Rubber-based farming diversification:
Current practices and their impact on economic sustainability of small-scale rubber farmers

A systematic review **protocol**

Deliverable 1b

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1. Introduction

Rubber is an important cash crop for many smallholders and the 90% of the world's natural rubber is produced on small-holdings (Association of Natural Rubber Producing Countries, 2019). Rubber is grown in more than 20 countries but only four dominate worldwide production. In these four countries, smallholders produce 93 % of rubber in Malaysia, 90 % in Thailand, 89 % in India and 85 % in Indonesia (Rubber Board 2005). Many of these smallholders, are however, facing poverty, with the main threat to livelihood deriving from price volatility for natural rubber on world markets (e.g. Anon, 2016; Stroesser et al., 2018; Wee and Singaravelloo, 2018).

Rubber can be produced naturally or synthetically, and since crude oil is one of the main raw materials of synthetic rubber, there is a strong correlation between the prices of crude oil, synthetic rubber, and natural rubber (Khin et al., 2012). In the last 10 years, world market prices for natural rubber have fluctuated drastically. An all-time high of US$ 6.26 per Kilogram was recorded for smoked rubber sheets (RSS3) in February 2011 (source indexmundi) as a result of increased demand caused by recession-linked low prices in 2009 and supply disruptions caused by El Niño related low rainfall in the dominant producing countries in South-East Asia (Accenture, 2015). This was followed by a dramatic crash in natural rubber price (for example, in October 2019 the price was US$ 1.43 per kilogram – source indexmundi) driven by oversupply and low oil prices (Anon, 2016).

Where smallholders rely primarily on income from monoculture rubber they are particularly vulnerable to these fluctuations in price (Romyen et al., 2018). On-farm strategies, such as growing other cash crops with rubber, provide a potential strategy for these farmers to mitigate this risk (e.g. Stroesser et al., 2018).

In addition to fluctuations in rubber price, smallholders wishing to grow rubber face the challenge that rubber trees have a long gestation period before becoming productive, which serves as another disincentive for investors in rubber farming. Tapping of rubber trees for latex usually starts in the fifth to seventh year after planting and then continues for 25 to 30 years (Balsiger et al., 2000; Michels et al., 2012; Hougni et al., 2018; Liu et al., 2018). After approximately 30 years a decline in latex production makes further tapping of the trees uneconomic (Balsiger et al., 2000). The long immature period means that monocropping rubber represents a loss in income for smallholders in the first years. Growing other crops with rubber, for example, is a way of enhancing an early return on investment, as well as

reducing vulnerability to fluctuations in rubber price in the mature period and potentially providing additional income when production starts to decline.

This study aims to identify on-farm practices that aim to improve the overall economic sustainability, of producing natural rubber, including reducing the vulnerability of small-scale rubber farmers to rubber price volatility. Indicators of economic sustainability in this study are defined as those related to productivity (i.e. yield) as well as financial (e.g. income, profit, costs, margins etc). A secondary objective of the map is to identify any barriers and facilitators to uptake of on-farm practices to improve economic sustainability. This secondary objective will be addressed through the literature gathered for the primary objective.

2. Topic development

The topic for this review was funded by The British Council (www.britishcouncil.org) under The Newton Fund. The Newton Fund is managed by the UK Department for Business, Energy and Industrial Strategy (BEIS), in order to build research and innovation partnerships with 18 partner countries including Thailand, to support their economic development and social welfare, and to develop their research and innovation capacity for long-term sustainable growth (The British Council, 2018).

The scope of this project was refined through expert discussions as part of the process of drafting an application in response to the call by The Newton Fund. Participants in the discussion, consisted of the broader The Newton Fund Institutional Links, The British Council in the UK and Thailand, Office of Higher Education Commission in Thailand, and researchers from the Departments of Land, Farm and Agri-business Management at Harper Adams University in the UK and Departments of Agricultural and Resource Economics, at Kasetsart University in Thailand. Within the stakeholder group, methodological experts on systematic maps and reviews as well as experts in agribusiness models and natural rubber production were represented and involved in discussions of the scope and search strategy for the map.

We anticipated that the broad topic we want to address will capture highly heterogeneous studies including different methodologies, interventions and outcomes, a mixture of quantitative and qualitative research, and evidence not limited to primary research. Systematic mapping methodology is increasingly being used in these instances to gain an overview of a broad topic, identify knowledge gaps (topics that are underrepresented in the

literature that would benefit from primary research) and sub-sets of evidence that may be suitable for secondary synthesis or analysis (e.g. systematic review). Systematic maps do not answer a question as do systematic reviews because there is no qualitative or quantitative synthesis of study results, for example using meta-analysis. Systematic mapping, however, does follow the same rigorous, objective and transparent processes as systematic reviews to capture and screen literature, with the aim of reducing reviewer selection bias and publication bias, associated with traditional literature reviews, and providing transparency regards decisions made for inclusion of evidence (James et al., 2016).

3. Methods

The review will follow the Collaboration for Environmental Evidence guidelines and standards for evidence synthesis in environmental management and it conforms to ROSES (RepOrting standards for Systematic Evidence Syntheses) reporting standards (Collaboration for Environmental Evidence, 2018).

The primary question for the systematic map is:

"What evidence is there for farming diversification practices aimed at improving the economic sustainability of rubber production?"

The secondary questions to be addressed using evidence gathered for the primary question are:

- "What are the economic outcomes of farming diversification practices in comparison with monoculture rubber farming?
- "What are the barriers and facilitators to uptake of practices to improve on-farm economic sustainability for rubber farmers?"

3.1 PICO elements

The primary question can be defined using Population, Intervention Comparator and Outcome (PICO) key elements:

- Population(s): Natural rubber farms of any size and ownership
- Intervention(s): Any on-farm practice that is undertaken to improve economic sustainability in rubber farming. Any off-farm means of improving economic sustainability will not be searched for directly but be recorded where mentioned in studies captured.

- Comparator(s): Before and after on-farm practice that aims to improve economic sustainability; no on-farm practice that aims to improve economic sustainability (control); comparison between on-farm practices that aim to improve economic sustainability; no comparator(s).
- Outcome(s): Indicators of economic sustainability (e.g. yield, income, profit, margins, stability, risk, variability, portfolio)

The systematic map will identify a comprehensive list of studies on practices to improve economic sustainability in rubber farming. The systematic map will then describe these studies in terms of the settings, the PIO elements [population(s), intervention(s) and outcome(s)] and methods in each study. The key outputs will be as follows:

1) A list of on-farm practices aimed at improving the economic sustainability of rubber farming.
2) A series of cross tabulations of key descriptors, e.g. interventions and outcomes, interventions and populations/settings, and interventions and methods that will be used to systematically identify knowledge clusters (subtopics that are well-represented by research studies) and knowledge gaps (subtopics that are un- or under-represented by research studies).
3) A list of barriers and facilitators to uptake of practices to improve economic sustainability for rubber farmers.
4) A detailed database of studies and narrative description of the evidence base

3.2 Search terms

A comprehensive search to capture an un-biased sample of published and grey literature will be undertaken using multiple information sources. Searches for published literature will be performed using English language search terms. Searches for grey literature will be conducted in both the English and Thai language.

Search terms were formulated by the review team. A scoping search was performed to validate the methodology. Keywords were tested for specificity and sensitivity using the online database ISI Web of Knowledge (core collection) (Appendix I).

Population terms for "rubber farmers"

(rubber) AND NOT (tyre OR tire OR synthetic* OR man*made)) AND (Farm* OR plantation* OR tapp* OR agro*forest* OR rural OR smallholder*)

Intervention terms for "farming diversifications"

(sustain* OR "best practice*" OR inter*crop* OR "mixed farm*" OR multi*crop*
OR diversif* OR portfolio* OR variabilit* OR technolo* OR innovat*)

Outcome terms for "economic outcomes"

(sustain* OR economic OR poverty OR poor OR inequal* OR income* OR
livelihood* OR profit* OR risk* OR portfolio* OR variabilit* OR yield* OR
productivity OR efficien* OR stability OR wealth OR optimi*ation* OR
maximi*ation OR return* OR financ* OR benefit* OR gain*)

The terms for intervention and outcomes may overlap. To avoid missing anything relevant,
we used OR rather than AND to combine the two strings. The following final search string
was used to capture literature between February and April 2019.

(rubber) AND NOT (tyre OR tire OR synthetic* OR man*made)) AND (Farm* OR
plantation* OR tapp* OR agro*forest* OR rural OR smallholder*) AND (sustain*
OR "best practice*" OR inter*crop* OR "mixed farm*" OR multi*crop* OR
diversif* OR technolo* OR innovat* OR economic OR poverty OR poor OR inequal*
OR income* OR livelihood* OR profit* OR risk* OR portfolio* OR variabilit* OR
yield* OR productivity OR efficien* OR stability OR wealth OR optimi*ation* OR
maximi*ation OR return* OR financ* OR benefit* OR gain*)

The search string will be adapted to the syntax of each source searched and a record of each
search will be recorded including: exact search string used, name of database/organisation,
date of search, whether the search term has been applied to topic, title, abstract or keyword,
number of article hits.

3.3 Sources of literature and searches
The following sources of literature will be searched:

Bibliographic databases

1) Scopus
2) Web of Science Core Collections
3) AgEcon
4) EBSCO Host: CAB Abstracts, Greenfile, Library, information science &
   technology abstracts and Business Source Complete

5) Econlit

6) Emerald

7) AGRIS

8) Thai theses databases

9) PROQUEST

10) PROQUEST Dissertations and Theses Global

11) Kaestart University E-Theses

12) Access to research

13) Electronic Theses Online Service (eThOS)

14) Digital Access to Research Theses (DART)

Organisational websites

Searches will be performed across a suite of relevant organisational websites for agroforestry diversification publications (Table 1). Literature from organisational websites will be screened separately for relevance before being combined with other records.

Table 1 List of websites from relevant organisations

1) Center for International Forestry Research (CIFOR)	https://www.cifor.org/
2) Association of Natural rubber producing countries	www.anrpc.org
3) CIRAD Agricultural Research for Development	https://www.cirad.fr/en
4) Department of Agriculture (DOA) Thailand	http://www.doa.go.th/
5) Food and Agriculture Organization of the United Nations (FAO)	http://www.fao.org/
6) International Rubber Consortium Limited (IRCO)	https://ircorubber.com/
7) International Rubber Study Group (IRSG)	http://www.rubberstudy.com/
8) Ministry of Agriculture and Cooperatives (MOAC)	https://www.moac.go.th/
9) Plastics Institute Of Thailand	http://www.thaiplastics.org/ http://rubber.oie.go.th/Elibrary.aspx?cid=1087
10) Rubber Authority of Thailand (RAOT)	http://www.raot.co.th/
11) Thai Latex Association	http://www.tla-latex.org/
12) The Thailand Research Fund (TRF)	https://www.trf.or.th/
13) The Thai Rubber Association	http://www.thainr.com/th/
14) The Consultative Group for International Agricultural Research (CGIAR)	https://www.cgiar.org/research/research-centers/
15) The World Agroforestry (ICRAF)	http://www.worldagroforestry.org/
16) Tropical Agricultural Research and Higher Education Center (CATIE)	https://catie.ac.cr/en/

Results of the bibliographic searching will be combined using Endnote and duplicates will be removed prior to screening. A library of search results will be assembled in EPPI reviewer systematic reviewing management software.

3.4 Article screening and study inclusion criteria

All retrieved studies will be screened for relevance against the pre-defined inclusion criteria, using specialised Eppi Reviewer systematic review software. Screening of articles against inclusion criteria will be conducted at two levels: (i) title and abstract (screened concurrently for efficiency) (ii) full text. Articles that cannot not be located or accessed at full text will be recorded. The number of articles included and excluded at each screening stage, and reasons for exclusion at full text will be recorded.

Prior to commencing screening, consistency checking and a Cohen's Kappa analysis will be calculated for a subset (10%) of articles at title and abstract level to ensure that bias is reduced and inclusion criteria are being applied consistently between reviewers. A Cohen's Kappa statistic of 0.6 or higher is considered acceptable indicating substantial agreement (Landis and Koch, 1977). Where the level of agreement is low (below c. 0.6 agreement), in depth discussions about disagreements for inclusion and further consistency checking will be performed. Where there is uncertainty about inclusion of an article, or disagreements about inclusion all reviewers examined the text and a consensus agreement will be made.

The following inclusion criteria will be applied at all levels of screening:

- Eligible population(s): All rubber farming systems at all sizes and ownerships (e.g. family farms (smallholders); state owned farms; corporate farms).
- Eligible intervention(s): Any farming diversification practice that is undertaken with the aim of improving economic sustainability of rubber farming. Any off-farm means of improving economic sustainability will NOT be searched for directly but be recorded where mentioned in studies captured.
- Eligible comparator(s): Any or no comparator (e.g. Before and after farming diversification practice that aims to improve economic sustainability; comparison between different farming diversification practices that aim to improve economic sustainability; mono rubber farming (control)).
- Eligible outcome(s): For inclusion the study must focus primarily on economic sustainability of rubber farming and/or rubber-based farming diversification. This includes outcomes related to financial outcomes (e.g. returns, costs, margins,

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profit, income etc). Productivity indicators such as yield and growth of rubber will be recorded. But if productivity indicators are the only outcomes for the study, the study will be excluded.

- Eligible study type(s): Any study type based on quantitative and/or qualitative data. Masters and undergraduate theses are ineligible but PhD theses are eligible.
- Timeframe: No date restrictions for inclusion of literature
- Language: English language for bibliographic database searches and English and Thai language for grey literature searches

3.5 Data extraction

Extraction of meta-data for all eligible studies will be carried out using EPPI-Reviewer (a specialised online-based systematic reviewing software). Details of data extraction are presented in table 3. The meta-data extracted will provide in depth detail about each study (e.g. study setting, design, intervention/s, outcomes) and bibliographic information of the article (e.g. author, title, year, publication type). Meta-data extraction (coding) will take two different forms: a priori coding (Bazeley and Jackson, 2013) guided by previous studies in the topic area and indigenous coding with codes derived directly from data and concept generated coding (Hutchinson, Johnston and Breckon, 2010). All and any outcomes will be included iteratively as they are identified within the relevant literature and coded accordingly. Coding consistency checking will be carried out on a parallel coding of all full texts, discussing all disagreements. Where meta-data are missing from articles this will be stated as "not reported"/"unclear", since making efforts to obtain these data will not possible within the resources allocated to this project. Meta-data will be extracted from the licenced specialised systematic review software and presented in an Excel spreadsheet.

3.6 Study mapping and presentation

The evidence base identified within this systematic map will be presented and described as a narrative synthesis and systematic map database; a searchable spreadsheet with columns containing codes and meta-data related to the variables described in the meta-data extraction and coding schema. Cross tabulations of various combination of variables will be used to identify trends in the evidence base, knowledge gaps and clusters.

Table 3. Examples of coding variables and meta-data to be extracted from each study

Coding variable	Meta-data
Full reference	Author(s), title, date, publisher
Year of publication	Date
Publication type	Peer-review journal, conference paper, thesis, published report, unpublished report, Book, Book chapter other etc.
Language of study	English or Thai
Country of study	Name of country
Location of study	Location of study site(s)
Linked article	Article reporting the same study
Research strategy	Monomethod qualitative, monomethod quantitative, multimethod qualitative, multimethod quantitative, mixed method qualitative, mixed method quantitative, grounded theory
Study design	Experimental (with control); Case study; programming or modelling study;
Data collection method and scoring system for assessment of bias	5-Longitudinal random controlled trial 4-Large scale cross-sectional survey 3-In-depth interviews and focus group discussions 2-Small-scale survey 1-Single case study or equivalent (project-based study, insufficient information), documentary data and other secondary sources
Sampling strategy	5- Random representative sampling, 4- Stratified/multistage representative sampling 3- Purposive sampling/critical case smapling 2- Convenience sampling/snowballing/self-selection 1- Sampling information unclear
Sample size specification	5-Sample size for each crop 4-Sample size for each category 3-Sample size for each location 2-Sample size for the total sample 1-Sample unclear
Sample size	5-100 farms or more 4-50-99 farms 3-10-49 farms 2-1-19 farms 1- not provided
Farming context	
Farm size specification	5-Average farm size for each cropping system 4-Average farm size for each group of crops 3-Average farm size for the total sample 2-Farm size unclear

	1- Farm size not reported at all
Rubber context specification- Density	5-Rubber density provided for each cropping system 4-Rubber density provided for each group 3-Rubber density specified partly 2-Rubber density specified for monoculture rubber only 1- Rubber density not specified
Rubber context specification- lifespan	5-Rubber lifespan specified for all 3-Rubber tapping (production) years provided 1-No information provided
Rubber context specification- maturity of rubber plantation used for study	5-Both young and mature rubber / full cycle 3-immature or mature stage only 1- Not provided
Data analysis – Key economic indicators used	5-NPV with sensitivity test 4-NPV with no sensitivity test 3-Net farm income with sensitivity test 2-Net farm income or gross margin with no sensitivity test 1- Income with no sensitivity test
Completeness of relevant data	5-Complete data for all years studied 4-Complete data for some years, but not for all years 3-Incomplete data with key information provided 2-Incomplete data with some key information missing 1- Incomplete data with key information missing
Other data analysis techniques used	Economic analysis (e.g. cost-benefit analysis, cost analysis), Optimisation modelling (e.g. Linear programming (LP), Quadratic programing, Mathematical programming, Non-linear programming, Dynamic programming (DP), Optimal control), scenario-based model, thematic analysis, fsQCA, typology; LCA/LCC/Social LCA
Farm ownership	Smallholder, state, corporate
Spatial scale	On-station trials; Farm, regional, not known
Length of study	Number of months, years etc
Site of study	Site location
Control variable	Detail of control (monoculture rubber farming) if relevant
Detail of intervention	Detail of farming diversification practice (e.g. crops, intercropping or multi-cropping etc)

Table 3. Examples of coding variables and meta-data to be extracted from each study (continued)

Coding variable	Meta-data
Description of intervention	- tree food crop, - small tree, shrub or palm food crops, - root food crop, - above-ground non-tree food crops, - timber trees, - non-food non-timber crops, - livestock, - any other
Detail of outcome	- Productivity (growth and yield of rubber) - Economic outcomes
Description of Economic outcome	- Cost focussed = Total cost; Variable cost - Estimated returns = Income; Net farm income; Monetary advantage; Total returns; Net returns; Gross margin or returns; Cumulative returns; Net benefit; Profit: Equivalent ratios = Annual equivalent return or ratio; Income equivalence ratio - Increments = Mean Annual Increment; Current Annual Increment - Land focussed = Returns to land; Land expectation value - Marginal returns = Marginal rate of return; Marginal annual production - Net Present Value (NPV) = Net present value; Internal rate of return: - Non NPV = Payback period - Physical resources = Labour; Return to Labour; Land equivalence ratio; Average Annual Production - Return costs ratios = Revenue/cost; Benefit/cost ratio; Economic ratio input/output - Any other
Barrier and facilitators to uptake	E.g. Skills; knowledge; experience; capital Investment; financing options; labour; fertilizer; marketing system; policy implication; group dynamics; access to technology; Training; technology; information system; education

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APPENDIX I Scoping searches

Search terms were formulated by the review team. A scoping search was performed to validate the methodology. Keywords were tested for specificity and sensitivity using the online database ISI Web of Knowledge (core collection).

Table 1. Scoping searches in Web of science

Table 1. Scoping searches in Web of science

Database	Search string	Number of articles	Date
WOS, core collection, Topic, all years	TS=(((rubber) NOT (tyre OR synthetic* OR man*made)) AND (sustain* OR "best practice*" OR inter*cropping* OR diversif*))	1, 064	16.01.19 Economic terms need to be added.
WOS, core collection, Topic, all years	TS=(((rubber) NOT (tyre OR synthetic* OR man*made)) AND (sustain* OR "best practice*" OR inter*cropping* OR diversif* OR economic OR poverty OR income OR livelihood))	1, 851	16.01.19 Economic terms need to be added.
WOS, core collection, Topic, all years	TS=((rubber) NOT (tyre OR tire OR synthetic* OR man*made)) AND TS=(sustain* OR "best practice*" OR inter*crop* OR diversif* OR	1,119	29.01.19 Economic terms added.

	technolo* OR innovat* OR economic OR poverty OR poor OR inequal* OR income* OR livelihood* OR profit* OR risk* OR portfolio* OR variabilit* OR yield* OR productivity OR efficien* OR stability OR wealth OR optimi*ation* OR maximi*ation) AND TS=(Farm* OR plantation* OR tapp* OR agro*forest* OR rural OR smallholder*)		
WOS, core collection, Topic, all years	(rubber) AND NOT (tyre OR tire OR synthetic* OR man*made)) AND (Farm* OR plantation* OR tapp* OR agro*forest* OR rural OR smallholder*) AND (sustain* OR "best practice*" OR inter*crop* OR "mixed farm*" OR multi*crop* OR	1,282	29.01.19 mixed and multi crop terms added This search string will be used

	diversif* OR technolo* OR innovat* OR economic OR poverty OR poor OR inequal* OR income* OR livelihood* OR profit* OR risk* OR portfolio* OR variabilit* OR yield* OR productivity OR efficien* OR stability OR wealth OR optimi*ation* OR maximi*ation OR return* OR financ* OR benefit* OR gain*)		