yasaratne *et al.*, 1993).

Moneragala district is divided into 11 departments called Divisional Secretariat. After a first field visit by Ksapa, they chose the following districts as study areas: Moneragala (DS), Badalkumbura, Medagama and Bibila. These areas are in the central-western part of the district in the intermediate climatic zone.

Agriculture is strongly established in Moneragala. **Rice** is the most important crop of the district, covering almost 5,4% of the area, i.e., 30 450 ha. Rice is essential for the inhabitants as it represents the basis of their daily diet. The second most common crop is **sugar cane**, which is grown on almost 2,3% of the district i.e., 13 150 ha (Uva province statistics, 2015). The other different crops in the region can be divided into two categories: food crops and cash crops. Food crops are many and varied, including **several types of fruit and vegetables**, mostly grown in home gardens. Some fruits are grown on a large scale, such as bananas, of which Moneragala is the largest producer in Sri Lanka with nearly 8 000 ha. In addition, 2 000 ha are dedicated to **mango** cultivation (Ministry of Agriculture, 2016). **Papaya, rambutan, orange, passion fruit** and **pineapple** are also produced in the district.

Nowadays, Moneragala is the 5th most productive rubber region preceded by the 4 historical regions where rubber is cultivated. In 2014, rubber was grown on 5 876 ha. There were 7 800 producers in the district in 2010, of which 7 250 had less than 2 ha, 4 808 less than 0,8 ha and 141 less than 0,4 ha (Ministry of Plantation Industries & Export Agriculture, 2018). Most of rubber farmers in Moneragala District are therefore small-scale producers.

1.4.2. Ampara

Ampara is located in the east of Moneragala, with an area of 4 445 km². The population density is much higher than Moneragala and is 145 inhabitants/km² (Ampara District, 2020). On average the temperature is between 25°C and 36°C in the dry season and in the rainy season the temperature can drop to 22°C (Department of Meteorology). Like Moneragala, Ampara experiences the two rainy seasons Maha and Yala.

It is divided into 19 Divisional Secretariat (Ampara District Secretariat, 2016). Two of them are potential study area: Ampara (DS) and Damana. As in Moneragala, agriculture is the main source of income for the inhabitants. Ampara is the largest producer of **rice** in the country, estimated at over 25% of national production. There are also other widely grown crops such **as corn, coconuts, cashew nuts** and a wide variety of **fruit trees** (Ministry of Agriculture of Sri Lanka, 2019).

Ampara is a new area for rubber cultivation. Indeed, after having significantly developed the rubber sector in the Moneragala district, the government is encouraging farmers in the easternmost district of the island to grow this crop, which is recognised as economically strategic. In 2014, Ampara had 335 rubber smallholders, compared to 80 500 nationwide (Ministry of Plantation Industries & Export Agriculture, 2020). The amount of rubber smallholders is still quite insignificant, but it is likely to increase in the coming years due to development programs undertaken by stakeholders such as Ksapa and the government.

1.5. Definition of the key words and problematic

To understand the context of the mission, here are some definitions selected by YAPI Expertise to shape the conceptual framework:

The term "intercrop system" refers to an agricultural system made up of "practices of soil valorisation with a simultaneous or sequential association of trees and crops or animals in order to obtain products and services useful to humans" (Torquebiau E., 2000).

An “performant model” is defined, in this study, by the choice of several crops and by the practices associated with them in order to obtain a production (model) that satisfies a given number of constraints related to the socio-economic and pedoclimatic environment (performance). In the current situation, the model is characterised by the establishment of intercrops in association with the rubber tree (in the mature and/or immature phase) and the capacity of this model to respond to the constraints.

These different elements lead to the following problematic:

“Given the favourable context for the establishment of new rubber growing areas in the districts of Moneragala and Ampara, the expertise aims to define several performant intercrops models in order to complete a training program. The performant model considers the agronomic aspect and the socio-economic dimension.”

2. PART 2: METHODOLOGY

The overall study consists in a multi-criteria approach to assess performance and acceptability of intercropping introduction in rubber farming systems. It is an agronomical study combined with a socio-economic approach of intercropping in the two districts of the study.

The multi-criteria approach is a methodological tool that YAPI Expertise considers to be the most suitable regarding the various dimensions of the questions raised. Indeed, due to the Sri Lankan context, it was necessary to adopt a global approach allowing to identify the largest amount of information for each intercrop. The main objective was to compare the different intercrops and thus determine the most performant ones from an agronomic and socio-economic point of view.

The study is divided into two steps. The first step is a **literature search** to identify and characterise all crops that can be associated with rubber in the districts of Ampara and Moneragala. The second step is a **field survey.** It consists in an assessment of existing intercrops in the study areas, an evaluation of the position of producers regarding these intercrops through adoption criteria. Finally, an evaluation of the markets linked to intercrops will be undertaken. The results of the two steps will be combined to determine performant intercropping models and to define the definitive study areas for the continuation of the RIVER project.

Reading the annexes is essential for a good understanding of the methodology!

2.1. Step 1: Agronomic literature search on intercrops

YAPI Expertise drafted, before the initially scheduled field mission, a first deliverable corresponding to a literature review for Ksapa called *"Literature review of intercropping with rubber trees"*. It concerned intercrops that could be planted in rubber plots in the districts of Moneragala and Ampara, Sri Lanka. A comparative table of these intercrops was constructed, using previously defined agronomic selection criteria. This comparative table enabled to classify the crops according to their compatibility with the rubber tree. The ten most compatible crops were selected, and technical sheets were written for each of them. The technical sheets outlined the needs of the crop, their cultivation practices, and the market position of the products in Sri Lanka.

As mentioned above, the field mission turned into a desk study leading YAPI Expertise to deepen *"Literature review of intercropping with rubber trees"* and expand its literature search. The overall objective is to obtain a precise list of crops adapted to the pedo-climatic context of Moneragala and Ampara and that can be associated with rubber trees.

According to Rodrigo V.H.L. in 2004, rubber trees can be arranged in several ways on the plot depending on the type of cropping system, but the main special arrangements are:

- Simple spacing, i.e., a single row of rubber trees with an inter-row distance of 8,1 m (Annex 6: Simple spacing scheme)
- Double spacing, which consists of planting rubber trees in double rows with a space of 14,1 m between each double row (Annex 7: Double spacing scheme).

According to the literature review, double spacing would allow the inclusion of more intercropping. As stated by LOAM, single spacing is more frequent in Sri Lanka. In order to propose a model that is as faithful as possible to the realities of the ground, YAPI Expertise decided to base its study only on single spacing.

Table 1 below summarises the stages of the agronomic literature search's methodology:

1. Identification of possible intercrops with rubber	2. Creation of the list of crops	3. Definition of selection criteria
(Langenberger et al., 2016)	*Only crops present in Sri Lanka* *Some crops are both in the immature and mature phase*	*Some crops are both in the immature and mature phase*
Total: 80 crops	In immature phase of rubber tree: 38 crops	Three categories
	In mature phase of rubber tree: 39 crops **Total: 70 crops**	Climate: 7 criteria Soil: 4 criteria Crop: 4 criteria **Total: 15 criteria**
4. Prioritisation of selection criteria	**5. Preselection of potential intercrops**	**6. Final selection of potential intercrops**
	Only based on the criteria with a degree of impact of 4 (9) *Only one table*	*Based on all criteria (15)* *Two tables: one for the immature phase and one for the mature phase*
Four degrees of impact The lowest: 1 The highest: 4 Number criteria with degrees of impact 1: 1 Number criteria with degrees of impact 2: 3 Number criteria with degrees of impact 3: 2 Number criteria with degrees of impact 4: 9	In immature phase of rubber tree Suppressed crops: 4 Retained crops: 35 In mature phase of rubber tree Supressed crops: 2 Retained crops: 37 **Total retained crops: 65**	In immature phase of rubber tree Studied crops: 35 In mature phase of rubber tree Studied crops: 37
7. Final ranking		
Two tables: one for the immature phase and one for the mature phase		
In immature phase of rubber tree Number of crops with a mark between 30 and 40: 17 Number of crops with a mark between 41 and 49: 18 In mature phase of rubber tree Number of crops with a mark between 30 and 40: 18 Number of crops with a mark between 41 and 49: 19		
Maximum score which can be achieved: 49		

Table 1: Stage of agronomic literature search's methodology

2.1.1. List of potential intercrops

This study began by completing the initial list of intercrops that have been made for the first deliverable. The list is mostly based on the one presented in the article "Rubber intercropping: a viable concept for the 21st century?" (Langenberger G. *et al.*, 2016). Thus, 80 crops have been identified. Only crops that are present in Sri Lanka have been retained, i.e., 70 crops. The following data are given for each crop in the list (Annex 8: List of potential intercrops):

- Life cycle duration (annual, multiannual or perennial)
- Phase of the rubber tree in which the crop can be planted (mature and/or immature). It is based on the production period of the intercrop and its tolerance to shading
- Type of crop (fruit tree, medicinal plants, etc.)

Table 2 below shows *Alpinia oxiphylla*, *Ammonum villosum*, *Anacardium occidentale L.* and *Ananas comosus (L.)* as an example.

	Initial list of crops						
Crops name	Common name	Annual plants	Multiannual plants	Perennials	Intercrops production during the immature phase	Intercrops production during the mature phase	Type
Alpinia oxiphylla	Black cardamom	x			x		Other
Ammonum villosum	Medicinal cardamom	x			x	x	Medicine
Anacardium occidentale L.	Cashew nut			x		x	Fruit tree
Ananas comosus (L.)	Pineapple		x		x		Fruit plant

Table 2: Example of the initial list of crops

The intercrops have been sorted in a second table according to the development phase of the rubber tree (Annex 9: Initial list of potential intercrops according to the development phase of the rubber tree).

2.1.2. Definition of the selection criteria for the potential intercrops

To reduce the list obtained, selection criteria were determined and defined on the basis of bibliographic research, which revealed the main variables that can have an impact on the establishment of intercrops in a rubber tree plot. These criteria have been approved by experts in agronomy. They are divided into 3 categories: climate, soil and crop (Annex 10: Definition of selection criteria).

The “climate” category compares the needs and resistance of each crop studied with the climatic conditions (rainfall, temperature, etc.) of the study areas.

In the "soil" category, the criteria are based on the types of soil present in the two study areas (Reddish brown earth soil and Red yellow podzolic soil in Moneragala, Vertisol in Ampara), the favourable soil to rubber cultivation (Feralitic soil) as well as on the potential biomass contribution of the intercrops to the soil. These criteria enable to evaluate the good development of the intercrop in the study areas’ soil conditions.

Finally, the criteria of the "crop" category are mainly based on the exchanges between the intercrop and the rubber tree. Indeed, the criteria of this category are the following: the water competition between the intercrop and the rubber tree, the light competition of the rubber tree on the intercrop and the required spacing between the intercrop and the rubber tree. These criteria enable the selection of crops that have the least risk of competing with the rubber tree.

A colour scale has been used to determine whether the needs of the crop are compatible with the criteria:

- Green: compatible;
- Orange: moderately compatible;
- Red: not compatible.

For each colour on this scale, specific values are given according to the criterion. To illustrate, the table 3 below shows the criteria "Temperature":

CLIMATE	**Temperature**	This criterion is based on the temperatures of the study areas: Moneragala and Ampara. . It evaluates the suitability of the needs of the crop with these temperatures. GREEN: 15-30° C ORANGE: 12-15° C RED: <12° or >31° C

Table 3: Example of the definition and colour scale of the "Temperature" criterion

2.1.3. Selection criteria prioritisation

Not all criteria have the same impact on the selection of the crop. Thus, **degrees of impact** have been established from 1 to 4: **1 being the lowest** and **4 being the highest level**.

For example, temperature is an essential criterion. Indeed, if the crop does not tolerate the temperatures of the study areas, it cannot be planted and therefore cannot be part of the final selection. On the other hand, the criterion "biomass to be returned to the soil" is not prohibitive. If the crop does not contribute organic matter to the soil, this does not prevent it from being planted and therefore selected. This criterion therefore has a lower impact level (1) than the "temperature" criterion (4). The degrees of impact were assigned to the criteria with the help of Eric Penot.

The aim is to assign a mark to each crop in order to be able to rank them. To do this, a **numerical scoring system** was set up. However, it was necessary to take into account the degree of impact of each criterion as well as the colour scale. In fact, each colour cannot have the same mark. Thus, for each degree of impact, numerical values were attributed according to the colour.

Considering the example of temperature, which has a degree of impact of 4. If the needs of the studied crop are compatible with the temperatures of the study areas (green: 15°C-30°C), then the maximum mark will be given to the studied crop, i.e., **4/4**. However, if the needs of the studied crop are moderately compatible with the temperatures of the study areas (orange: 12°C-15°C), the studied crop will be given a score of **2/4**. Finally, if the crop is not compatible with the criterion (red: <12°C or >31°C), then, it will have a mark of **0/4**.

Degree of impact of the selection criteria		
Degree of impact	**Index**	**Definition**
Very important	**4**	The criterion is of high importance. If it is not respected, the crop will not be included in the study. **GREEN: 4/4** **ORANGE: 2/4** **RED: 0/4**
Important	**3**	The criterion has an important impact on crop selection. **GREEN: 3/3** **ORANGE: 1,5/3** **RED: 0/3**
Moderate	**2**	The criterion has a moderate impact on crop selection. **GREEN: 2/2** **ORANGE: 1/2** **RED: 0/2**
Weak	**1**	This criterion has a weak impact on crop selection. This criterion corresponds to a "bonus" in the analysis of crops. **GREEN: 1/1** **ORANGE: 0,5/1** **RED: 0/1**

Table 4: Degree of impact pf the selection criteria

2.1.4. Pre-selection of potential intercrops

A preselection was carried out on the basis of **the most important criteria, i.e., having a degree of impact of 4**. In the table, crops are sorted according to the phase of the rubber tree's development during which they produce.

Only the **colour scale** presented in *Part 2.1.2* was used to select the crops. At the end of this first selection, 5 crops were removed from the list, leaving 65 crops to be studied (Annex 11: Preselection of potential intercrops). Thus, the immature phase of the rubber tree includes 35 crops whereas the mature phase includes 37. Some crops are listed in both phases (Annex 12: New list of potential intercrops from the preselection).

2.1.5. Final selection of potential intercrops

As the pre-selection was not sufficient to reduce the number of crops on the list, a second and final selection was undertaken. This last selection was **based on all the criteria**, unlike the pre-selection, which was based only on the criteria having a degree of impact of 4. Two tables were constructed from this last selection: one table for crops compatible with the immature phase of the rubber tree and another for the mature phase of the rubber tree (Annex 13: Final selection of potential

intercrops for the immature phase of rubber tree and Annex 14: Final selection of potential intercrops for the mature phase of rubber tree).

Finally, from these two tables, the **colour scale** and the **numerical scoring system**, a final score could be assigned for each crop. **Two ranking tables** were constructed: one for the immature phase and one for the mature phase (3.*1. Results of agronomic literature search on intercrops, page 25.*).

2.2. Step 2: Field survey

The second step of the methodology is a socio-economic approach of intercropping with rubber farming systems in Sri Lanka. It relies on the publication about the evaluation of the overall performance of a farm (Zahm *et al.*, 2013) to determine agronomic, economic and adoption criteria. The objective of the field survey was to collect data regarding two categories of criteria: **performance criteria** and **adoption criteria for intercropping.**

2.2.1. Performance criteria

The notion of "performance" is to be considered as it has been defined in *1.5. Definition of the key concepts and problematic* (page 12). This word covers 3 main categories:

- Economic performance;
- Social performance;
- Agronomic performance (Zahm F. *et al.*, 2013).

Most of the criteria defined refer to the scale of analysis of the cropping system, as the objective is to study the performance of intercrops models. However, as the performance of a model corresponds to its capacity to respond to the constraints of the context (both agronomic and socio-economic) and to satisfy the needs of the farmers who implement it, some criteria extend the analysis to the scale of the production system.

The "agronomic" category is assessed by the first step of the methodology. The following tables present all the “social” and “economic” performances criteria:

Criteria	Unity	Definition
Rubber yield (RubbTYield)	Kg/year	The intercropping model studied should not have a negative impact on natural rubber yields. In fact, the training program (SUTTI) in which these results will be used has the overall objective of improving cultivation techniques and the resilience of producers.
Ecological performance (EcoLperf)	Kg	One of the objective of intercropping systems is to limit the addition of phytosanitary inputs within the system, notably through the various ecosystem services (EcoSySryc). In addition to the ecological aspect, the reduction of inputs is economically beneficial to smallholders, especially in Sri Lanka where the quality of inputs is often poor (Uva Provinces Statistics,2016). Models where phytosanitary inputs have disappeared are therefore more performant.
Ecosystemic services (EcoSySrvc)		One of the most interesting aspects of setting up an intercropping plot is the ecosystem services the different species within the system can provide to each other (CIRAD, 2020). A performant intercropping system is therefore logically one in which each species maximises the benefits of the ecosystem services provided by the various crops. It is therefore important to quantify this criteria thanks to an index to see if these services are present and well exploited.

Table 5: Social performance criteria

Criteria	Unity	Definition
Income from intercropping (IncoInterCrop)	LKR	Economic branch of the performance definition is outlined in the problematic. The crop association must be a good source of income or food resources. As studied in Thailand by Stroesser L., income from intercrop production can make smallholder rubber farmers more resilient to the volatility of natural rubber prices. Nonetheless, the work mobilised for the intercrops should not have a negative impact on the time allocated to the good management of the rubber plantations (mature and immature).
Production cost of the plot (ProdCost)	LKR	Smallholders, especially in Moneragala district, have limited income (UVA Statistic district, 2022). In fact, production costs should not be multiplied by the introduction of inter-row cultivation. It should allow producers to make a monetary or food profit and ideally to reinvest in their production system.
Initial investment (IniInvst)	LKR	As mentioned above (ProdCost), smallholders in the Moneragala district have a very low monthly income. Therefore, the initial investment in establishing a large intercrop is a major constraint to its establishment. Furthermore, it is also important to consider the production cycle factors and the profit per production cycle in order to be able to estimate the duration of the crop's ability to recover its initial investment.

Table 6: Economic performance criteria

It should be noted that each criterion was corrected and adjusted in collaboration with the Sri Lankan partners and CIRAD.

2.2.2. Adoption criteria

The intercropping models that will be designed following the analysis of the results of this report can be considered as real agricultural innovations for farmers. An agricultural innovation is defined as a new idea, practice or technique that can sustainably increase agricultural productivity and income. Any innovation proposed to a population must be adopted by it. Adoption is defined as the decision to apply the innovation and to continue using it (Kam O., 2013).

The following table presents the adoption criteria:

Criteria	Unity	Definition
Labour required (InterCropLab)	Day/month Or Hour/day Or Unity of Human work	The availability of labour is one of the potential limiting factors for the implementation of such complex agronomic models. Moreover, as detailed by Rodrigo *et al.* and Herat *P.* in 2020 and 2012 respectively, the increase of the amount of labour force may be one of the major reasons for not implementing these practices. Thus, a crop requiring a high labour input will be considered as less performant.
Geographical access to the market (GeoMrkt)	Km	The 2009 WTO (World Trade Organisation, 2009) report on Sri Lanka highlights the poor condition of the road system as one of the factors limiting its economic development. The low wages of smallholder rubber farmers (Harivarman *et al.*, 2016) may limit investment in a transport system. The geographical criteria of market access are therefore relevant to consider.

Table 7: Adoption criteria

They were reviewed and reworked with the help of Charlotte Simon, Alexis Thoumazeau's PhD student who is focusing her thesis on the factors of adoption by farmers towards a transition to intercrop systems with rubber.

2.2.3. Semi-structured interviews guide with farmers

The interview guides were constructed from the data needed to fulfil the performance and adoption criteria explained above. Also, they were worded in such a way that the exchange with the farmers did not last more than one hour (Annex 15: Interview guides for farmers).

YAPI Expertise conducted a remote training session in mid-May, at the beginning of the survey, with LOAM's team. LOAM sent feedbacks and adjustments to YAPI Expertise after the first few interviews conducted. It helped to clarify misunderstandings and to prioritise the information requested by the multi-criteria study.

The completed interview guides were scanned in English as the surveys were completed. This allowed YAPI Expertise to keep an eye on the progress of the field phase and to answer questions to the Sri Lankan interviewers.

2.2.3.1. Sampling

Sampling was based on LOAM's deployment capacity. YAPI Expertise' team requested that three groups of interviewers could interview 2 to 3 producers per day for 10 days. On this basis, the sample was estimated to be around 70 rubber farmers randomly distributed between Ampara and Moneragala, although this was based on the availability of petrol and LOAM's organisation in the field. In total, **80 interviews** were carried out, including **61 in Moneragala** and **19 in Ampara**.

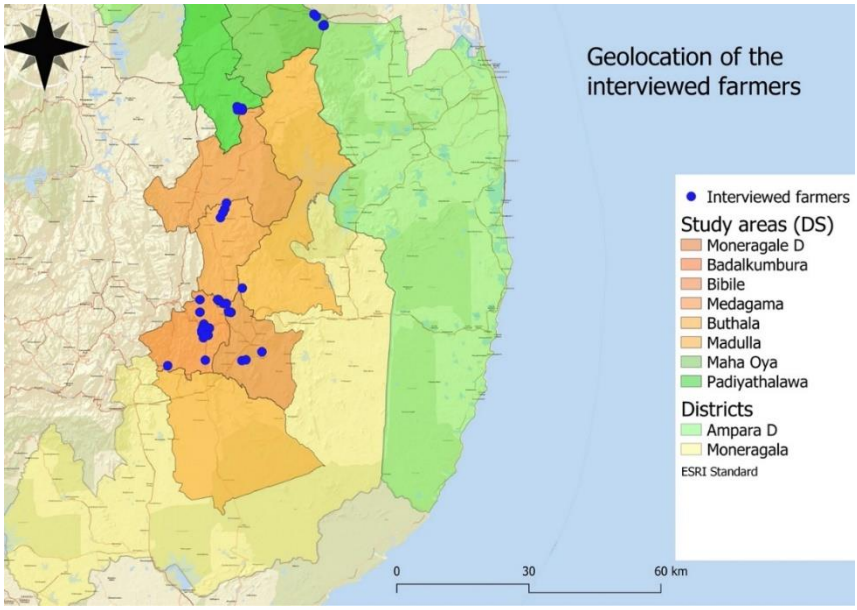


Figure 2: Geolocation of the interviewed farmers

2.2.3.2. Methodology of the interviews' analysis

The answers obtained from the interviews are quantitative or qualitative variables. They are associated with performance, socio-agronomic or economic criteria or with adoption criteria presented in *2.2.3. Semi-structured interviews guide with farmers*. The variables and their modalities are presented and organized into categories in *Table 8*. The **Multiple Correspondence Analysis** (MCA) method is chosen by YAPI Expertise because it allows the analysis of the association between several qualitative variables.

It should be noted that the answers related to economic performance were obtained through precise and closed questions. Whereas those related to socio-agronomic performance or adoption criteria were asked through open questions. The variables of these criteria, presented in the tables on pages 22 and 23, have therefore been defined according to the responses obtained. They also complement the performance criteria (*Tables 8, 9 and 10*). For the implementation of the MCA, all modalities, even quantitative, were discretised. Variables were also selected according to their relevance or according to the quality of the results obtained. Indeed, some questions were almost never answered or could not be used. For instance, a few intercrops were only grown by a very small number of farmers and the variable "Use of intercrop" did not obtain a good quality of responses.

To do this, a **range of values** was defined using **Box Plots** (quartile, median):

- "Low" corresponds to values below the first quartile;
- "Medium" corresponds to values between the first and third quartiles;
- "High" corresponds to values above the third quartile.

Details of the value ranges can be found in Annex 16. The correspondences identified through the graphical projection of the ACM results were highlighted through a clustering performed using a **Hierarchical Clustering on Principal Components** (HCPC). Finally, **Chi²** tests were conducted to significantly associate each response to the variables with an intercrop or group of intercrops. For economic performance, the interdependence between all the variables was verified through this test. All statistical tests were carried out using **R software** and the scripts used are listed in Annex 16 (R script).

Economic Performance		
Variable category	**Qualitative variable**	**Modalities**
Crop	Cocoa	COCOA ; NO.COCOA ; NG[1]
	Banana	BANANA ; NO.BANANA ; NG
	Pineapple	PINEAPPLE ; NO.PINEAPPLE ; NG
	Corn	CORN ; NO.CORN ; NG
	Cowpea	COWPEA ; NO.COWPEA ; NG
	Mungbean	MUNGBEAN ; NO.MUNGBEAN ; NG
	Pepper	PEPPER ; NO.PEPPER ; NG
	Sugarcane	SUGARCANE ; NO.SUGARCANE ; NG
Crop Yield	Yield of each intercrop	high ; medium ; low ; NG
Seed Cost	Seed cost of each intercrop	high ; medium ; low ; NG
Initial Investment	Initial investment of each intercrop	high ; medium ; low ; NG
Rubber Yield	Rubber yield	high ; medium ; low ; NG
Cost Input[2]	Cost input	high ; medium ; low ; NG
People Household	People household	high ; medium ; low ; NG
Extra People[3]	Extra people	high ; medium ; low ; NG
Salary	Salary	high ; medium ; low ; NG
Use of intercrop	Use of intercrop	AUTOCONSUMPTION ; SELL ; NG

Table 8: Economic performance variables

Socio-agronomic Performance		
Variable category	**Qualitative variable**	**Modalities**
Major Issues	Pest attack	PEST.ATTACK ; NO.PEST.ATTACK ; NG
	Lack of water	LACK.OF.WATER ; NO.LACK.WATER ; NG
	Lack of input	LACK.OF.WATER ; NO.LACK.WATER ; NG
	Wild animal attack	WILD.ANIMAL.ATTACK ; NO.WILD.ANIMAL.ATTACK ; NG
	Lack of labour	LACK.OF.LABOUR ; NO.LACK.OF.LABOUR ; NG
	Erosion	EROSION ; NO.EROSION ; NG
	Marketing problems	MARKETING.PROBLEMS ; NO.MARKETING.PROBLEM ; NG

[1] NG: when the data is not given
[2] Cost Input: Sum of fertiliser, herbicide and pesticide costs
[3] Extra People: Labour force employed by the household

	High cost of irrigation	HIGH.COST.IRRIGATION ; NO.HIGH.COST.IRRIGATION ; NG
	Drought	DROUGHT ; NO.DROUGHT ; NG
	Fuel crisis	FUEL.CRISIS ; NO.FUEL.CRISIS ; NG
	Expensive input	EXPENSIVE.INPUT ; NO.EXPENSIVE.INPUT ; NG
	High labour cost	HIGH.LABOUR.COST ; NO.HIGH.LABOUR.COST ; NG
	Lack of harvest	LACK.HARVEST ; NO.LACK.HARVEST ; NG
	Transportation problems	TRANSPORTATION.PROBLEMS ; NO.TRANSPORTATION.PROBLEMS ; NG
	Poor soil condition	POOR.SOIL.CONDITION ; NO.POOR.CONDITION ; NG
	Lack of technical knowledge	LACK OF TECHNICAL KNOWLEDGE ; NO.LACK OF TECHNICAL KNOWLEDGE ; NG
	Processing issues	PROCESSING.ISSUES ; NO.PROCESSING.ISSUES ; NG

Table 9: Socio-agronomic performance variables

Adoption criteria		
Variable category	**Qualitative variable**	**Modalities**
Reasons[4]	Moisture	MOISTURE.CONSERVATION ; NO.MOISTURE.CONSERVATION
	Soil erosion	SOIL.EROSION ; NO.SOIL.EROSION
	Extra income	EXTRA.INCOME ; NO.EXTRA.INCOME
	Society	SOCIETY.CHOICE ; NO.SOCIETY.CHOICE
	Less maintenance cost for rubber	LESS.MAINTENANCE.COST.FOR.RUBBER ; NO.LESS.MAINTENANCE.COST.FOR.RUBBER
	Availability of planting material	AVAILABILITY.OF.PLANTING.MATERIAL ; NO.AVAILABILITY.OF.PLANTING.MATERIAL
	Land preparation	LAND.PREPARATION ; NO. LAND.PREPARATION
	Adapted to climate	ADAPTED.TO.CLIMATE ; NO.ADAPTED TO.CLIMATE
	Easy maintenance	EASY.MAINTENANCE ; NO. EASY.MAINTENANCE
	Support rubber growth	SUPPORT.RUBBER.GROWTH ; NO. SUPPORT.RUBBER.GROWTH
	Use available space[5]	USE.AVAILABLE.SPACE ; NO. USE.AVAILABLE.SPACE
	Soil nutrition	SOIL.NUTRITION ; NO. SOIL.NUTRITION
	Shade	SHADE ; NO.SHADE

[4] Reasons: Reasons why the farmers chose the grow the intercrop
[5] Use available space: The farmer wanted to use the space left in the rubber plot

Table 10: Adoption variables

2.2.4. Focus groups

The focus groups are intended to compare the data collected from smallholders with agricultural representatives and agronomic experts. It also seemed interesting to YAPI Expertise to obtain a global overview of the political, social, and economic organisation of the agricultural communities around rubber and its main intercrop. The focus groups would also enable the filling in of the grid for determining the study areas, as requested by Ksapa.

An open-ended interview guide was drafted for LOAM's interviewers, along with a facilitation note available in Annexes 17 (focus group guides) and 18 (Focus Group Organisation). The focus groups were set up in such a way that experts from research, the field and the economic environment met to discuss rubber cultivation in intercropping systems. The main idea was to discuss a specific crop to be associated with rubber. Based on LOAM's capacity, it was agreed to organise **3 focus group sessions** over 2 days. Also, fearing that not everyone would have enough time to speak, YAPI Expertise suggested to build groups of 5 to 6 people maximum.

LOAM sent YAPI Expertise the interview guides with comments attached. It allowed YAPI Expertise to get an overall idea of the preconceptions and motivation of each party in the implementation of intercrop systems in rubber cultivation.

2.2.4.1 Key persons

The three focus groups are composed of several key persons which are all linked with rubber cultivation but with different objective and divergent visions. The focus groups have reunited respectively, 8, 9 and 11 people in the DS of Moneragala, Badalkumbura and Bibila. The composition of the different focus groups is relatively similar.

There are always one or two **farmers**, who are the first to be impacted by the establishment of intercropping plots. Next, there is a **farmer inspector** and a **representative of the society** (Thurusaviya). These two actors have an overall vision of the rubber industry in the region and are aware of the main issues the rubber farmers face. The presence of the **District Director of Agriculture** provides a government perspective on rubber cultivation in the region.

Entities linked to research, such as the **Rubber Research Institute** and the **Rubber Development Department**, were present only in the first focus group in Moneragala. The presence of these actors provides a scientific opinion on the development of intercrops among smallholders.

All the remaining stakeholders in the different focus groups are linked to the economic segment of the project. **Camso Loadstar**'s presence in all the focus groups is essential. Indeed, as the main actor of the project and the main buyer of rubber from the smallholders, their point of view is important.

The main **buyers of intercrop products** are also represented, and finally the **Export Agriculture Department**, which is linked to the marketing of cash crop products (cocoa, cinnamon, etc.). Both will provide an opinion on the economic aspect of the establishment of a particular crop and the economic issues that may be linked to it.

3. PART 3: RESULTS AND INTERPRETATION

3.1. Results of agronomic literature search on intercrops

The literature review of the selected crops led to the creation of a rating of the mature and immature phase of rubber tree, through the scoring system. The maximum score that can be assigned to the crops is 49. As shown in the tables bellow, the selected crops were classified according to the methodology presented previously. The gradient is represented by colours from green (the best) to red (the worst). The higher score corresponds to the crops which fits the most with the soil and climate conditions of the study areas and can be planted with rubber tree. Conversely, a low score is represented by a red colour and indicates that the crop does not correspond to the soil and climate conditions of the study areas and is not recommended as an intercrop with rubber (*Table 11 and 12*).

Table 11: Results of the intercrops compatible with the immature phase

Immature phase: results	
Crops	Mark
Centrosema pubescens - butterfly pea	47
Arachis pintoï	46
Mucuna bracteata	45
Mucuna cochinchinensis	45
Manihot esculenta - cassava (culture < 12 months)	44,5
Flemingia macrophylla	43
Pueraria phaseoloides - tropical kudzu	43
Noicotiana spp. - tobacco	42,5
Alpinia oxiphylla - black cardamom	42
Arachis hypogaea L. - groundnut	42
Cajanus cajan (L.) - pigeon pea	42
Ananas comosus (L.) - pineapple	42
Ammonum villosum - medicinal cardamom	42
Capsicum annuum L. - chili pepper	41,5
Cymbopogon citratus (DC.) - lemon grass	41,5
Calopogonium caeruleum	41
Stylosanthes guianensis - common stylo	41
Citrullus colocynthis - bitter cucumber	40,5
Sorghum bicolor (L.) - sorghum	40,5
Musa acuminata - banana	40
Crotalaria spp. - rattlepods	40
Glycine max (L.) - soybean	40
Morinda officinalis - morinda	40
Theobroma cacao L. - cocoa	40
Ipomoea batatas L. - sweet potato	39,5
Psophocarpus tetragonolobus (L.)	39,5
Luffa acutangulas - angled Loofah	39,5
Vigna radiata (L.) - mung bean	39
Pogostemon cablin (Blanco) - patchouly	39
Curcuma domestica - turmeric	37,5
Coffea canephora - coffea robusta	37,5
Citrullus lanatus - watermelon	34
Saccharum officinarum L. - sugar cane	33
Oryza sativa L. - upland rice	32

Mature phase: results	
Crops	Mark
Azadirachta indica - neem	49
Centrosema pubescens - butterfly pea	47
Pterocarpus sp. - padouk, narra	47
Arachis pintoï	46
Aquilaria sp. - eaglewood	45
Fagraea fragrans - iron wood	45
Cocos nucifera - coconut	44,5
Gmelina arborea - gmelina	43
Pueraria phaseoloides - tropical kudzu	43
Ammonum villosum - medicinal cardamom	42
Nephelium lappaceum L. - rambutan	42
Piper nigrum L. - pepper	41,5
Mangifera indica L. - mango	41,5
Tectona grandis L. - teak	41,5
Calopogonium caeruleum	41
Parkia speciosa - stink bean	41
Stylosanthes guianensis - common stylo	41
Paraserianthes falcataria (L.) - white albizia	41
Passiflora edulis Silms - passion fruit	41
Artocarpus altilis - breadfruit	40,5
Cinamomum verum - cinnamon	40,5
Shorea macrophylla - light red meranti	40,5
Garcinia mangostana L. - mangosteen	40
Morinda officinalis - morinda	40
Annona reticulata L. - custard-apple	39,5
Artocarpus heterophyllus - jackfruit	39
Salacca zalacca - snake fruit	39
Vanilla fragrans - vanilla	38,5
Anacardium occidentale L. - cashew nut	38
Areca catechu - betel nut tree	37,5
Citrus x paradisi - Grapefruit	37
Citrus reticulata - tangerine	37
Citrus x sinensis - orange	37
Durio zibethinus - durian	36
Carica papaya L. - papaya	35
Citrus aurantiifolia - lime	35
Macadamia sp. - macadamia nut	35

Table 12 : Results of the intercrops compatible with the mature phase

3.2. Results of the field survey

3.2.1. Results of the semi-structured interviews guide with farmers

3.2.1.1. Distribution of intercrops in the study areas

Figure 3 highlights the difference in intercrops cultivated between the two study areas. Intercrops in Ampara are more diversified than in Moneragala. The most common intercrops grown in Ampara are cover and food crops with cowpea (21,2%), mungbean (13,5%) and corn (13,5%) while in Moneragala there is a large majority of cash crops with cocoa (42,6%), banana (21,3%) and pepper (16,7%).

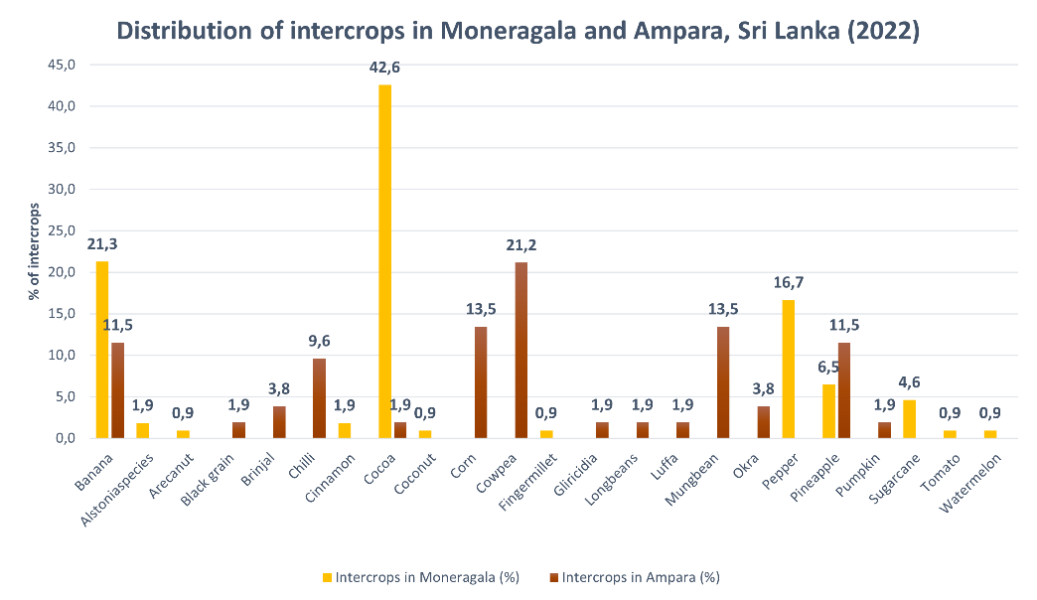


Figure 3: Distribution of rubber tree intercrops in Moneragala and Ampara

3.2.1.2. MCA and dendrogram

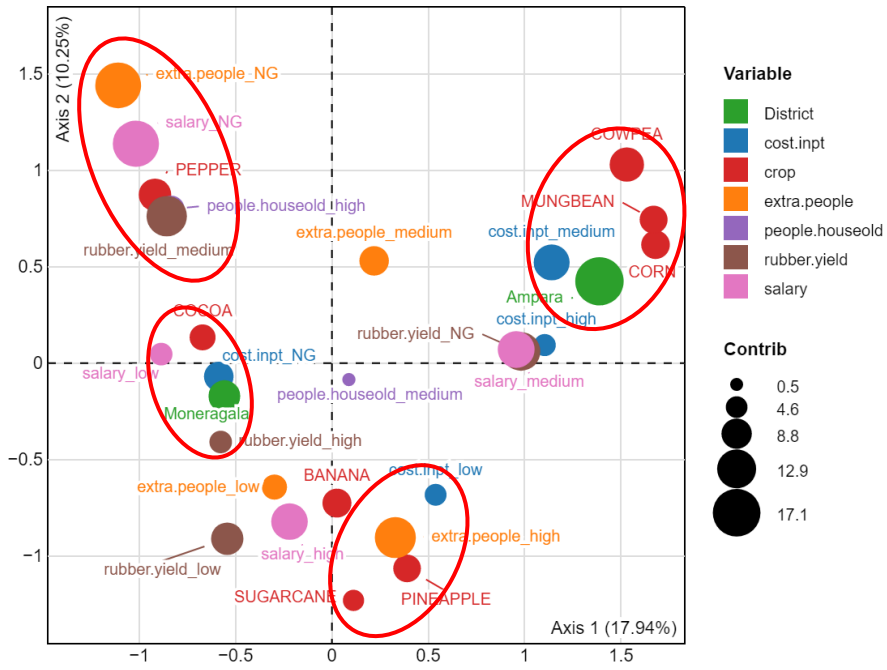


Figure 4: MCA of economic performance data

The projection of the points on the two factorial axes shows that some modalities are gathered, and form clusters highlighted by the red circles. Note that the modalities followed by the letter NG correspond to answers not given by the surveyed for this variable. The size of the dots depends on their contribution to the factorial axis. The hierarchy presented in *Figure 5* just below highlights these clusters more clearly and precisely.

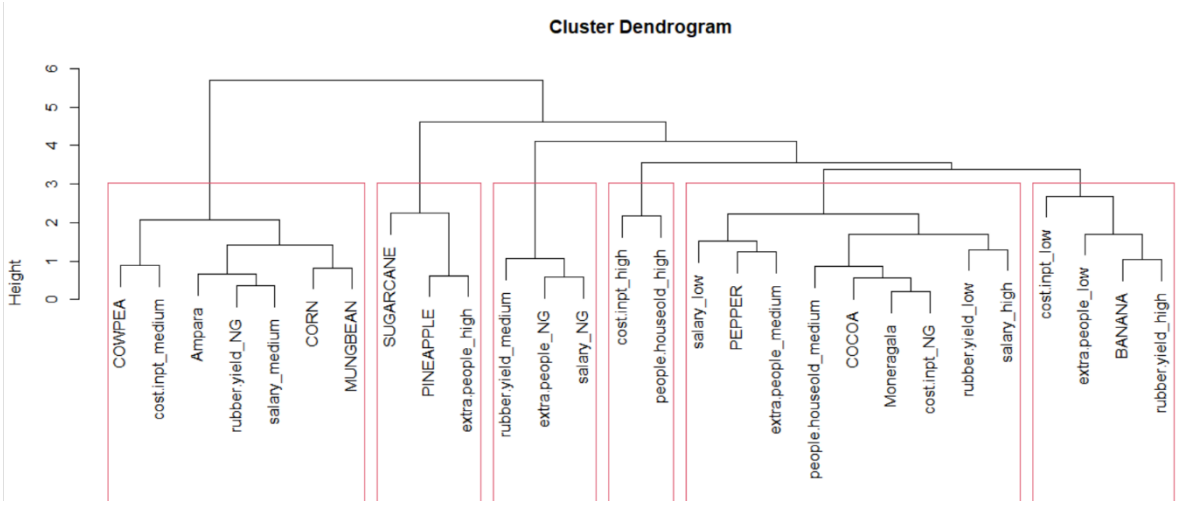


Figure 5: Cluster dendrogram of economic performance data

These results associate the establishment of intercrops with specific economic characteristics. Thus:

- Sugar cane and pineapple require much more field work than other crops;
- Pepper requires moderately more field work than other crops;
- Banana increases the rubber yield and lowers input costs.

Graphs of the analysis of the main issues faced by producers are available in Annex 19 (MCA representation and Dendogram of major issues data). They associate the issues with intercrops. However, some variables and modalities are not clearly linked to certain crops, this is the case of lack of labour and low harvest. Thus:

- Cocoa is highly related to wild animal attacks (giant squirrel and monkey);
- Banana and pepper imply high workforce costs and they resist very badly to drought periods;
- Pepper cultivation is strongly linked to pest attacks;
- There is a global market issue for each intercrop.

The projection of the MCA (Annex 19: MCA representation and Dendogram of major issues data) for the adoption criteria forms very few clusters. It should be noted that the modality "other" refers to intercrops that were identified very few times and are therefore not significant to analyse. On the other hand, the clusters are more visible on the dendrogram (Annex 20: MCA representation and Dendogram of reasons data). The results of the dendrogram are as follows:

- Farmers choose sugarcane as an intercrop because it is adapted to the pedo-climatic conditions of the study areas.
- Farmers choose pineapple as an intercrop because it would help to prevent soil erosion and would also reduce the cost of the rubber plot's maintenance.
- Cowpea, mungbean and corn provide soil nutrition and support rubber tree's growth. It is the main reasons why farmers use them as intercrops.

Finally, the histogram in (Annex 21: Histogram of the society choice data (Chi²)) highlights that societies encourage producers to grow cash crops. Histogram in (Annex 22: Histogram of the extra income data (Chi²)) shows that the main reasons why farmers decided to add intercrops to their rubber plots was to bring in extra income.

3.2.1.3. Chi²

In order to further analyse the links between the variables, Chi² tests have been carried out. The null hypothesis of this test is "there is no interdependence between the variables". Only Chi² test with a p-value lower than 0.05 are interdependent. The p-values of the performance variables, the main issues variables and the adoption variables have been reported in *Tables 13, 14 and 15*. Below are the p-values of the variables related to economic performance, the main issues encountered by farmers and the reasons for adopting intercrops. P-values below 0.05, i.e., the variables are interdependent, are in green.

	Pest attack	Lack of water	Lack of input	Wild animal attack	Lack of labour marketing	Drought	Fuel crisis	High labour cost	Lack of harvest
Crop	0.04993	0.5604	0.03587	0.02741	0.1415	0.4578	0.03018	0.6523	0.2675

Table 13: p-value of the "major issues"

	District	Rubber yield	Cost input	People household	Extra people	Salary
Crop	8,62E-16	0,2098	0,7923	0.4163	7.25E-06	6.93E-06

Table 14: p-values of the economic performance

	Moisture conservation	Soil erosion	Extra income	Society choice	Less maintenance cost for rubber	Adapted to climate	Easy maintenance	Support rubber growth	Soil nutrition	Shade
Crop	0.000003614	0.6306	0.9706	0.1776	0.09223	0.00000000002119	0.01297	0.0001769	1.923E-07	0.5242

Table 15: p-values of the "adoption"

3.2.1.4. Global interpretation

The statistical results of the interviews with farmers reveal that the main reason why farmers have chosen to grow intercrops in rubber cultivation is to earn extra income. A variety of intercrop choices are available, but societies encourage to grow cash crops such as cocoa, banana and pepper. However, banana, pepper and sugar cane are labour intensive crops and require producers to hire employees. This is a fact which needs to be taken into consideration as there is a relatively high labour deficit in Moneragala and Ampara. On the other hand, cocoa is subject to recurrent attacks by wild animals. However, some crops have a positive impact on the soil, such as cowpea, mungbean and corn, while banana increases the rubber yield. Finally, markets seem to be poorly developed in the study areas, which may justify the lack of interest of farmers in intercropping.

3.2.2. Results of the focus groups

The focus groups' feedback drawn up by LOAM are available in Annex 18 (Focus Group Organisation). There is one for each focus group. The following table summarises the main information:

Subject	Comments

AGRONOMIC PART	
General trends of intercrops	There are many annual plants in the immature phase (mungbean, finger millet, corn, cowpea) and cocoa in the mature phase.
Most wanted intercrops	Cocoa and pineapple: they have positive impacts on the plot environment → Moisture conservation and climate Corns, mungbean, finger millet, cowpea: well-known crops to producers and used for self-consumption → Safe annual crops
Historical of the lands	The rubber lands were previously "Chena"[6] cultivated area where corn, pepper or sugar cane were cultivated, which became less fertile.
Origin of the seeds	Producers buy their seeds from private or government agencies. Prices fluctuate between sellers but remain similar from one area to another.
Rubber yield	Buyers indicate the same latex yields, which are around 3000 L/ha/year and do not differ between areas. However, producers report much higher yields. The yields given in the interviews were also much higher than average, suggesting that producers are exaggerating their yields.
Workforce and salary	It is difficult to analyse the workforce required by crop. Sugar cane cultivation requires a larger workforce. Salaries are the same in all areas.
Major issues faced by producers	Producers face the same issues in all three zones. They are the following: animals attacks, lack of knowledge and technical materials, expensive workforce, problem of producers' behaviour.
ECONOMIC PART	
Intercrop network	Not very common. Especially for cocoa and sugar cane crops.
Certification	Certifications are specific to the zones and to the cocoa crop.
Collection site	Only few existing sites in Moneragala, especially for cocoa and pepper.
Type de contract	Agreements between the producers and the societies
Major downsides of the societies	Weak organisation is reported as well as internal conflicts within societies and with producers. Producers tend to sell their products outside the societies because the societies do not sell them at prices that are attractive to the producers. Societies are therefore very unstable, and producers have little hope for the future of these organisations.

Table 16: Summary of the focus groups

3.2.3. Localisation grid selection

With the help of the field survey, the localisation selection grid requested in the "Terms of Reference" page 9 was filled together with LOAM. Ksapa had initially identified Ampara and Damana (Divisional Secretariat divisions) in Ampara District, however LOAM found it more interesting to study Mahaoya and Padiyathalawa as Camso Loadstar has centres in Moneragala, Badalkubura and Madagama. Moneragala was chosen as the starting point for calculating the distances between the areas. The grid is available in Annex 23: Localisation grid selection fulfilled.

[6] Slash-and-burn

CONCLUSION

The objective of YAPI Expertise's study for Ksapa is to establish intercrop models with rubber trees adapted to the study areas. Based on the literature review and on the field surveys' analysis, YAPI Expertise was able to select a final list of interesting crops for the modeling of rubber systems.

The list of the final selected crops is based on the performance and adoption criteria of the field surveys combined with the results of the bibliographic study. It is as follows:

Types of crop	Crops
Cash crop	*Annona muricata*
	Theobroma cacao
	Ananas comosus
	Passiflora edulis
Cover crop	*Vigna radiata*
	Arachis hypogeae
	Clitoria ternatea
	Mucuna pruriens
Timber crop	*Azadirachta indica*

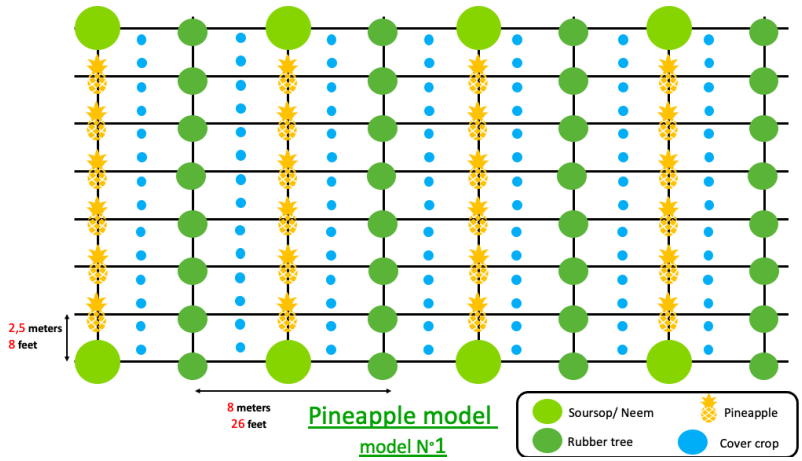
Table 17: Final selection of the intercrops for the models

LOAM and YAPI Expertise made together the final choice of the crops which would be part of the models. Banana, pineapple, cocoa and mungbean are crops that already exist as intercrops in the study areas, as the field survey showed, and they have been selected. However, sugarcane, corn and pepper were not efficient enough. Indeed, sugarcane and corn are very low in the ranking of the literature search. From an agronomic point of view, they need a lot of water to develop, a need that can hinder rubber trees' growth. From a socio-economic point of view, their maintenance costs (chemical inputs, seed costs and workforce) are high, and therefore, less attractive for producers to implement. Regarding pepper, the cultivation calendar does not correspond to the climatic conditions of the study areas because of global warming. The changing of seasons does not allow the flowering of pepper. Cowpea was also not included in the final list because the corn-cowpea association is already widespread and does not correspond to an agronomic innovation in the study areas. On the other hand, groundnut, mucuna sp, butterfly pea and neem are crops not identified in the field surveys. However, LOAM found it interesting to include them in the models because they are already well-established crops in the study areas.

The models are constructed along three axes: spatial, temporal and functional. The temporal axis of the models is represented in the annexes 24 to 28 like GANTT diagrams. The time of cultivation on the plot, the periods of sowing, growth, maintenance and harvesting are explained for each model. The models are built over the ten first year of the rubber tree. Indeed, the mature phase is not compatible with many intercrops systems. Finally, the spatial and functional axes are represented in the diagrams below.

Each model represents different intercrop combinations according to the farmers' cropping patterns. The study also proposes different intercrop's possibility according to the plots' profile. In addition, the following criteria have been assessed for each model: the study area, the soil, the surface of the plot, the workforce, the initial investment and the risk of wild animal attacks.

Model 1: Pineapple Model



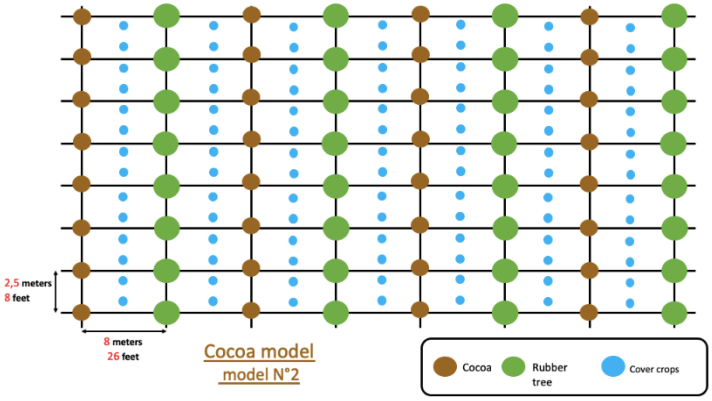
Criteria :

- Place : Moneragala and Ampara
- Field : 1ha +
- Labour force : ***
- Initial cost : ***
- Wild animals : **

Figure 6 : Diagram of Model 1

In this first model, there is a row of pineapples between two rows of rubber trees, that are surrounded by a cover crop. The choice of the cover crop is free, the farmer can choose to put the one that seems the most adapted to his context. Finally, Neem trees frame the plot, as they are quite imposing and take a lot of space. The framing of the plot by these kind of trees limits attacks by fungi. Moreover, they do not require any maintenance work. When the rubber trees have reached the mature phase, the amount of light that filters through the canopy will be too low and the cover crops will disappear by themselves. Pineapple will be also removed because they need a lot of sun to grow. It means that during the mature phase of the rubber tree, the plot will be in monoculture.

Model 2: Cocoa Model



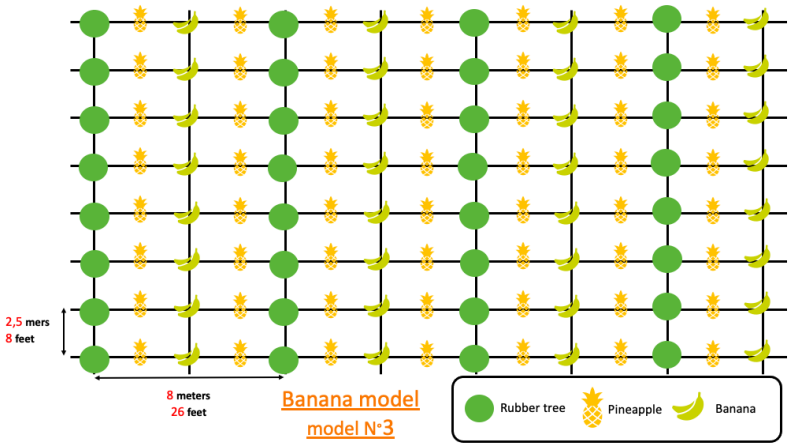
Criteria :

- Place : Moneragala and Ampara
- Field : 0,4 – 1ha
- Labour force : ****

Figure 7 : Diagram of Model 2

The second model is based on cocoa trees placed between rows of rubber trees. There are also cover crops between the rubber trees and the cocoa. They aim to limit weeds and fix nitrogen in the soil. Like the first model, the cover crops will disappear by themselves when the shade provided by the rubber trees is too important. However, the cocoa trees will still be present during the mature phase of the rubber trees, but a decrease in cocoa's yield is likely to be observed.

Model 3: Banana Model



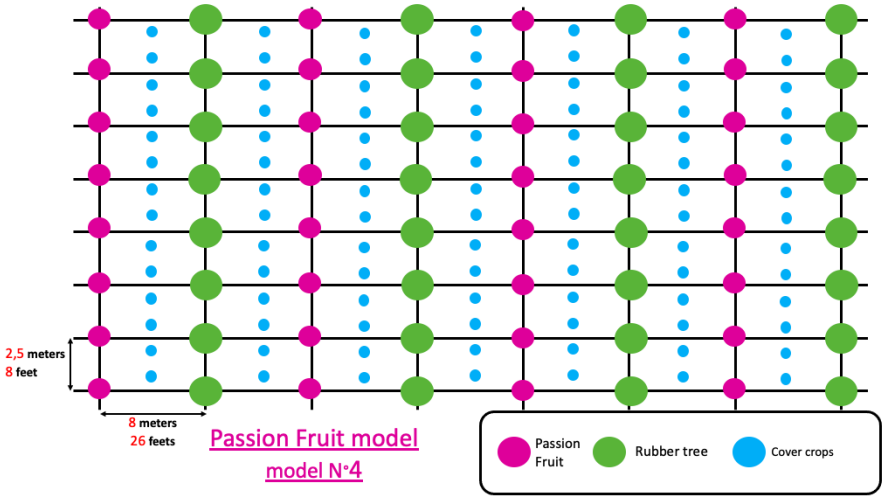
Criteria :

- Place : Moneragala and Ampara
- Field : 0,4 – 1ha
- Labour force : ***
- Initial cost : ***
- Wild animals : **

Figure 8 : Diagram of Model 3

This model has been enthusiastically welcomed by LOAM, particularly because of the combination of rubber and banana. According to Rodrigo, the combination of rubber and banana allows for a better use of resources in the soil. A row of pineapple has also been added between the rubber and banana rows. These intercrops can be grown for the first 6 years of the rubber tree's life. After that the tree canopy will be too important and the amount of light too low to enable the bananas and pineapples to grow. From the 7th year onwards, the field will be a monoculture of rubber trees.

Model 4: Passion Fruit Model



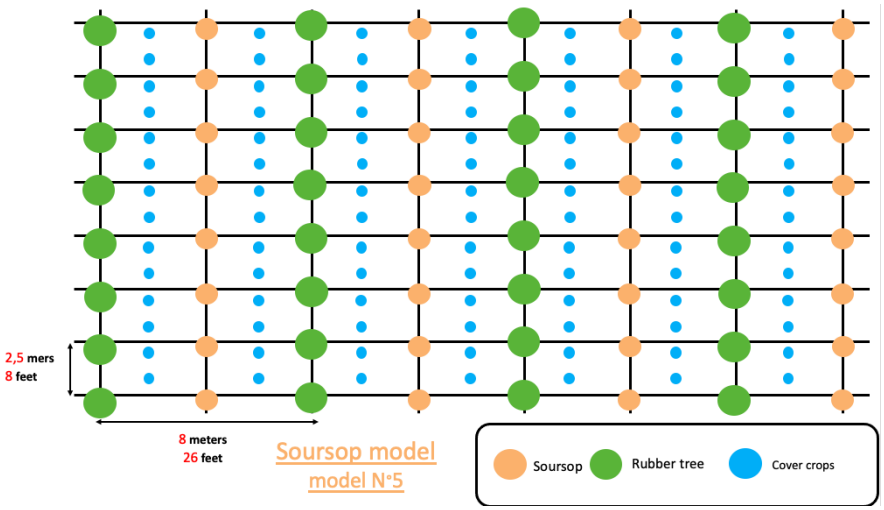
Criteria :

- Place : Ampara
- Field : 0,4 – 1ha

Figure 9 : Diagram of Model 4

This model is highly advised in Ampara and in the driest areas of Moneragala. Indeed, the passion fruit is a liana that needs sun and a dry climate to grow properly and produce fruit. Passion fruit should be planted during the immature period of the rubber tree and then removed during the mature period. A cover crop is planted between the rubber trees and the passion fruits like in the first two models. The cover crop will disappear during the mature phase of the rubber tree, leaving the plot in monoculture.

Model 5: Soursop Model



Criteria :

- Place : Moneragala and Ampara
- Field : 0,4 – 1ha

Figure 10 : Diagram of Model 5

The last model is based on the recommendations of local stakeholders. Soursop is a tree already present in Sri Lanka, in this model it is planted in the immature phase of the rubber tree and remains on the plot throughout the life of the rubber tree. Between the trees' rows, cover crops are planted, which will disappear during the mature phase of the rubber tree.

DISCUSSION AND RECOMMENDATION

YAPI Expertise's study raised many questions and encountered many limits, as it was carried out as a desk study.

Firstly, the literature review on intercropping provided a high amount of data on each crop. These data were obtained from literature that is sometimes several years old, or whose source is difficult to trace. The data has also been verified and sometimes modified by experts who have given it a sense

of reliability. However, these experts are not located in Sri Lanka and had not visited the country for several years. Despite the verification of the data through multiple research and expert statements, the data is not fully representative of the field.

In addition, the data needed to define the criteria for intercrop selection were difficult to find and could not be verified by fieldwork. For example, the different rainfall conditions during the dry and wet seasons of the study area are not accurate. Also, some criteria rely on the cultivation techniques practiced on the field, such as biomass input. To overcome these difficulties, the data were provided to local stakeholders.

The desk study context with a field survey is favorable towards misunderstandings despite easy and regular communication with the mission's local partners. The quality of the survey data may have been affected by the translation from local languages to English.

Furthermore, for certain reasons, some of the data provided during the interviews had outliers and were not taken into account in the analysis.

Finally, the intercropping models were mainly based on agronomic data. The lack of information on social categories (available labour, labour required, etc.) and economic categories (input costs, place of crops on the Sri Lankan market, selling costs of crops, etc.) led to the construction of models based on a questionable database.

Indeed, according to the definitions mentioned in "Definition of the key concepts and problematic" on page 12, a performant model cannot rely only on agronomic analysis. In order to adapt these models to the reality of the country, it will be essential to budget inputs and adapt the choice of crops to the local market (consumer demand, presence of collection and resale centres, etc.) and above all to the farmers' needs.

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Vanilla fragrans – vanilla

DEPARTMENT OF EXPORT AGRICULTURE. 2022. Vanilla.
[2022/06/23]. http://www.dea.gov.lk/vanilla/

MAVANI. 2022. La fécondation naturelle de la vanille.
[2022/06/23]. https://www.mavany.com/accueil/guide-vanille/la-vanille/culture-vanille/pollinisation-vanille/#:~:text=Une%20mati%C3%A8re%20organique%20abondante%20Ses%20valeurs%20de%20pH,plante%20m%C3%BBrit%20et%20produise%20des%20gousses%20de%20vanille.

Vigna radiata (L.) - mung bean

LA FERME DE SAINTE- MARTHRE. Réussir la culture des haricotes mungo.
[2022/06/23]. https://www.fermedesaintemarthe.com/reussir-la-culture-des-haricots-mungo-p-21898

USEFUL TROPICAL PLANTS. 2021. Vigna Radiata.
[2022/06/23]. https://tropical.theferns.info/viewtropical.php?id=Vigna+radiata

Vigna unguiculata – cow pea

USEFUL TROPICAL PLANTS. 2021. Vigna unguiculata.
[2022/06/27]. https://tropical.theferns.info/viewtropical.php?id=Vigna+unguiculata+unguiculata

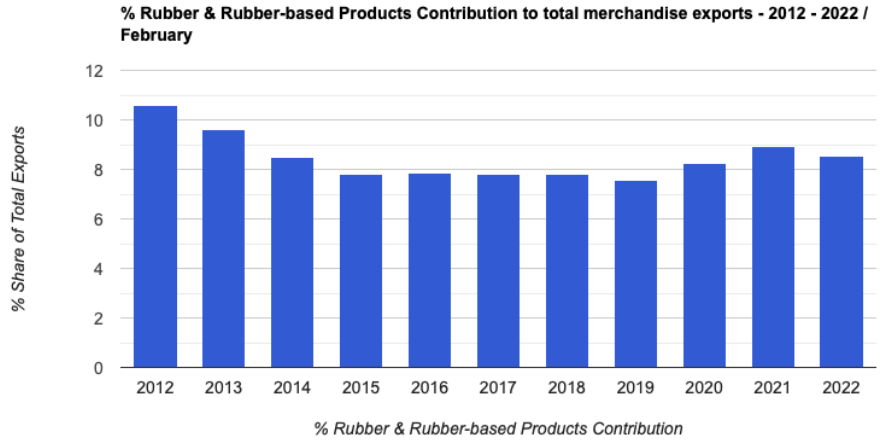
CONTEXT

Annex 1: Diagram of the main partners of the RIVER Project

Annex 1-Diagram of the main partners of the RIVER Project

Source: Ksapa

Annex 2: Contribution of rubber products to Sri Lanka's exports

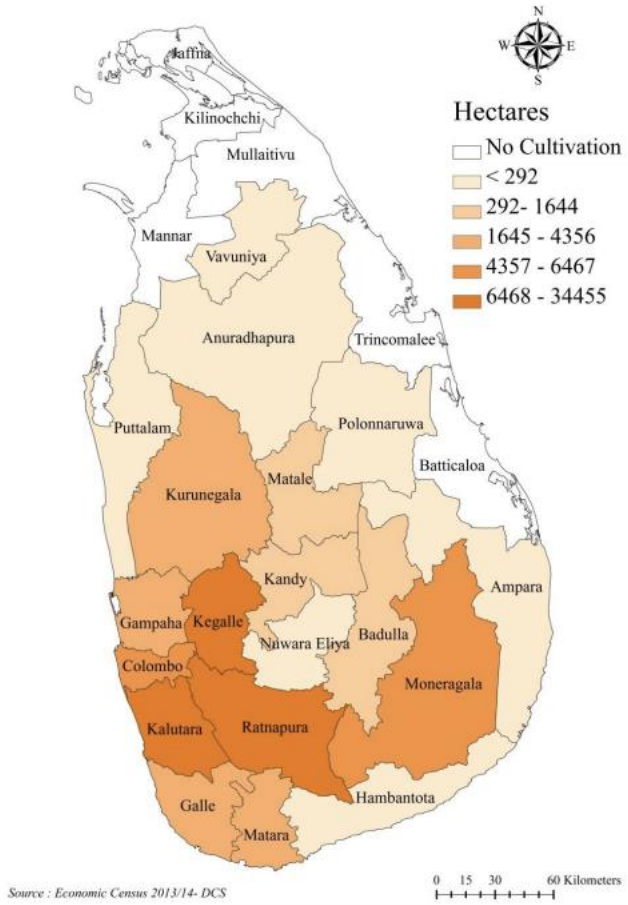


Annex 2-Contribution of rubber products to Sri Lanka's exports

Source: Export development board Sri Lanka

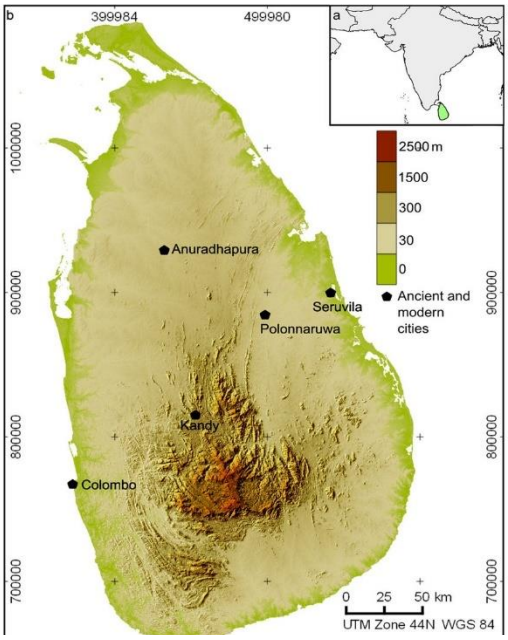
Annex 3: Map of the area occupied by rubber cultivation in Sri Lanka

Annex 3-Map of the area occupied by rubber cultivation in Sri Lanka



Source: Statistical Information on Plantation Crops 2018 Ministry of Plantation Industries & Export Agriculture

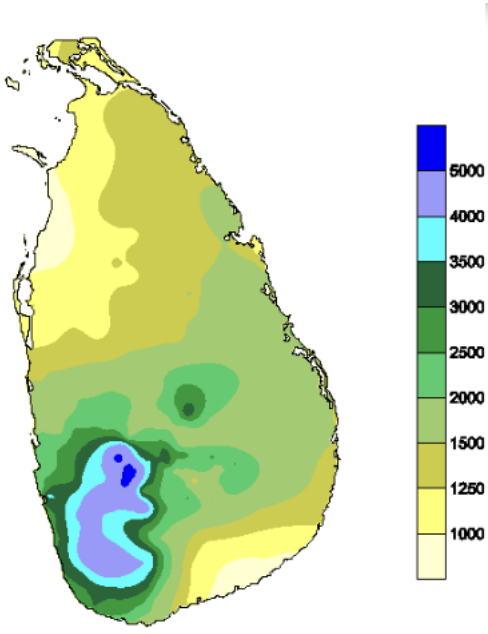
Annex 4: Topographic map of Sri Lanka



Annex 4-Topographic map of Sri Lanka

Source: Thusitha wagalawatta et al. 2016. An Ethnoarchaeological Study of Stone Quarrying Techniques in Historical Anuradhapura.

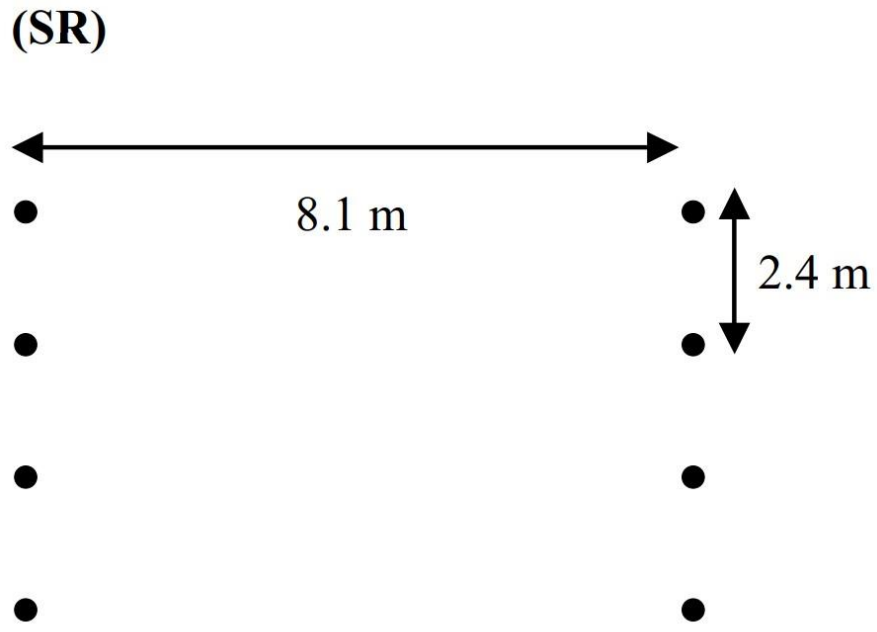
Annex 5: Rainfall map of Sri Lanka



Annex 5-Rainfall map of Sri Lanka

Source: Department of meteorology of Sri Lanka

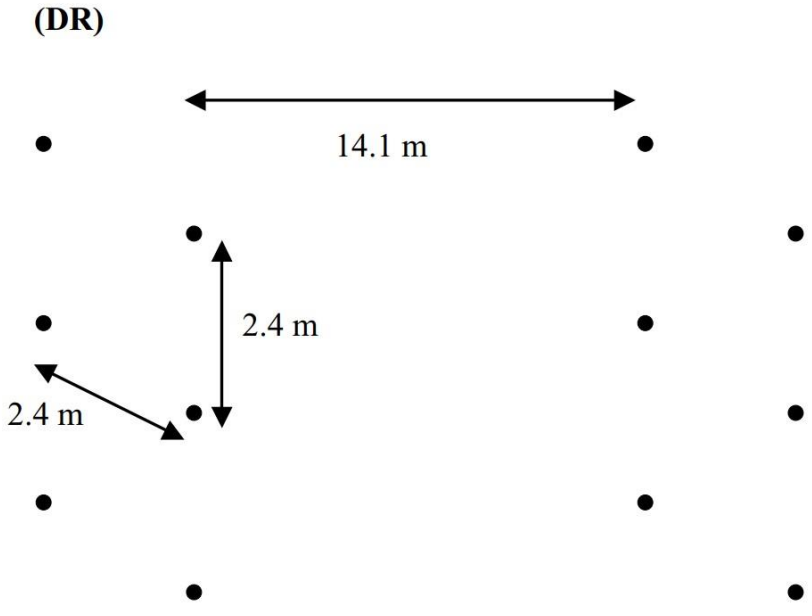
Annex 6: Scheme of simple spacing



Annex 6-Scheme of simple spacing

Source: Rodrigo V. H. L. *et al.*, 2004.

Annex 7: Scheme of double spacing



Source: Rodrigo V. H. L. *et al.*, 2004.

Annex 7-Scheme of double spacing

Annex 8: List of potential intercrops

Initial list of crops							
Crops name	Common name	Annual plants	Multiannual plants	Perennials	Intercrops production during the immature phase	Intercrops production during the mature phase	Type
Alpinia oxiphylla	Black cardamom	x			x		Other
Ammonum villosum	Medicinal cardamom	x			x	x	Medicine
Anacardium occidentale L.	Cashew nut			x		x	Fruit tree
Ananas comosus (L.)	Pineapple		x		x		Fruit plant
Annona reticulata L.	Custard-apple			x		x	Fruit tree
Aquilaria sp. - eaglewood	Eaglewood			x		x	Timber
Arachis hypogea L.	Groundnut	x			x		Legume
Arachis pintoï				x	x	x	Legume
Areca catechu	Betel nut tree			x		x	Fruit tree
Artocarpus altilis	Breadfruit			x		x	Timber
Artocarpus heterophyllus	Jackfruit			x		x	Timber
Azadirachta indica	Neem			x		x	Timber synergy
Cajanus cajan (L.)	Pigeon pea	x			x		Legume
Calopogonium caeruleum		x			x	x	Cover
Capsicum annuum L.	Chili pepper		x		x		Fruit tree
Carica papaya L.	Papaya		x			x	Fruit tree
Cassia cobanensis	Cassia	x			x		Cover synergy
Centrosema pubescens	Butterfly pea			x	x	x	Legume
Cinamomum verum	Cinnamon			x		x	Timber
Citrullus colocynthis	Bitter cucumber	x			x		Other
Citrullus lanatus	Watermelon	x			x		Fruit plant
Citrus aurantiifolia	lime			x		x	Fruit tree
Citrus x paradisi	Grapefruit			x		x	Fruit tree

Citrus reticulata	Tangerine			x		x	Fruit tree
Citrus x sinensis	Orange			x		x	Fruit tree
Cocos nucifera	Coconut			x		x	Fruit tree
Coffea canephora	Coffea Robusta			x	x		Fruit tree
Colocasia esculenta (L.)	Taro	x			x		Other
Crotalaria spp.	Rattlepods			x	x		Legume
Curcuma domestica	Turmeric			x	x		Cover
Cymbopogon citratus (DC.)	Lemon grass			x	x		Cover
Durio zibethinus	Durian			x		x	Fruit tree
Flemingia macrophylla				x	x		Cover
Fagraea fragrans	Ironwood			x		x	Timber
Garcinia mangostana L.	Mangosteen			x		x	Fruit tree
Glycine max (L.)	Soybean			x	x		Legume
Gmelina arborea	Gmelina			x		x	Timber
Ipomoea batatas L.	Sweet potato	x			x		Cover
Luffa acutangulas	Angled Loofah		x		x		Cover
Macadamia sp.	Macadamia nut			x		x	Fruit tree
Mangifera indica L.	Mango			x		x	Fruit tree
Manihot esculenta	Cassava	x			x		Other
Morinda officinalis	Morinda			x	x	x	Medicine
Mucuna bracteata		x			x		Cover
Mucuna cochinchinensis		x			x		Cover
Musa acuminata	Banana		x		x		Fruit tree
Nephelium lappaceum L.	Rambutan			x		x	Fruit tree
Noicotiana spp.	Tobacco	x			x		Cover
Oryza sativa L.	Upland Rice	x			x		Cover
Paraserianthes falcataria (L.)	White Albizia			x		x	Timber

Parkia speciosa	Stink Bean			x		x	Timber
Passiflora edulis Silms	Passion Fruit			x		x	Fruit tree
Piper nigrum L.	Pepper	x				x	Other
Pogostemon cablin (Blanco)	Patchouly		x		x		Tree
Psophocarpus tetragonolobus (L.)	Winged bean	x			x		Cover
Pterocarpus sp.	Padouk narra			x		x	Timber
Pueraria phaseoloides	Tropical kudzu			x	x	x	Legume
Ricinus communis L.	Castor bean			x	x		Medicine
Saccharum officinarum L.	Sugar cane		x		x		Cover
Salacca zalacca	Snake Fruit			x		x	Fruit tree
Shorea macrophylla	Light red meranti			x		x	Timber
Sorghum bicolor (L.)	Sorghum	x			x		Cover
Stylosanthes guianensis	Common stylo			x	x	x	Legume
Syzygium aromaticum L.	Cloves			x		x	Fruit tree
Tectona grandis L.	Teak			x		x	Timber
Theobroma cacao L.	Cocoa			x	x		Fruit tree
Trichosanthes cucumerina	Snake gourd		x			x	Other
Vanilla fragrans	Vanilla		x			x	Other
Vigna radiata (L.)	Mung bean	x			x		Legume
Vigna unguicalata	Cow pea	x			x		Legume

Annex 8-List of potential intercrops

Source: YAPI Expertise

Annex 9: Initial list of potential intercrops according to the development phase of rubber tree

Second list of crops	
Intercrops production during the immature phase	**Intercrops production during the mature phase**
Alpinia oxiphylla - black cardamom	Ammonum villosum - medicinal cardamom
Ammonum villosum - medicinal cardamom	Calopogonium caeruleum
Arachis hypogaea L. - groundnut	Piper nigrum L. - pepper
Cajanus cajan (L.) - pigeon pea	Carica papaya L. - papaya
Calopogonium caeruleum	Trichosanthes cucumerina - snake gourd
Cassia cobanensis - cassia	Vanilla fragrans - vanilla
Citrullus colocynthis - bitter cucumber	Anacardium occidentale L. - cashew nut
Citrullus lanatus - watermelon	Annona reticulata L. - custard-apple
Colocasia esculenta (L.) - taro	Aquilaria sp. - eaglewood
Ipomoea batatas L. - sweet potato	Arachis pintoï
Manihot esculenta - cassava	Areca catechu - betel nut tree
Mucuna bracteata	Artocarpus altilis - breadfruit
Mucuna cochinchinensis	Artocarpus heterophyllus - jackfruit
Noicotiana spp. - tobacco	Azadirachta indica - neem
Oryza sativa L. - upland rice	Centrosema pubescens - butterfly pea
Psophocarpus tetragonolobus (L.)	Cinamomum verum - cinnamon
Sorghum bicolor (L.) - sorghum	Citrus aurantiifolia - lime
Vigna radiata (L.) - mung bean	Citrus x paradisi - Grapefruit
Vigna unguicalata - cow pea	Citrus reticulata - tangerine
Ananas comosus (L.) - pineapple	Citrus x sinensis - orange
Capsicum annuum L. - chili pepper	Cocos nucifera - coconut
Luffa acutangulas - angled Loofah	Durio zibethinus - durian
Musa acuminata - banana	Fagraea fragrans - iron wood
Pogostemon cablin (Blanco) - patchouly	Garcinia mangostana L. - mangosteen
Saccharum officinarum L. - sugar cane	Gmelina arborea - gmelina
Arachis pintoï	Macadamia sp. - macadamia nut
Centrosema pubescens - butterfly pea	Mangifera indica L. - mango
Coffea canephora - coffea robusta	Morinda officinalis - morinda
Crotalaria spp. - rattlepods	Nephelium lappaceum L. - rambutan
Curcuma domestica - turmeric	Paraserianthes falcataria (L.) - white albizia
Cymbopogon citratus (DC.) - lemon grass	Parkia speciosa - stink bean
Flemingia macrophylla	Passiflora edulis Silms - passion fruit
Glycine max (L.) - soybean	Pterocarpus sp. - padouk, narra
Morinda officinalis - morinda	Pueraria phaseoloides - tropical kudzu
Pueraria phaseoloides - tropical kudzu	Salacca zalacca - snake fruit
Ricinus communis L. - castor bean	Shorea macrophylla - light red meranti
Stylosanthes guianensis - common stylo	Stylosanthes guianensis - common stylo
Theobroma cacao L. - cocoa	Syzygium aromaticum L. - cloves
	Tectona grandis L. - teak

Key
Annual plants
Multiannual plants
Perennials

Annex 9-Initial list of potential intercrops according to the development phase of rubber tree

Source: YAPI Expertise

Annex 10: Definition of selection criteria

Definition of the selection criteria			
Category	**Criterion**	**Definition**	**Index**
CLIMATE	**Rainfall during the dry season**	This criterion is based on dry season rainfall in the study areas: Moneragala and Ampara. It evaluates the suitability of the needs of the crop with this rainfall. 2 Dry seasons: - Long (main): June - September (4 months) - Short (secondary): February - March (2 months) **GREEN: 600-1200 mm/year** **ORANGE: 300-600 mm/year** **RED: <300 mm/year**	**4**
	Rainfall during the wet season	This criterion is based on the rainfall of the rainy seasons in the study areas: Moneragala and Ampara. It evaluates the suitability of the needs of the crop with this rainfall. 2 rainy seasons: 1328 - 1821 mm/year - Maha (main): October - January (4 months) - Yala (secondary): April - May (2 months) **GREEN: 1300-3000 mm/year** **ORANGE: 1000-1300mm/year** **RED: <1000 mm/ year**	**4**
	Temperature	This criterion is based on the temperatures of the study areas: Moneragala and Ampara,. It evaluates the suitability of the needs of the crop with these temperatures. **GREEN: 15-30° C** **ORANGE: 12-15° C** **RED: <12° or >31° C**	**4**
CLIMATE	**Altitude (<600 m)**	This criterion indicates the altitude that is suitable for rubber tree cultivation. Crops must be able to be grown at altitudes below 600 meters. **GREEN: <600m** **ORANGE: >700 m**	**3**
	Resistance to high heat	This criterion indicates the intercrops' capacity to withstand high heat. **GREEN: resistant (no impact on the yield)** **ORANGE: tolerant (yield decrease)** **RED: not resistant (death of the plant)**	**3**
	Resistance to wind	This criterion indicates the intercrops' capacity to withstand wind. **GREEN: resistant (no impact on the yield)** **ORANGE: tolerant (yield decrease)** **RED: not resistant (death of the plant)**	**2**
	Resistance to heavy rain	This criterion indicates the ability of intercrops to withstand to heavy rains. **GREEN: resistant (no impact on yield)** **ORANGE: tolerant (yield decrease)** **RED: not resistant (death of the plant)**	**2**

SOIL	**Adaptation to Reddish brown earth and Red yellow podzolic soil**	This criterion indicates the type of soil present in Moneragala. It assesses the suitability of the crop for this type of soil. Reddish Brown Earth (RBE): pH: 6-7 Red yellow podzolic (RYP): pH: <5 Texture: layer of sandy loam to light clay loam overlying a clay subsoil **GREEN: Soil suitability (texture and pH)** **ORANGE: Partial suitability (texture and/or pH)** **RED: Unsuitable soil (neither texture nor pH)**	**4**
	Adaptation to Vertisol	This criterion indicates the type of soil present in Ampara. It assesses the suitability of the crop for this type of soil. pH: 7-7,5 Texture: 40-45% of clay **GREEN: Soil suitability (texture and pH)** **ORANGE: Partial suitability (texture and/or pH)** **RED: Unsuitable soil (neither texture nor pH)**	**4**
	Adaptation to feralitic soil	This criterion indicates the type of soil suitable for rubber tree cultivation. It assesses the suitability of the crop for this type of soil. pH: 5-6,5 Texture: majority of clay, with a layer of organic matter **GREEN: Soil suitability (texture and pH)** **ORANGE: Partial suitability (texture and/or pH)** **RED: Unsuitable soil (neither texture nor pH)**	**4**
	Biomass to be return to the soil	This criterion evaluates the amount of biomass that returns to the soil thanks to the crop's organic residues (leaves, branches, etc.). It depends on the type of crop and the cultivation practices used (e.g. leaf removal, total harvest, waste left over...). **GREEN: High organic matter input (crop producing a lot of organic wastes left on the ground)** **ORANGE: Low to moderate organic matter input (crop producing many organic wastes left on the ground or crop producing small amount of organic wastes left on the ground)**	**1**
CROP	**Water competition with rubber trees**	This criterion is based on the crop's water needs and thus assesses the potential competition with rubber trees. **GREEN: No competition with rubber trees** **ORANGE: Potential competition under certain conditions (temperature, rainfall)** **RED: Increased competition leading to a deficiency in the rubber tree**	**4**
	Light competition from rubber trees	This criterion evaluates the crop's access to light in relation to the development of the rubber tree. **GREEN: No competition from rubber trees (shade tolerance)** **ORANGE: Potential competition under some conditions (size, shade tolerance and arrangement)** **RED: Increased competition (shade intolerance)**	**4**
	Required space between crops and rubber trees	This criterion indicates the distance needed between the crops and the rubber trees. As a reminder, the study focuses only on simple spacing, i.e., a rubber tree inter-row space of 6-8 m. **GREEN: 3-4 m** **ORANGE: >4m**	**4**
	Need of mechanisation	This criterion indicates the potential need of mechanisation during the crop cycle. **GREEN: no mechanisation** **ORANGE: low mechanisation** **RED: important mechanisation** It's difficult to assess the importance of this criterion on the basis of the literature.	**2**

Annex 10-Definition of selection criteria

Source: YAPI Expertise

Annex 11: Preselection of potential intercrops

First crops selection										
Crops	Climate			Soil			Crop		Validity of the crop	Comments about intercrops
	Rainfall during the dry season (600-1200 mm/year)	Rainfall during the wet season (1200-3000 mm/year)	Temperature (15-30° C)	Adaptation to Reddish brown earth and Red yellow podzolic soil (pH = 4,5-6)	Adaptation to Vertisol (pH = 7-7,5)	Adaptation to feralitic soil (pH = 5-6,5)	Water competition with rubber trees	Light competition from rubber trees		
Production during the immature phase										
Alpinia oxiphylla - black cardamom										Stable market in Sri Lanka
Ammonum villosum - medicinal cardamom										
Arachis hypogaea L. - groundnut										
Cajanus cajan (L.) - pigeon pea										
Calopogonium caeruleum										
Cassia cobanensis - cassia										Crop not adapted (rainfall)
Citrullus colocynthis - bitter cucumber										Rainfall: 300-500 mm/year Harvesting: 5 month after seeding => Risky planting during the wet season
Citrullus lanatus - watermelon										
Colocasia esculenta (L.) - taro										Crop not adapted (rainfall)
Ipomoea batatas L. - sweet potato										
Manihot esculenta - cassava (culture < 12 months)										
Manihot esculenta - cassava (culture > 12 months)										Crop only planted for 12 months because after this time there is a risk of root diseases with the rubber tree
Mucuna bracteata										Risky crop (rainfall) Can disappear if there is too much shade
Mucuna cochinchinensis										Risky crop (rainfall) Can disappear if there is too much shade
Noicotiana spp. - tobacco										Risky crop (rainfall)
Oryza sativa L. - upland rice										Risky crop (rainfall)
Psophocarpus tetragonolobus (L.)										Can disappear if there is too much shade
Sorghum bicolor (L.) - sorghum										
Vigna radiata (L.) - mung bean										To be used in the dry season (harvested 2 months after seeding)
Vigna unguiculata - cow pea										
Ananas comosus (L.) - pineapple										
Capsicum annuum L. - chili pepper										
Luffa acutangulas - angled Loofah										Low yield in intercropping
Musa acuminata - banana										
Pogostemon cablin (Blanco) - patchouly										Not drought resistant Harvesting: after 6 months after seeding
Saccharum officinarum L. - sugar cane										
Arachis pintoï										
Centrosema pubescens - butterfly pea										
Coffea canephora - coffea robusta										Low yield in intercropping
Crotalaria spp. - rattlepods										
Curcuma domestica - turmeric										
Cymbopogon citratus (DC.) - lemon grass										Can disappear if there is too much shade
Flemingia macrophylla										Can disappear if there is too much shade
Glycine max (L.) - soybean										
Morinda officinalis - morinda										
Pueraria phaseoloides - tropical kudzu										
Ricinus communis L. - castor bean										Beware, it can become a plant plague
Stylosanthes guianensis - common stylo										
Theobroma cacao L. - cocoa										Risky crop (rainfall, water and light competition)

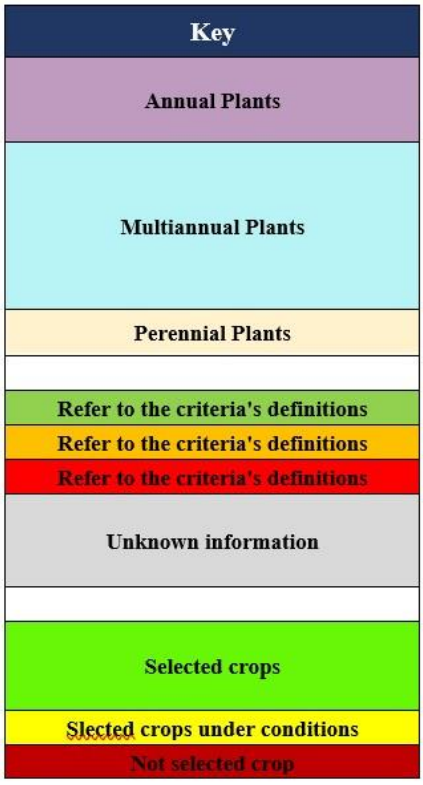
Production during the mature phase										
Ammonum villosum - medicinal cardamom										
Calopogonium caeruleum										Can disappear if there is too much shade
Piper nigrum L. - pepper										If the rubber tree canopees are well developed, they can overshade the crop
Carica papaya L. - papaya										
Trichosanthes cucumerina - snake gourd										Crop not adapted (water competition)
Vanilla fragrans - vanilla										If the rubber tree canopees are well developed, they can overshade the crop
Anacardium occidentale L. - cashew nut										
Annona reticulata L. - custard-apple										
Aquilaria sp. - eaglewood										
Arachis pintoï										
Areca catechu - betel nut tree										
Artocarpus altilis - breadfruit										
Artocarpus heterophyllus - jackfruit										
Azadirachta indica - neem										
Centrosema pubescens - butterfly pea										
Cinamomum verum - cinnamon										
Citrus aurantiifolia - lime										
Citrus x paradisi - Grapefruit										
Citrus reticulata - tangerine										
Citrus x sinensis - orange										
Cocos nucifera - coconut										
Durio zibethinus - durian										
Fagraea fragrans - iron wood										
Garcinia mangostana L. - mangosteen										
Gmelina arborea - gmelina										
Macadamia sp. - macadamia nut										
Mangifera indica L. - mango										
Morinda officinalis - morinda										
Nephelium lappaceum L. - rambutan										
Paraserianthes falcataria (L.) - white albizia										
Parkia speciosa - stink bean										
Passiflora edulis Silms - passion fruit										
Pterocarpus sp. - padouk, narra										
Pueraria phaseoloides - tropical kudzu										
Salacca zalacca - snake fruit										
Shorea macrophylla - light red meranti										
Stylosanthes guianensis - common stylo										
Syzygium aromaticum L. - cloves										Crop not adapted (light competition)
Tectona grandis L. - teak										

Annex 11-Preselection of potential intercrops

Annex 12: New list of potential intercrops from the preselection

Crops selection	
Intercrops production during the immature phase	**Intercrops production during the mature phase**
Alpinia oxiphylla - black cardamom	Ammonum villosum - medicinal cardamom
Ammonum villosum - medicinal cardamom	Calopogonium caeruleum
Arachis hypogaea L. - groundnut	Piper nigrum L. - pepper
Cajanus cajan (L.) - pigeon pea	Carica papaya L. - papaya
Calopogonium caeruleum	Vanilla fragrans - vanilla
Citrullus colocynthis - bitter cucumber	Anacardium occidentale L. - cashew nut
Citrullus lanatus - watermelon	Annona reticulata L. - custard-apple
Ipomoea batatas L. - sweet potato	Aquilaria sp. - eaglewood
Manihot esculenta - cassava (culture < 12 months)	Arachis pintoï
Mucuna bracteata	Areca catechu - betel nut tree
Mucuna cochinchinensis	Artocarpus altilis - breadfruit
Noicotiana spp. - tobacco	Artocarpus heterophyllus - jackfruit
Oryza sativa L. - upland rice	Azadirachta indica - neem
Psophocarpus tetragonolobus (L.)	Centrosema pubescens - butterfly pea
Sorghum bicolor (L.) - sorghum	Cinamomum verum - cinnamon
Vigna radiata (L.) - mung bean	Citrus aurantiifolia - lime
Vigna unguiculata - cow pea	Citrus x paradisi - Grapefruit

Ananas comosus (L.) - pineapple	Citrus reticulata - tangerine
Capsicum annuum L. - chili pepper	Citrus x sinensis - orange
Luffa acutangulas - angled Loofah	Cocos nucifera - coconut
Musa acuminata - banana	Durio zibethinus - durian
Pogostemon cablin (Blanco) - patchouly	Fagraea fragrans - iron wood
Saccharum officinarum L. - sugar cane	Garcinia mangostana L. - mangosteen
Arachis pintoï	Gmelina arborea - gmelina
Centrosema pubescens - butterfly pea	Macadamia sp. - macadamia nut
Coffea canephora - coffea robusta	Mangifera indica L. - mango
Crotalaria spp. - rattlepods	Morinda officinalis - morinda
Curcuma domestica - turmeric	Nephelium lappaceum L. - rambutan
Cymbopogon citratus (DC.) - lemon grass	Paraserianthes falcataria (L.) - white albizia
Flemingia macrophylla	Parkia speciosa - stink bean
Glycine max (L.) - soybean	Passiflora edulis Silms - passion fruit
Morinda officinalis - morinda	Pterocarpus sp. - padouk, narra
Pueraria phaseoloides - tropical kudzu	Pueraria phaseoloides - tropical kudzu
Stylosanthes guianensis - common stylo	Salacca zalacca - snake fruit
Theobroma cacao L. - cocoa	Shorea macrophylla - light red meranti
	Stylosanthes guianensis - common stylo
	Tectona grandis L. - teak

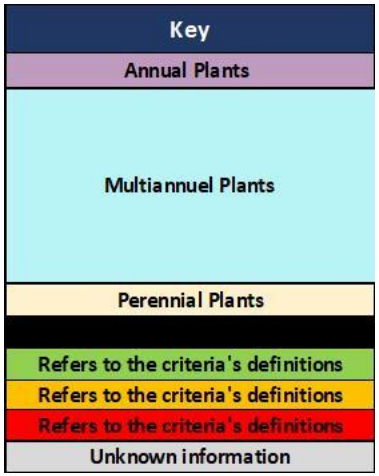


Annex 12-New list of potential intercrops from the preselection

Source: YAPI Expertise

Annex 13: Final selection of potential intercrops for the immature phase of rubber tree

Crops	Climate							Soil				Crop				Mark	Comments
	Rainfall during the dry season (600-1200 mm/year)	Rainfall during the wet season (1200-3000 mm/year)	Temperature (15-30°C)	Altitude (<600 m)	Resistance to high heat	Resistance to wind	Resistance to heavy rain	Adaptation to Reddish brown earth and Red yellow podzolic soil (pH = 4,5-6)	Adaptation to Vertisol (pH = 7-7,5)	Adaptation to feralitic soil (pH = 5-6,5)	Biomass to be return to the soil	Water competition with rubber trees	Light competition from rubber trees	Required space between crops and rubber trees	Need of mechanisation		
Degree of impact	4	4	4	3	3	2	2	4	4	4	1	4	4	4	2	49	
Alpinia oxiphylla - black cardamom	4	4	4	3	1,5	2	2	4	4	4	1	2	2	4	2	42	
Ammonum villosum - medicinal cardamom	2	4	4	1,5	1,5	2	2	4	4	2	1	4	4	4	2	42	
Arachis hypogaea L. - groundnut	4	4	4	3	3	1	0	4	0	4	1	4	4	4	2	42	
Cajanus cajan (L.) - pigeon pea	4	4	4	3	3	2	0	2	2	4	1	4	4	4	1	42	
Calopogonium caeruleum	2	4	4	3	3	2	2	4	2	4	1	4	2	4	2	41	
Citrullus colocynthis - bitter cucumber	0	4	4	3	3	2	0	4	4	4	0,5	2	4	4	2	40,5	
Citrullus lanatus - watermelon	0	4	4	3	1,5	2	1	2	0	4	0,5	4	2	4	2	34	
Ipomoea batatas L. - sweet potato	2	4	4	3	3	1	2	4	0	4	0,5	4	2	4	2	39,5	
Manihot esculenta - cassava (culture < 12 months)	4	4	4	3	3	2	2	4	2	2	0,5	4	4	4	2	44,5	
Mucuna bracteata	4	4	4	3	3	2	2	4	2	4	1	4	2	4	2	45	
Mucuna cochinchinensis	4	4	4	3	3	2	2	4	2	4	1	4	2	4	2	45	
Noicotiana spp. - tobacco	0	4	4	3	3	2	2	4	4	4	0,5	4	2	4	2	42,5	
Oryza sativa L. - upland rice	0	4	2	3	1,5	2	2	2	2	4	0,5	2	2	4	1	32	
Psophocarpus tetragonolobus (L.)	4	4	4	3	3	2	1	4	2	2	0,5	2	2	4	2	39,5	
Sorghum bicolor (L.) - sorghum	4	2	4	3	3	1	1	2	4	4	0,5	4	2	4	2	40,5	
Vigna radiata (L.) - mung bean	4	0	4	3	3	2	2	2	2	2	1	4	4	4	2	39	
Vigna unguiculata - cow pea	4	4	4	3	3	1	2	2	4	4	1	4	2	4	2	44	
Ananas comosus (L.) - pineapple	4	4	4	3	3	2	2	4	0	4	1	2	4	4	2	42	
Capsicum annuum L. - chili pepper	4	4	4	3	3	1	0	4	0	4	0,5	4	4	4	2	41,5	
Luffa acutangulas - angled Loofah	4	4	4	3	3	2	1	0	2	4	0,5	4	2	4	2	39,5	
Musa acuminata - banana	2	4	4	3	1,5	0	1	4	4	4	0,5	2	4	4	2	40	
Pogostemon cablin (Blanco) - patchouly	2	4	4	3	1,5	1	1	4	2	4	0,5	2	4	4	2	39	
Saccharum officinarum L. - sugar cane	2	2	4	3	3	2	2	2	0	4	1	0	2	4	2	33	
Arachis pintoï	2	4	4	3	3	2	1	4	4	4	1	4	4	4	2	46	
Centrosema pubescens - butterfly pea	2	4	4	3	3	2	2	4	4	4	1	4	4	4	2	47	
Coffea canephora - coffea robusta	0	4	4	3	3	2	2	4	4	4	0,5	2	2	2	1	37,5	
Crotalaria spp. - rattlepods	2	4	4	3	3	2	1	2	4	2	1	2	4	4	2	40	
Curcuma domestica - turmeric	2	4	4	3	3	2	2	2	0	4	0,5	4	2	4	1	37,5	
Cymbopogon citratus (DC.) - lemon grass	2	4	4	3	3	2	1	2	4	4	0,5	4	2	4	2	41,5	
Flemingia macrophylla	2	4	4	3	3	2	2	4	4	4	1	4	2	4	2	43	
Glycine max (L.) - soybean	2	4	4	3	1,5	2	1	2	2	4	0,5	4	4	4	2	40	
Morinda officinalis - morinda	4	4	4	1,5	3	1	2	4	2	4	0,5	4	4	4	2	40	
Pueraria phaseoloides - tropical kudzu	2	4	4	3	3	2	2	4	2	4	1	4	2	4	2	43	
Stylosanthes guianensis - common stylo	2	4	4	3	3	2	2	4	0	4	1	2	4	4	2	41	
Theobroma cacao L. - cocoa	2	4	4	3	3	2	2	4	4	4	1	2	2	2	1	40	

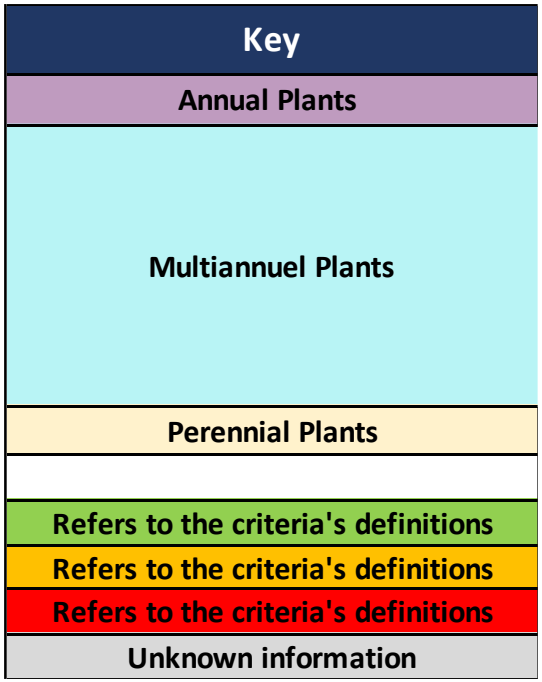


Annex 13-Final selection of potential intercrops for the immature phase of rubber tree

Source: YAPI Expertise

Annex 14: Final selection of potential intercrops for the mature phase of rubber tree

Final crop selection table - Mature phase of rubber tree																	
	Climate							Soil				Crop					
Crops	Rainfall during the dry season (600-1200 mm/year)	Rainfall during the wet season (1200-3000 mm/year)	Temperature (15-30°C)	Altitude (<600 m)	Resistance to high heat	Resistance to wind	Resistance to heavy rain	Adaptation to Reddish brown earth and Red yellow podzolic soil (pH = 4,5-6)	Adaptation to Vertisol (pH = 7-7,5)	Adaptation to feralitic soil (pH = 5-6,5)	Biomass to be return to the soil	Water competition with rubber trees	Light competition from rubber trees	Required space between crops and rubber trees	Need of mechanisation	Mark	Comments
Degree of impact	4	4	4	3	3	2	2	4	4	4	1	4	4	4	2	49	
Ammonum villosum - medicinal cardamom	2	4	4	1,5	1,5	2	2	4	4	2	1	4	4	4	2	42	
Calopogonium caeruleum	2	4	4	3	3	2	2	4	2	4	1	4	2	4	2	41	
Piper nigrum L. - pepper	4	4	4	3	0	2	0	2	4	4	0,5	4	4	4	2	41,5	
Carica papaya L. - papaya	4	4	4	3	1,5	0	2	2	2	2	0,5	2	2	4	2	35	Water competition is not sure
Vanilla fragrans - vanilla	4	4	4	3	0	1	2	2	2	4	0,5	2	4	4	2	38,5	
Anacardium occidentale L. - cashew nut	4	4	4	3	3	2	1	4	2	2	1	2	2	2	2	38	Water competition is not sure
Annona reticulata L. - custard-apple	4	4	4	3	3	0	1	4	2	2	0,5	2	4	4	2	39,5	Water competition is not sure
Aquilaria sp. - eaglewood	4	4	2	3	3	1	1	4	4	4	1	4	4	4	2	45	
Arachis pintoï	2	4	4	3	3	2	1	4	4	4	1	4	4	4	2	46	
Areca catechu - betel nut tree	2	4	4	3	3	1	2	4	2	2	0,5	2	2	4	2	37,5	Water competition is not sure
Artocarpus altilis - breadfruit	2	4	4	3	3	2	2	4	4	4	0,5	2	2	2	2	40,5	
Artocarpus heterophyllus - jackfruit	2	4	4	3	1,5	2	2	4	4	4	0,5	2	2	2	2	39	
Azadirachta indica - neem	4	4	4	3	3	2	2	4	4	4	1	4	4	4	2	49	
Centrosema pubescens - butterfly pea	2	4	4	3	3	2	2	4	4	4	1	4	4	4	2	47	
Cinamomum verum - cinnamon	2	4	4	3	3	2	2	4	2	2	0,5	4	2	4	2	40,5	
Citrus aurantiifolia - lime	2	4	4	3	1,5	1	1	2	2	4	0,5	2	2	4	2	35	Water competition is not sure
Citrus x paradisi - Grapefruit	2	4	4	3	1,5	1	1	2	4	4	0,5	2	2	4	2	37	Water competition is not sure
Citrus reticulata - tangerine	2	4	4	3	1,5	1	1	4	2	4	0,5	2	2	4	2	37	Water competition is not sure
Citrus x sinensis - orange	2	4	4	3	1,5	1	1	4	2	4	0,5	2	2	4	2	37	Water competition is not sure
Cocos nucifera - coconut	2	4	4	3	3	2	2	4	4	4	0,5	2	4	4	2	44,5	Water competition is not sure
Durio zibethinus - durian	2	4	2	3	3	1	2	4	2	4	1	2	2	2	2	36	Water competition is not sure
Fagraea fragrans - iron wood	4	4	4	3	3	2	2	4	2	4	1	4	2	4	2	45	
Garcinia mangostana L. - mangosteen	2	4	4	3	3	1	2	2	2	4	1	2	4	4	2	40	Water competition is not sure
Gmelina arborea - gmelina	4	4	4	3	3	2	2	2	2	4	1	4	2	4	2	43	
Macadamia sp. - macadamia nut	4	4	4	3	3	0	2	4	0	2	1	2	2	2	2	35	Water competition is not sure
Mangifera indica L. - mango	4	4	4	3	1,5	1	1	4	4	4	1	2	2	4	2	41,5	Water competition is not sure
Morinda officinalis - morinda	4	4	4	1,5	3	1	2	4	2	4	0,5	4	4	4	2	40	
Nephelium lappaceum L. - rambutan	4	4	4	3	3	1	2	4	2	4	1	2	2	4	2	42	Water competition is not sure
Paraserianthes falcataria (L.) - white albizia	2	4	4	3	3	2	2	2	4	2	1	4	2	4	2	41	
Parkia speciosa - stink bean	4	4	4	3	3	2	2	0	2	4	1	4	2	4	2	41	
Passiflora edulis Silms - passion fruit	4	4	4	3	1,5	1	1	2	4	4	0,5	2	4	4	2	41	Water competition is not sure
Pterocarpus sp. - padouk, narra	2	4	4	3	3	2	2	4	4	4	1	4	4	4	2	47	
Pueraria phaseoloides - tropical kudzu	2	4	4	3	3	2	2	4	2	4	1	4	2	4	2	43	
Salacca zalacca - snake fruit	4	4	4	3	1,5	1	1	4	0	4	0,5	4	2	4	2	39	
Shorea macrophylla - light red meranti	4	4	4	3	3	2	2	4	0	4	0,5	4	2	2	2	40,5	
Stylosanthes guianensis - common stylo	2	4	4	3	3	2	2	4	0	4	1	2	4	4	2	41	Water competition is not sure
Tectona grandis L. - teak	2	4	4	3	1,5	1	2	4	4	4	1	4	2	4	1	41,5	



Annex 14-Final selection of potential intercrops for the mature phase of rubber tree

Source: YAPI Expertise

Annex 15: Interview guides for farmers

District	Village	Date	Translator
Surveys: Name First name (statut)			
General information			

Member of society		Number of plots		Type of crops of each plot		Area of each plot (ha)	
yes	no	Mature	Immature	Mature	Immature	Mature (ha)	Immature (ha)

"The interviewer must introduce himself, explain the reason and purpose of his request and even anticipate the answers to three often unformulated questions:

- Why this research?
- Why this person?
- What is the purpose of the work?

He should notify that this is a free and open interview and that it is he/she, his/her point of view, situation or story that interests him/her and that there are no right or wrong answers. The interviewer should also indicate the duration of the interview and, in some cases, discuss the choice of location which can have an impact on what is said: workplace, researcher's office, home of either party (Blanchet, 1994) », Pierret J., 2004.

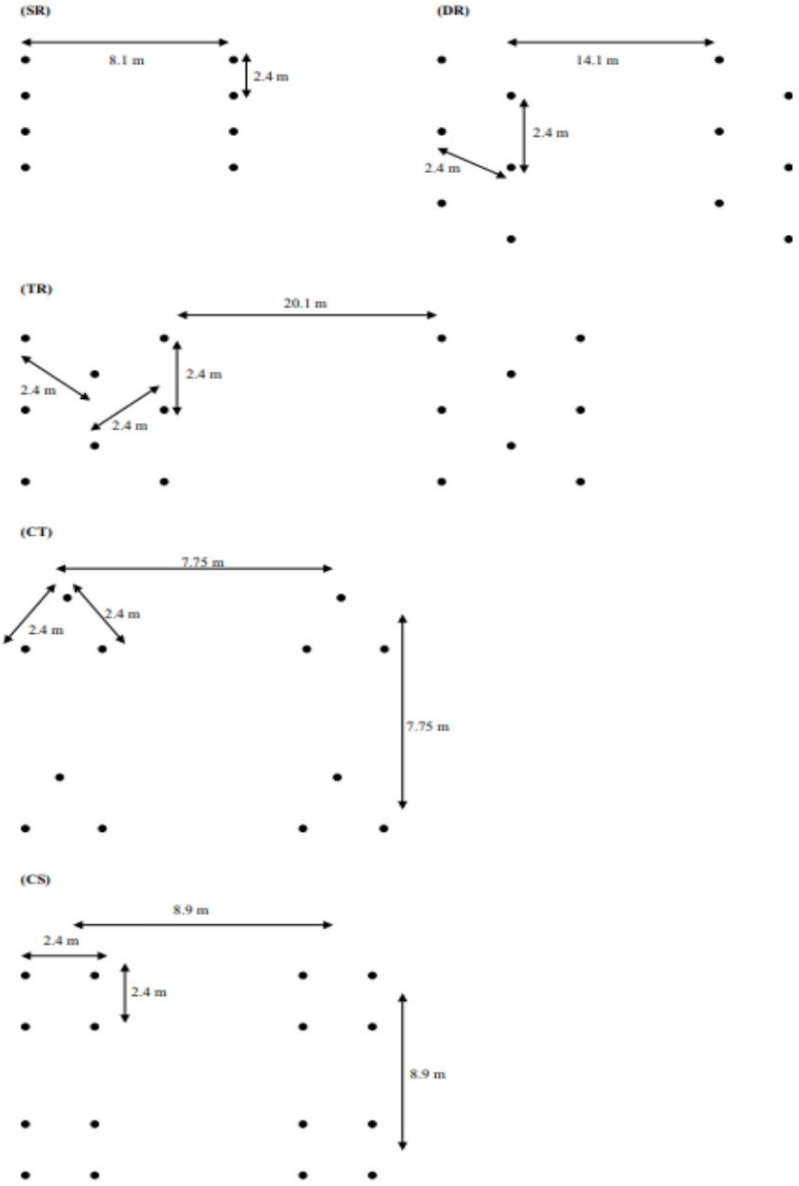
Intercropping in the immature period: association of rubber trees and other crops
Ex:/Pineapple, banana, sugar cane, passion fruit

IC (InterCrop)

Topic	Questions	Answer	
Intercrop ***(Cocoa, corn, pepper, banana…)***	Initial investissement		
	Species		
	Variety		
	Reason (why you choose this crop, 3 reasons minimum)		
	Paddy field?	Why?	
Agronomic strategy	Date of rubber plantation		
	Date plantation IC		
	Crop before the actual IC if existing		
	Seeding cost (LKR/Kg)		
Spatial arrangement	Single row (YES or NO)	Why?	
	Double row (YES or NO)	Why?	
	Three rows (YES or NO)	Why?	
	Three plant triangular (YES or NO)	Why?	
	Four plant square cluster (YES or NO)	Why?	
	Rubber density (nb plants/ha) -distance between two ranks -distance between two trees		
	IC density (nb plants/ha) -distance between two ranks -distance between two crops		
Yield	Rubber (Kg/ha/year)		
	Intercrop (Kg/ha/year)		
	Sale price (For each intercropp)		
Inputs	Fertilizer Quantity, Cost, name	Yes	No

	Herbicide Quantity, Cost, name	Yes	No
	Pesticide Quantity, Cost, name	Yes	No
Workforce	Number of people from the household		
	Number of extra people		
	Salary		
Use of IC	Self-consumption	Sale	
By-products of IC (Secondary product obtained during the manufacture of the main product)	Name		
	Valorization	Yes	No
	How		
Co-products of IC (a co-product is a substance or product resulting from a production process that is neither a product, nor a residue, nor a waste)	Name		
	Valorization		
	How		
Major issues of IC (Animal attack, diseases, social factors…)			

Schematic diagram showing the layout of different spatial arrangements of planting rubber. Codes refer to SR: single row; DR: double row; TR: three row; CT: three plant triangular cluster; CS: four plant square cluster planting systems.



Annex 15-Interview guides for farmers

Annex 16: R script and range of values

R script

```
data=read.delim2("MAJORISSUES!v2.txt")

data.acm=MCA(data)

explor(data.acm)

data1=table(data$crops,data$pest.attack)

chisq.test(data1)

mosaicplot(data1,shade=TRUE)

table(ANIM.ATTACK)

prop.table(toto,1)

barplot(t(prop.table(toto,1)),beside=T)

barplot(t(prop.table(toto,1)),legend=T,col=c("blue","green"),ylab="frequency")

barplot(t(prop.table(toto,1)), col=c("blue","green"), legend.text = TRUE, args.legend=list(x = "topright", inset = c(- 0.05, 0)))


perfDist=dist(PERF2.ACM$var$coord)

hc=hclust(perfDist,method="ward.D2")

plot(hc,cex=1)

rect.hclust(hc,k=6)


data=read.delim2("PERF.txt")

head(data)

 data.clean=subset(data,data$rubber.yield!="NG")

toto=table(data.clean$crop,data.clean$rubber.yield)


par(mar = c(3, 2, 2, 6))

barplot(t(prop.table(toto,1)), col=c("blue","green","grey"), legend.text=TRUE, args.legend=list( x=7, y=0.5, bty = "n"))
```

	Salary	Rubber yield	Household	Extra people
Low	<1499	<1120	<1	<6
Medium	1500 to 1563	1120 to 3000	1 to 2	6 to 48
High	>1564	>3000	>2	>48
Unity	LKR/day	kg/ha/year		

Crops	Cocoa	Banana	Pineapple	Corn	Cowpea	Mungbean	Pepper	Sugarcane
Avarage Initial investment	29011,5	38194	42857	34200	20761	19329	29946	146320

INITIAL INVEST

LKR	Banana	Pineapple	Corn	Cowpea	Mungbean	Pepper	Sugarcane	Cocoa
Low	<23305	<22500	<24500	<16400	<8100	<8578	<121000	<13 650
Medium	23305 to 40250	22500 to 69500	24500 to 27000	16400 to 20500	8100 to 9800	8578 to 29206	121000 to 147000	13 650 to 32235
High	>40250	>69500	>27000	>20500	>9800	>29206	>147000	>32235

SEED COST

LKR	Cocoa	Banana	Pineapple	Corn	Cowpea	Mungbean	Pepper	Sugarcane
Low	<8320	<5780	<119280	<3537040	<2660000	<1064000	< 4160	<12 544
Medium	8320 to 16640	5740 to 34000	119 280 to 307 518	3 537 040	2660000 to 3085600	1064000 to 3724000	4160 to 12 480	12 544 to 18816
High	>16640	> 34 000	> 307 518	>3537040	>3085600	>3724000	> 12 480	> 18816

YIELD INTERCROP

kg/ha/year	Cocoa	Banana	Corn	Cowpea	Mungbean	Pepper	Sugarcane
Low	<10	<594	<9750	<300	<200	<6610	<6610
Medium	10 to 1000	594 to 10000	9750 to 10000	300 to 550	200 to 388	6610 to 31250	6610 to 31250
High	>1000	> 10000	> 10000	> 550	> 388	>31250	>31 250

Annex 16-R script and range of values

Annex 17: Focus Group guides

Focus group n°	Date
People present	**Status**

PART 1 : AGRONOMY

Topic	Questions	Answer
Intercrop	Existing species	
	Reason	
	Most wanted IC species	
	Why ?	
Agronomic strategy	Average age of rubber trees in the region	
	Historic of the land	
	Which seed are sold What price Where	
	Single spacing system (YES OR NO)	Why?
	Double spacing system (YES OR NO)	Why ?

	Three spacing system (YES OR NO)	Why ?	
	Three plant triangular (YES OR NO)	Why ?	
	Four plant square cluster system (YES OR NO)	Why ?	
Yield	Rubber		
	Intercrop	• • • • • • • • • • • • • •	
Inputs	Pesticides	Yes	No
	Herbicides	Yes	No
	Fertilizers	Yes	No
Workforce	Number of man paid/days		
	Salary		
Use of IC	Self-consumption	Sale	
Major issues of IC (animal attack, diseases, social factors…)			

PART 2 : ECONOMY

Topic	Question	Answer
Economic strategy	IC network existing? (Except rubber and tea)	
	Collection site's organisation (transport, buyers, price, exportation or local market,…)	
	Type of contract between farmer and society	
	Certification ?	
	Disposal of IC (difficulties, stocks…)	
	Major downsides of the societies' organisation?	

Annex 17-Focus Group guides

Annex 18: Focus Group Organisation

Focus Group Organisation

By YAPI Expertise

A) INTERVIEWS WITH FARMERS

We would like a sample of 50 farmers minimum, but 70 farmers would be more representative. We would like to sort the sampling according to the following categories of intercrop:

	Perennial crop (Crops that last several years)	Annual crop (Crops that last 1 year)
Cash crop (Crop for sale)	Pepper, vanilla, cocoa, coffee…	Banana, ginger, curcuma…
Food crop (Crop for consumption)	Mango, papaya…	Vegetables, paddy, corn…

If you managed to interview around 50 farmers, we would need around 10 interviews per category. If you managed ton interview around 70 farmers, we would then need 15 interviews per category.

The interviews guide we sent you have clear questions; Therefore, we only need scans of the interviews.

B) FOCUS GROUP

The focus groups have to be planned a few days after the interviews of the farmers have started. Thus, the interviews will allow us to choose on which intercrops we will conduct the focus groups.

	Focus group 1	Focus group 2	Focus group 3
Key persons	**1 field officer** *specialized on the chosen intercrop* (If possible)	**1 field officer** *specialized on the chosen intercrop* (If possible)	**1 field officer** *specialized on the chosen intercrop* (If possible)
	1 society representer *specialized on the chosen intercrop* (If possible)	**1 society representer** *specialized on the chosen intercrop* (If possible)	**1 society representer** *specialized on the chosen intercrop* (If possible)
	1 Buyer *specialized on the chosen intercrop* (If possible)	**1 Buyer** *specialized on the chosen intercrop* (If possible)	**1 Buyer** *specialized on the chosen intercrop* (If possible)
	1 Member of the local authorities (Ex: mayor, DS manager…)	**1 Expert from Rubber Research Institute of Sri Lanka**	**Dissanayake** (Director of Rubber Development Department)
	1 or 2 People included in a rubber project (STARR project, Rubber, Master Plan, River Project)	**1 agronomist** or **1 quality manager from CAMSO LOADSTAR**	**1 field officer from DCOTF**

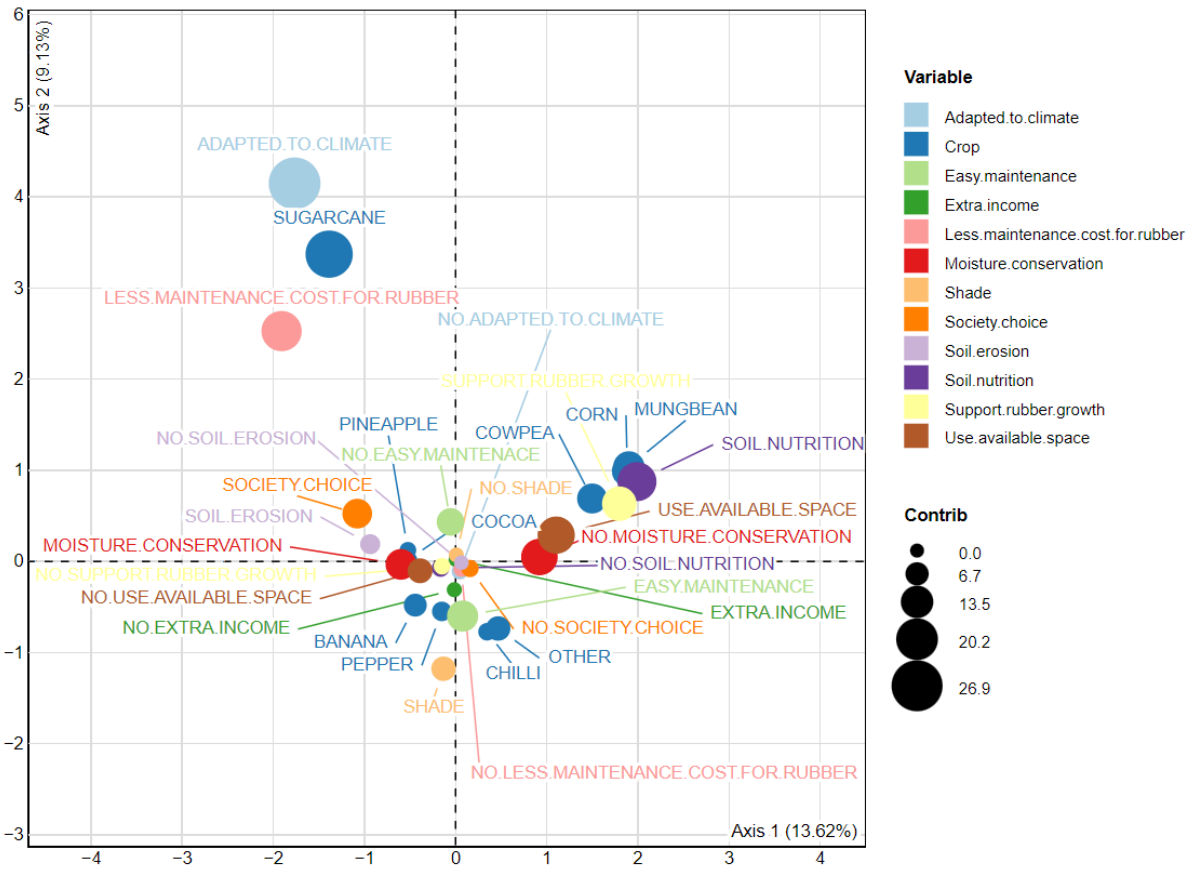
In order for the focus groups to run as smoothly as possible, here are some suggestions:

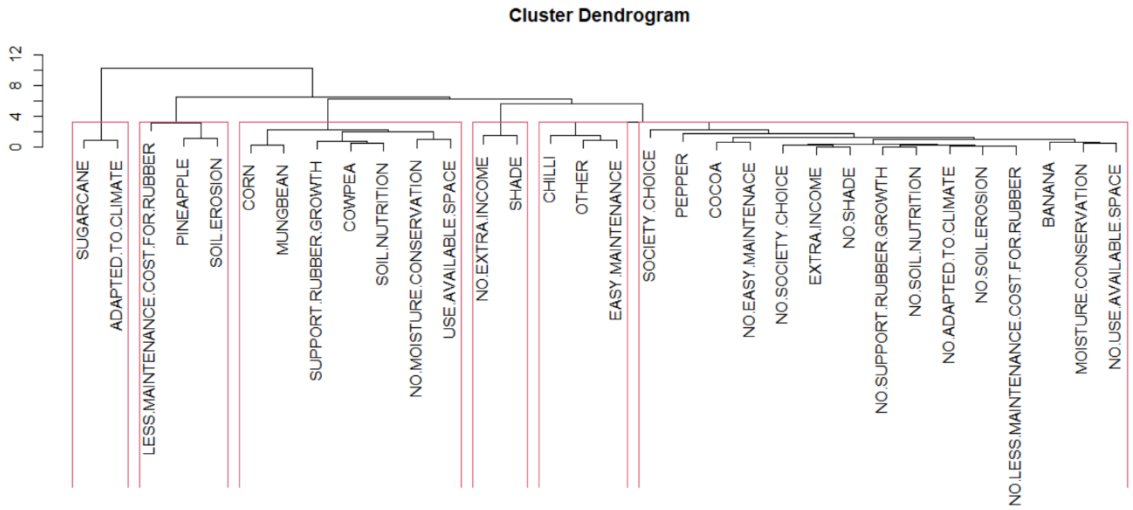
- The focus group should be run by 2 persons from LOAM: one who leads the talk and the other one who takes note.
- Every pertinent information should be written down with a colour code for each key person (it can facilitate understanding).
- Before the focus group, you should provide us with a document on how you want to proceed.
- After the focus group, you should provide us the completed questionary and a feed back of the meeting (main topic discussed, point a view, the average speaking time of each person present.

Annex 18-Focus Group Organisation

Source : YAPI Expertise

Annex 19: MCA representation and Dendrogram of major issues data

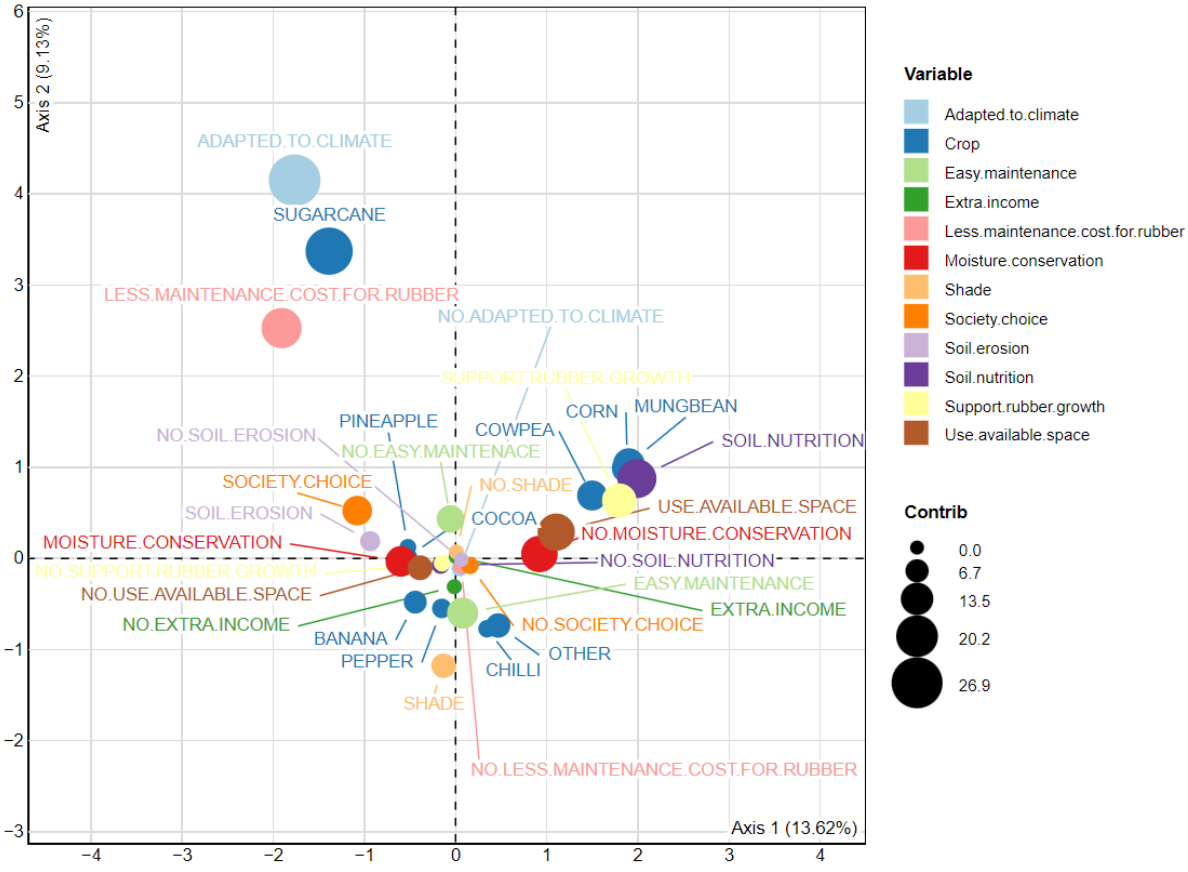


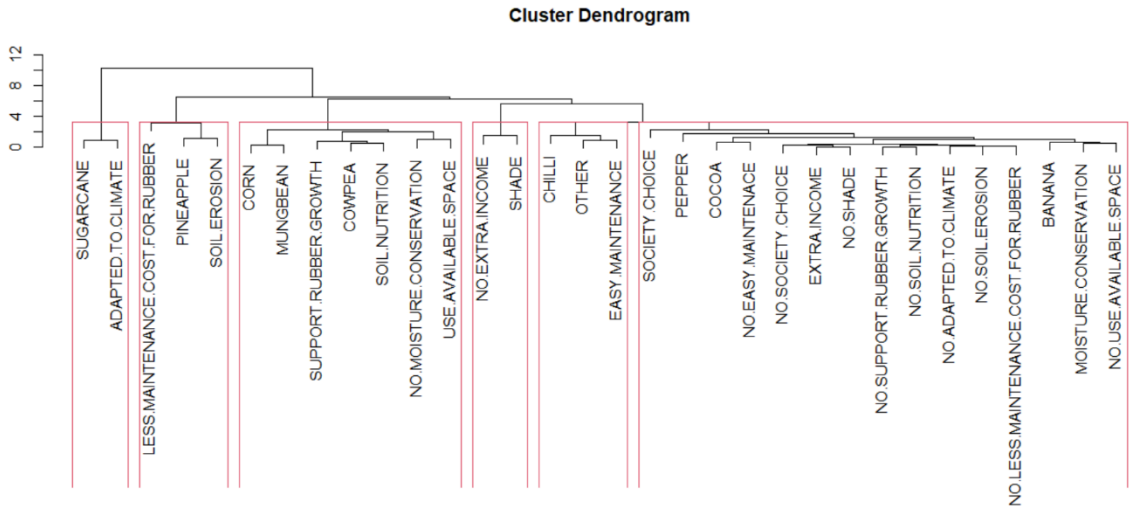


Annex 19-MCA representation and Dendrogram of major issues data

Source: YAPI Expertise

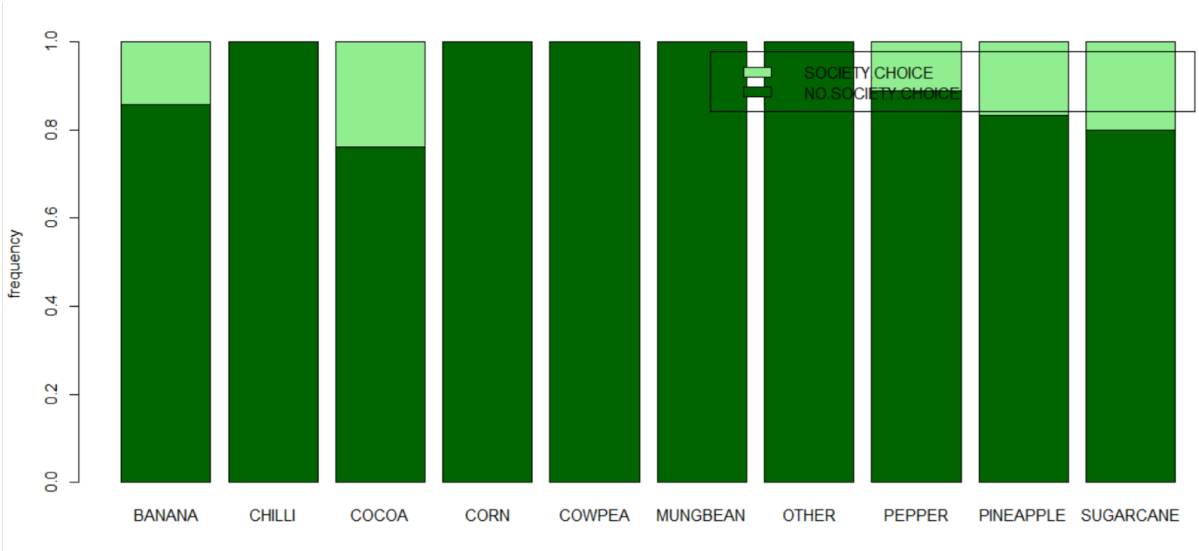
Annex 20: MCA representation and Dendrogram of reasons data





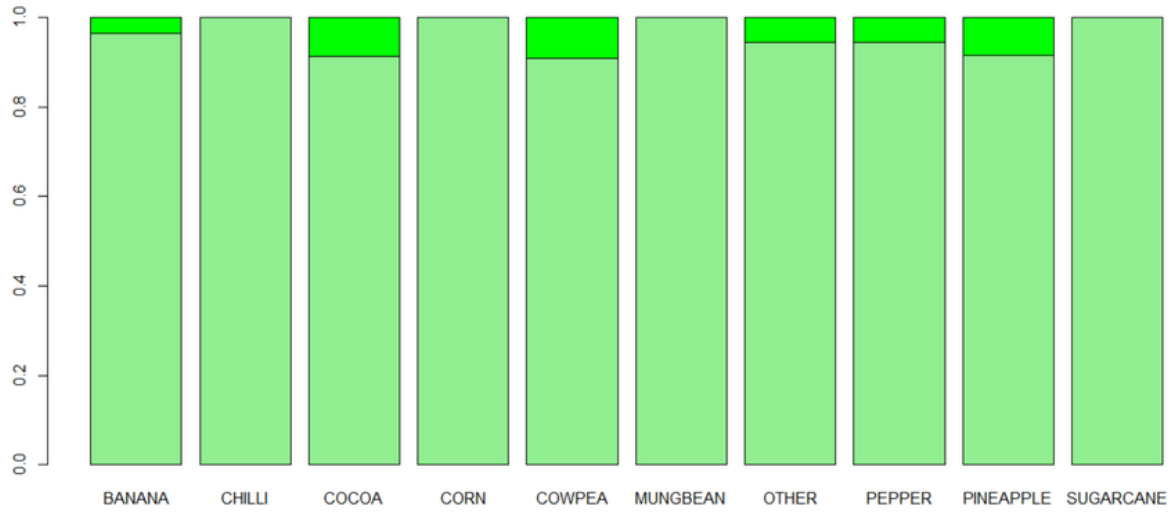
Annex 20-ACM representation and Dendrogram of reasons data

Annex 21: Histogram of the society choice data



Annex 21-Histogram of the society choice data (chi²)

Annex 22: Histogram of the extra income data



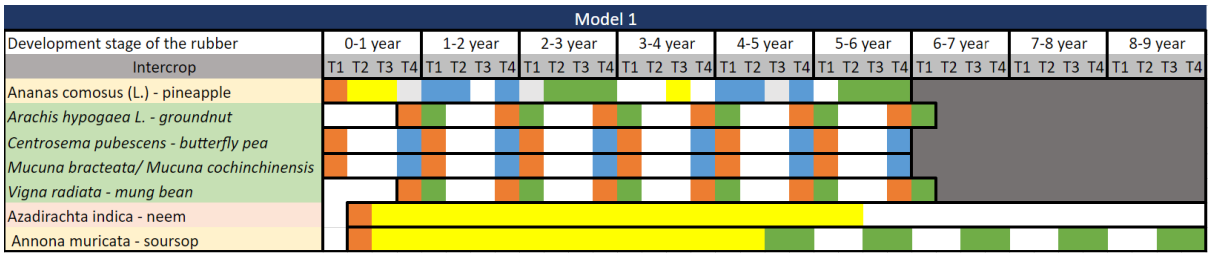
Annex 22-Histogram of the extra income data (chi²)

Annex 23: Localisation grid selection fulfilled

Criteria identified to reach 6000 participants	DISTRICT	Monaragala				Ampara	
	Divisional Secretariat divisions	Monaragala	Badalkumbura	Medagama	Bibila	Mahaoya	Padiyathalawa
		OBJECTIVE = select 3-4 DS maximum with the following grid					
Distance between already selected district and newly selected district (traveling time: more or less than 1 hour)		< 1 hour *(less than 30 min)*	< 1 hour *(less than 30 min)*	< 1 hour *(less than 30 min)*	> 1 hour	> 1 hour	> 1 hour
Location of CAMSO CC/ past or current CAMSO support (travelling time: less than 1hour, more than 1 hour)		< 1 hour *(less than 30 min)*	< 1 hour *(less than 30 min)*	< 1 hour *(less than 30 min)*	> 1 hour	> 1 hour	> 1 hour
Number of rubber farmers in each DS (more than 5000, less than 5000)		< 5000	< 5000	< 5000	< 5000	< 5000	< 5000
Network coverage (good, average, poor) *Internet connection easily available (less that 10 min) if off line mode is possible*		Poor	Poor	Poor	Poor	poor	poor
Area covered by STARR project (Y/N, % of village covered)		Yes	Yes	Yes	Yes	Yes	Yes
Average plantation maturity (age)		13	15	13	15	10	7
Identified deforestation risk (Y/N)		No	No	No	No	No	No
Identified animal interferences (Y/N)		Yes	Yes	Yes	Yes	Yes	Yes
Degree of need of local farmers for external intervention (low, medium, high)		Medium	Medium	Medium	High	High	High
Number of rubber training performed the past 2 years/ Most needed area where support has been litlle / Strategic area for the future		> 300 programs	> 100 programs	150 programs	8 programs	2 programs	2 programs
Distance to closest significant market (intercropping) TBD according to the selected intercropping		Around 10-20 kms	10-20 kms	10-20 kms	10-30 kms	10-30 kms	10-30 kms

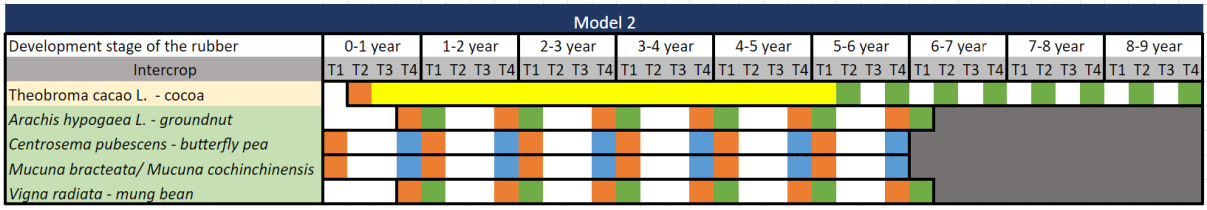
Annex 23-Localisation grid selection fulfilled

Annex 24: GANTT Diagram – Model 1



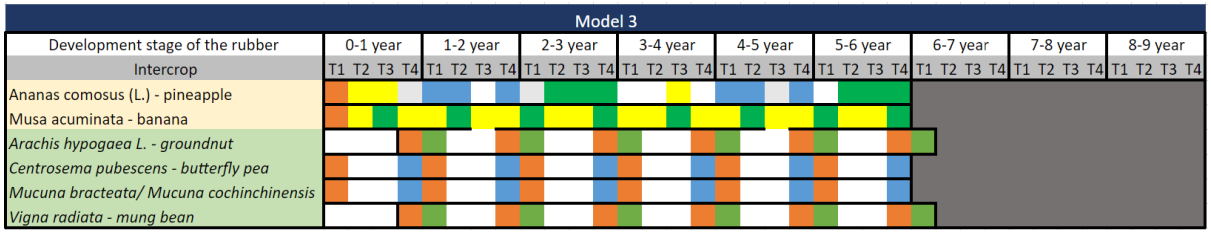
Annex 24-GANTT Diagram – Model 1

Annex 25: GANTT Diagram – Model 2



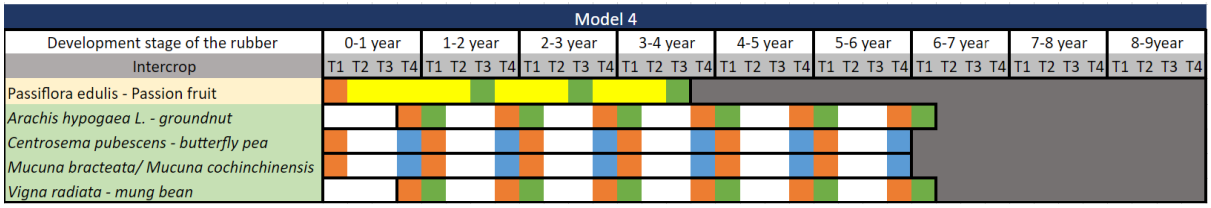
Annex 25-GANTT Diagram – Model 2

Annex 26: GANTT Diagram – Model 3



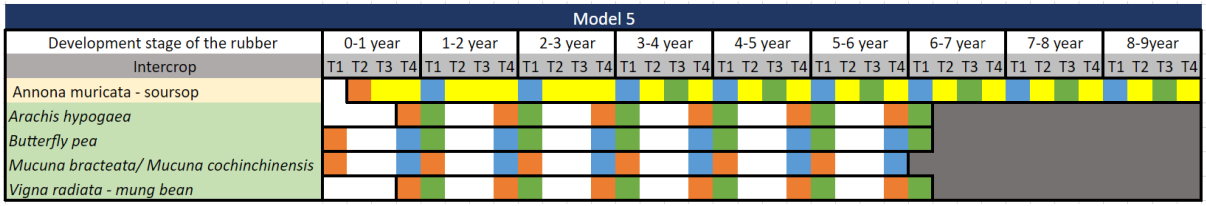
Annex 26-GANTT Diagram – Model 3

Annex 27: GANTT Diagram – Model 4



Annex 27-GANTT Diagram – Model 4

Annex 28: GANTT Diagram – Model 5



Annex 28-GANTT Diagram – Model 5

Legend	
Plant developpment	
Maintenance	
Seedling	
Harvest	
Type of crops	
Cover	
Timber	
Cash	