What on-farm practices are used to improve economic sustainability in agroforestry systems?

– A quick scoping map

Research Brief

Deliverable 1c

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Deliverable Document Sheet	
Project Title	Sustainable Agribusiness Model for Poverty Reduction Among Thai Small-scale Rubber Farmers
Grant Agreement number	414705735 Lowenberg-DeBoer THA
Funding Scheme	British Council Newton Fund Institutional Links
Project duration	12 months (January 2019 – January 2020)
Principal Investigator	Professor James Lowenberg-Deboer
Website	https://www.harper-adams.ac.uk/research/project/233/improving-the-economic-sustainability-of-smallscale-rubber-farms-in-thailand
Deliverable No.	Deliverable 1c
Deliverable title	Final Report: "What on-farm practices are used to improve economic sustainability in agroforestry systems? – A quick scoping map"
Report owner	Harper Adams University, UK Kasetsart University, Thailand
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Type	Report
Language	English – GB
Due Date	31 January 2020
Submission Date	31 January 2020

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1. Introduction

1.1 The need to identify research on diversification in agroforestry systems to improve economic sustainability

Thailand is the world's largest natural rubber producer and exporter and the majority of Thai rubber growers are small-scale farmers. Many of smallholder farmers face poverty because of price volatility for rubber on world markets. When the price of rubber is low, the income of small-scale rubber farmers declines because a large majority cannot manage risk through diversification. A steady decline in global rubber prices has led to government subsidies to support rural incomes in Thailand.

Rubber agroforestry systems are an alternative agriculture practice for rubber smallholders to improve incomes and reduce the risk associated with fluctuation in the world market for natural rubber.

1.2 Study aim

This study aimed to inform the development of sustainable agroforestry agribusiness scenario-based models of linear programming for small-scale rubber farmers in Thailand to achieve long-term financial sustainability.

2. Search of data and literature review

A total of 10,777 articles were identified through online searches of academic databases and stakeholder websites. Duplicates were removed (1,979 articles) and the remaining 8,798 articles were screened at title and abstract against inclusion criteria, resulting in 8,583 articles being excluded. The remaining 215 articles were screened at full text against inclusion criteria with a further 114 articles being excluded. An additional 21 relevant articles were sourced from a review being conducted concurrently by the same authors of this review. Therefore, in total 122 studies were analysed in detail identifying factors including: diversification method; economic outcomes; barriers and facilitators to uptake.

3. Main outcomes

- Research from Southeast Asia, South Asia and the Americas was most commonly reported in the literature, with fewer studies from Africa, East Asia, and Oceania.
- The majority of studies focussed on agrosilviculture (annual or perennial crops and trees). Less research was captured for agrosilvopasture systems (trees, crops and animals) and there is a gap in research for entomoforestry (combining trees and insects such as honeybees) and aquaforestry (combining trees and fish e.g. freshwater fish ponds).

- Horizontal diversification (adding any new products to the agroforestry system that are unrelated to the current product produced) through intercropping dominated the literature. Very few studies reported vertical diversification measures (adding value to the current product produced).
- Most studies were of short duration, with a third lasting no longer than a year. Research is needed over longer timeframes to better understand how to achieve long-term financial sustainability.
- The most commonly studied intercrops with rubber were fruit or nut woody perennials and other types of food-crops. Fewer studies investigated rubber intercropped with timber trees, other non-food crops (e.g. palm trees) and livestock.
- The most commonly diversified non-rubber agroforestry systems were those where the main tree crop was timber.
- Main crop cacao agroforestry, followed by coffee and coconut agroforestry were also commonly studied.
- A wide variety of other fruit or nut tree (excluding cacao, coconut and coffee) agroforestry systems were studied.
- It was difficult to distinguish any trends for the most common crops used to diversify timber, cacao, coconut, coffee or other fruit and nut agroforestry systems.
- Barriers to implementation of agroforestry included:
  - Lack of knowledge and skills
  - Start-up costs
  - Labour requirement
  - Land tenure
- Facilitators to take up of agroforestry included:
  - Capital support
  - Technical assistance by government and non-government organisations
  - Yield and nutrient acquisition advantages found in some intercropping systems
  - Intercropping may reduce labour requirement for weeding

4. Agroforestry systems

45 studies reported diversification of rubber agroforestry systems, the remaining 77 studies reported diversification in agroforestry systems other than rubber.

4.1 Rubber agroforestry systems

In addition to the plants and livestock listed in the table 1 below, diversification of rubber agroforestry systems was also carried out using entomoforestry (apiculture) and aquaforestry (fish ponds) however only a few studies reported these practices.

Table 1. Plants and livestock in rubber agroforestry systems

Tree-food crops	**Non-tree food crops**	**Timber species**	**Non-food crops**	**Livestock**
Anacardium occidentale (Cashew)	*Abelmoschus esculentus* (Okra)	*Acacia mangium* (Mangium)	Bambusoideae (subfamily) (Bamboo)	Cattle
Annona squamosa (Custard apple)	*Ananas comosus* (Pineapple)	*Albizia Falcataria* (Moluccan albizzia)	Calamoideae subfamily (Rattan)	Goats
Archidendron jiringa (Jering)	*Arachis hypogaea* (Groundnut)	*Alstonia macrophylla* (Hard alstonia)	*Calopogonium caeruleum*	Poultry (broiler)
Archidendron microcarpum (Kabu)	*Camellia sinensis* (Tea)	*Anthocepalus chinensis* (Bur-flower)	*Chrysalidocarpus lutescens* (Yellow palm)	Sheep
Areca catechu (Areca nut)	*Capsicum annuum (Chili)*	*Aquilaria crassna* (Eaglewood)	*Cinnamomum camphora* (Camphor)	
Artocarpus heterophyllus (Jackfruit)	Cocos nucifera (Coconut)	*Azadirachta excelsa* (Neem)	*Cyrtostachys renda* (Sealing wax palm)	
Artocarpus integer (Champada)	*Coffea* spp. (Coffee)	*Cordia globifera (Suk-hin)*	*Dimorphotheca* spp. (Cape marigold)	
Asimina trilobal (Pawpaw)	*Colocasia* spp. (Cocoyam)	*Dipterocarpus alatus* (Yang)	*Flemingia spp.*	
Baccaurea ramiflora (Rambeh)	*Cucumis melo* (Watermelon)	*Eugenia grandis* (Sea apple)	Flowers and ornamentals not specified	
Bouea oppsitifolia (Plum mango)	*Dioscorea* spp. (Yam)	*Garcinia merguensis* (Bastard garcinia)	*Gossypium* spp. (Cotton)	
Carica papaya (Papaya)	*Elaeis guineensis* (Oil palm)	*Garcinia spp.*	Grass unspecified	
Citrus limon (lemon)	*Glycine max* (Soybean)	*Gmelina arborea* (Gamhar)	*Johannesteijsmannia altifrons* (Litter collecting palm)	
Cola spp. (Cola)	*Manihot sculenta* (Cassava)	*Hopea odorata* (Ironwood)	*Licuala paludosa* (Miang Ka Pho)	
Dimocarpus longan (Longan)	Melon unspecified	*Ilex cymose*	*Livistona speciosa* (Livistona)	

Table 1. Plants and livestock in rubber agroforestry systems (continued)

Tree-food crops	Non-tree food crops	Timber species	Non-food crops	Livestock
Durio spp. (Durian)	*Musa* spp. (Banana)	*Intsia palembanica* (Malacca teak)	*Mucuna* spp.	
Garcinia mangostana (Mangosteen)	*Musa* spp. (Plantain)	*Justicia gendarussa* (Gendarussa)	*Myristica yunnaensis*	
Gnetum gnemon (Miang)	*Oryza sativac* (Rice)	*Lansium domesticum* (Longkong)	*Pueraria* spp.	
Lansium domesticum Corr. (Lansium)	*Pachyrhizus erosus* (Yam bean)	*Litsea grandis* (Tung)		
Lansium domesticum Serr. (Longkong)	*Pandanus amaryllifolius* (Pandan)	*Lumnitzera littorea* (Black mangrove)		
Mangifera indica (Mango)	*Panicum miliaceum* (Millet)	*Mesua ferrea* (Sri Lankan Ironwood)		
Nephelium lappaceum (Rambutan)	*Passiflora edulis* (Passionfruit)	*Michelia champaca* (Champaka)		
Parkia speciosa (Bitter bean)	*Piper nigrum* (Black pepper)	*Microcos tomentosa* (Cenderai)		
Parkia timoriana (Tree bean)	*Piper sarmentosum* (Pak mieng)	*Paramichelia baillonii* (Magnolia)		
Rhus spp. (Sumac)	*Salacca zalacca* (salak)	*Schima wallichii* (Needle wood)		
Sandoricum koetjape (Santol)	*Telfairia occidentalis* (Telfera)	*Shorea roxburghii* (White meranti)		
Shorea macrophylla (Tenkawang)	*Vernonia amygdalina*	*Shorea spp.* unspecified		
Syzygium aromaticum (Clove)	*Vigna radiata* (Mung bean)	*Swietenia macrophylla* (Mahogany)		
Theobroma cacao (Cocao)	*Vigna unguiculate* (Cowpea)	*Swietenia mahagoni* (American mahogany)		
	Vigna unguiculate (Yard long bean)	*Syzygium cumini* (Jambolan Plum)		
	Xanthosoma sagittifolium (Tannia)	*Toona ciliate* (Mouimein Cear)		
	Zea mays (Maize)			
	Zingiber cassumunar (Phlai)			
	Zingiber officinale (Ginger)			

4.2 Other agroforestry systems

Five main crop agroforestry systems were identified (Table 2): Timber, cacao, coffee, coconut and other fruit and nut trees (excluding cacao, coffee and coconut). A small number of other agroforestry main crop types were also identified.

Table 2. Plants and animal combinations with main crop timber, cacao, coffee, coconut, nut/fruit (and other) agroforestry systems

Timber	**Cacao**	**Coffee**	**Coconut**	**Nut/fruit**	**Other systems**
Acacia mangium/maize	Banana	Unspecified food crops	Banana	Arecanut/Aloe vera	Tea/red mung bean/maize/green manure
Acacia/Litsea/jackfruit/mango/rice/maize/pineapple/mung bean/black bean/*Cassia siamea*	Maize	Livestock unspecified	Banana/cassava	Arecanut/*Artemisia pallens*	Shan-tea/forage grass
Acacia/longan/coffee/soyabean/forage grass	Rice	Timber unspecified	Banana/cassava/fruit tree	Arecanut/*Asparagus racemous*	Tea/chili
Acacia/mango/maize/forage grass	Groundnut	Firewood unspecified	Banana/fruit tree unspecified	Arecanut/*Bacopa monnieri*	Tea/cabbage
Acacia nilotica/rice/linseed/arhar (pigeon pea)	Long bean	Planto/yucca	Lanzones/coffee/cacao/black pepper	Arecanut/*Catharanthus roseus*	Bamboo/sesame
Acrocarpus fraxinifolius/banana/common bean	Mung bean	Fruit/timber	Elephant foot yam	Arecanut/*Cymbopogon flexuous*	Oil palm/annual crops
Albizia chinensis/banana/common bean	Unspecified crop	Fruit tree unspecified	Dioscorea	Arecanut/*Cymbopogon martini*	
Astronium graveolens/Pigeon pea (*Cajanus cajan*)/ Maize (*Zea mays*)/beans (*Phaseolus* sp)	Unspecified fruit crop	*Cordia alliodora*	Tapioca	Arecanut/*Nilgirianthus ciliatus*	
Calliandra calothyrus/banana/common bean	Timber	*Terminalia amazonia*	Vegetables	Arecanut/*Ocimum basilicum*	
Cedrela oderata/banana/common bean	Yam	*Eucalyptus Deglupta*	Vanilla	Arecanut/*Piper longum*	
Cedrela odorata/Pigeon pea (*Cajanus cajan*)/Maize (*Zea mays*)/beans (*Phaseolus* sp)	Plantain	Banana	Cacao	Arecanut/*Pogostemon cablin*	
Cedrela serrata/banana/common bean	Cocoyam	Pepper	Vanilla/cacao	Arecanut/*Vetiveria zizanoides*	
Dalbergia retusa/Pigeon pea (*Cajanus cajan*)/Maize (*Zea mays*)/beans (*Phaseolus* sp)	Sandlewood/sweet potato	Timber (unspecified)*/ Desmodium ovaliforlium (legume grund cover)*	Cattle/*Brachiaria miliiformis*/*Pueraria phaseoloides*/*Gliricidia sepium*	Betel nut/tree crop	
Dyera lowrii - Jelutong/maize	Coconut	Plantain	Buffalo	Betel nut/agronomic crop	
Erythrina poeppigiana/banana/common bean	Laurel			Betel nut/fruit crops	
Eucalyptus/cowpea/fodder grasses (*Panicum maximum* or *Brachiaria ruziziensis*)	Safout			Breadfruit/pineapple/cassava	
Eucalyptus grandis/*Eucalyptus urophylla*/pasture/cattle (beef)/soyabean/corn	Mango			Canarium/plantain/kava/pacific kauri	
Gmelina arborea/maize	Ndjansang			Cashew/turmeric/amaranthus	

Table 2. Plants and animal combinations with main crop timber, cacao, coffee, coconut, nut/fruit (and other) agroforestry systems (continued)

Timber	**Cacao**	**Nut/fruit**
Hieronyma alchorneoides/Pigeon pea (*Cajanus cajan*)/Maize (*Zea mays*)/beans (*Phaseolus* sp)	Safout/ Ndjansang	Cashew/elephant foot yam/bhindi
Leucaena diversifolia/banana/common bean	Mango/ Ndjansang	Cashew/colocasia/chilli
Leucaena leucocephala/cowpea	Safout/mango/ Ndjansang	Cashew/cowpea/palak
Mahogany/coffee	Cassava/cocoyam*/Khaya anthotheca/Pericopsis elata/Entandro utile/Tetrapleura tetreptera/Albizia adianthifolia/Tetrapleura tetreptera, Albizia adianthifolia/Newbouldia laevis*	Cashew/bhindi/basella/french bean
Markhamia lutea/banana/common bean	*Plantain/Cordia alliodora*	Cashew/amaranthus/dhaincha/capsicum
Melia azedarach/maize		Cashew/bhindi/cowpea/radish
Mixed timber/*T. daniellii*		Cashew/poultry (eggs & meat)
Paraserianthes falcataria/cabbage/maize		*Cassava/pineapple/Guaba/Gunanbana/Bolaina*
Paulowina/peanut/wheat		*Dacryodes edulis*/intercropped with fruit trees *(eg. Irvingia wombolu (excelsa))*
Pine/vanilla		*Dacryodes edulis*/food crop *(eg. fluted pumpkin, pineapple, cocoyam, yam, plantain)*
Pongamia/soyabean/safflower		*Dacryodes edulis/* timber tree species *(eg. Melicia excelsa)*
Poplar/*Coreopsis lanceolata*		Durian/cassava
Poplar/*Coreopsis tinctoria*		*Emblica offcinalis/*green gram/ fennel
Poplar/*Calendula officinalis*		Grewia/*M.pruriens*/Setaria
Poplar/*Chrysanthemum multicaul*		Guava/rice
Poplar/*Dianthus barbatus*		Lemon/rice
Poplar/*Dimorphotheca aurantiaca*		Longan/maize/forage grass
Poplar/*Gaillardia pulchelia*		Macadamia/coffee/soybean
Poplar/*Gamolepis elegans*		Mango/cassava
Poplar/*Helichrysum bracteatum*		*Moringa olefera*/green gram/fennel
Poplar/maize/wheat/tumeric		Morus/*M.pruriens*/Setaria
Poplar/other timber tree/Food crops		Noni (*Citrifolia sinensis*)/sandlewood/pigeon pea
Poplar/*Petunia hybrida*		Orange/maize/melon/soyabean/chilli pepper/amaranthus
Poplar/*Phlox drumondii*		Papaya/ginger/gliricidia
Poplar/pigeon pea/tumeric		Papaya/ginger/pigeonpea/gliricidia
Poplar/Verbena hybrida		Papaya/pigeonpea/Gliricidia
Pterocarpus indicus/maize		Papaya/ragi/gliricidia
Sandlewood/food crops		Papaya/ragi/pigeopea/gliricidia
Shorea contorta/maize		Peach/*M. pruriens*/Grewia optiva/Setaria sphacelata
Teak/plum/coffee/soyabean/forage grass		Peach/*M. pruriens*/Morus/Setaria
Teak/yam/maize		Peach/*M. pruriens*/Setaria
Terminalia Amazonia/Pigeon pea (*Cajanus cajan*)/ Maize (*Zea mays*)/ beans (*Phaseolus* sp)		Sapota/jatropha/basil
Timber unspecified & banana		Sapota/jatropha/kalmegh
		Son tra/forage grass

Table 2. Plants and animal combinations with main crop timber, cacao, coffee, coconut, nut/fruit (and other) agroforestry systems (continued)

Timber
Timber unspecified & long bean
Timber unspecified & mung bean
Timber unspecified & Pineapple
Timber unspecified & unspecified crop
Timber unspecified & upland rice
Timber unspecified/legume (*B. decumbens*) pasture/cattle
Timber unspecified/legume (*B. humidicola*) pasture/cattle
Vitex parviflora/maize