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Final report

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1 Acknowledgments

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List of acronyms

ACIAR	Australian Centre for International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CARDI	Cambodian Agricultural Research and Development Institute
CGIAR	Consultative Group on International Agricultural Research
CMD	Cassava Mosaic Disease
CRP	CGIAR Research Program
CWBD	Cassava Witches Broom Disease
DAFO	District Agriculture and Forestry Office (Laos)
IBM	Inclusive Business Models
IFAD	International Fund for Agricultural Development
HCMC	Ho Chi Minh City
HT	Humid Tropics
K	Potassium
MAFF	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
N	Nitrogen
NAFRI	National Agriculture and Forestry Research Institute of Lao PDR
NPK	Nitrogen:Phosphorus:Potassium
P	Phosphorus
PAFO	Provincial Agricultural and Forestry Office (Laos)
PDAFF	Provincial Department of Agriculture, Forestry and Fisheries
PIM	Policy Institutions and Markets
RTB	Roots, Tubers and Banana
SNV	Netherlands Development Organization
UQ	University of Queensland

2 Executive summary

The overall aim of ASEM/2014/053 was to identify the socio-economic conditions under which improved technology and market booms in commercial crops such as cassava can be harnessed to increase the profitability and sustainability of smallholder farming systems in the poorer countries of Mainland Southeast Asia and thereby contribute to poverty reduction.

In order to achieve this aim, the project had 3 interrelated objectives:

Objective 1 – Assess the current production, marketing, and institutional arrangements for cassava in major agroeconomic zones and value chains in Laos and Cambodia.
Objective 2 – Increase the adoption of improved cassava production, resource management, and post-harvest practices by strengthening linkages between farmers and research, extension, and industry actors.
Objective 3 – Develop capacity for farming systems research and policy analysis and promote policy dialogue on the opportunities for industry development and livelihood enhancement through supported smallholder models.

Key Project Findings and Recommendations
Evidence on the structure and impact of the sector on livelihood and economic development at different scales
The level of understanding of the cassava sector is relatively poor across scales and actors - from farmers in the village to national policy makers. The project was able to provide evidence on the contribution of the industry to household livelihoods, local economic development and the national economy. This has been subsequently used to inform large investment and development projects; government and industry stakeholders. Ongoing collection of market trends and household information across priority crops and activities is important to enable evidence-based decisions. This is particularly important given the ongoing need for the public sector and development partners to ensure the scaling of some technologies in certain value chains given the lack of incentive for the private sector to take a leading role.

Review incentive structure for projects with private sector partners identified as central to the impact pathway
Project research demonstrates that the scaling approach of always emphasising the role of the private sector as part of their impact pathway has several limitations depending on the specifics of the technology and value chain context.

It recommended that technical and development projects have sufficient resources to be able to evaluate the incentive structures for private sector involvement in technology dissemination. If there are limited incentives for the private sector, then the role of public sector and non-government actors in dissemination should be emphasised and fostered through appropriate training and capacity building

Working closer with development projects that can incentives activities, particularly those with link to finance sector and development projects

The project highlighted that in many situations in Laos and Cambodia there is an absence of appropriate private sector partners or there is a lack of incentive for private sector actors to engage with scaling technologies to smallholders. In this situation, an appropriate response is to develop closer links with multi-lateral and bilateral development projects which can support scaling of technologies to improve smallholder livelihoods and also can facilitate access to credit. The is significant scope for achieving impact by coordination with both development project directly targeting the sector (e.g. IFAD in Cambodia) and projects working in communities where cassava is a predominate crop (eg. LURAS in Laos).

Behavioural change and nudges.
In some cases, the agronomic results and the economic analysis showed very high economic returns to changed practices. The case of fertiliser is a good example where a relatively small outlay produced a significant return. Yet, follow up interview showed many farmers although recognising the benefits of fertiliser and interest in receiving free fertiliser (or on credit), indicated that they would not purchase fertiliser on their own accord often attributed to saving and

expenditure habits. That is, the income generated from the previous crop was already exhausted by the time fertiliser should be applied.

The project identified situations in which processors may bridge the gap by providing fertiliser on credit. However, this situation is not always relevant either due to the lack on processor (Cambodia) or strong competition and uncertainly between processors (Laos). Therefore, models for engagement with support value chain actors need further development. A number of 'nudges' rather than incentives could be explored. This could include exploring various pre-commitment mechanisms and links to financial services – nudging savings at harvest time, rather than loans and credit. As ACIAR continues to invest in research on financial services for farmers and value chain actors there is opportunities to link this to some situations identified in this project.

Establishing cassava innovation working groups and multi-donor activities

There have been attempts to coordinate activities in Cambodia with the Cassava Working Group. Greater coordination in activities and investments between different programs and projects would enable efficiencies and scaling and avoid multiple projects seeking technical advice from staff on an adhoc basis.

Similarly, in Laos there remains strong potential for more strategic collaboration to ensure efficiencies and sustainability. The National level training facilitated in 2021 partly supported by multiple projects is an example. Mechanisms for maintaining multi-stakeholder platforms in the absence of an external project and facilitation remain to be developed.

Seed system development to manage cassava disease

The importance of farmers having access to disease free planting material has been highlighted during this project. This project has provided the justification and established initial partnerships for this to occur. This recommendation has been taken forward in the new ACIAR project AGB/2018-172.

Investment in research on sustainable cassava systems meeting farmer needs

Project Research showed that conservation technologies that have been developed and promoted in the past (including intercropping and grass strips) have not been widely adopted and farmers continue to express a lack of interest once the additional labour requirements become apparent. This is common to many sectors with livestock forage systems such as cut-and-carry becoming increasingly unpopular with farmers who now prefer to establish pastures for grazing.

It is critical that new technologies are developed that address both the sustainability concerns and farmers interests. This is likely to include exploration of rotational systems, the role of mechanisation, and forage-livestock integration. This work needs to be conducted both on-station and on-farm and should engage a multidisciplinary team of physical and social scientists.

Impacts

Scientific impacts of the project that have the potential to extend over the coming 5 years include adoption by others of innovations in methods of working across different scales of value chains, disease screening and incorporation of economic assessment into promotion of conservation agriculture technologies.

The project has had *capacity building impacts* within CARDI and NAFRI, especially in the field of value chain assessments and market research which is of critical importance for developing more comprehensive research capacities. Project outputs have been extensively used by next users including FAO, UNDP, IFAD, IFC, WorldBank, ADB, USAID, AustralianAID, Khmer Enterprises, Helvetas, Winrock International and LuxDev. Key *economic impacts* of the project include potential gains of around USD11 million per year to Cambodian farmers resulting from a 10 percent increase in the adoption of disease resistant varieties trialled in the project. Significant economic benefits could accrue with adoption of fertiliser formulations developed and trialled under the project. Even a relatively modest fertiliser adoption rate of 10 percent in the 4 project districts in Laos could deliver annual benefits of more than USD 1 million to farmers and an additional USD500,000 per year to other value chain actors. In Cambodia, 10 percent adoption of project trialled fertiliser formulations could result in annual increase in net benefits to farmers of USD9.2 million.

3 Background

Importance of Cassava in Southeast Asia; For smallholders and the broader region:

The production, processing and use of cassava (*Manihot esculenta* Crantz) in Southeast Asia constitute a highly complex value chain that is undergoing rapid development. Globally, cassava is the world's seventh most important food crop in terms of area planted but ranked third in the tropics. While traditionally a subsistence crop, cassava has become a very important cash crop in Southeast Asia in terms of smallholder income and rural livelihoods, with significant contributions to regional and national economies. The global trade in cassava products (starch and dried cassava) has increased substantially in recent years and is now valued at around USD 3.79 billion annually (Commtrade). Both production and consumption of traded cassava are concentrated in Asia, which accounts for over 95% of global exports.

Increasing level of cassava production/ growth in Cambodia and Laos and the dominance of large land concessions resulting in uncertain impacts upon smallholders:

Changing trade policies and rising incomes in Asia have also seen the market for cassava products become increasingly focused on Asia, particularly China. Cassava production increased rapidly, first in Thailand and then in Vietnam, to meet the new market opportunities in the 1980 and 1990s. However, there is now limited opportunity for further expansion in these countries, with the industry turning to Laos and Cambodia (Table 1).

Table 1 – Area of cassava production in Southeast Asia (2015-2019)

Country	2015	2016	2017	2018	2019
Cambodia	598,949	675,126	612,861	650,510	652,531
Lao PDR	75,465	75,810	70,930	71,010	101,494
Myanmar	36,234	36,609	34,703	31,278	33,387
Viet Nam	567,998	569,233	532,501	513,021	519,300
Indonesia	949,916	822,744	772,975	697,384	630,000
Thailand	1,433,815	1,377,553	1,338,957	1,385,817	1,386,655
Total	**3,662,377**	**3,557,075**	**3,362,927**	**3,349,020**	**3,323,367**

The area of cassava in Cambodia has increased by 15 folds in the past 10 years. In Laos the increase has been more recent, with a five-fold increase in the past 5 years. Cassava has surpassed maize as the second most widely cultivated annual crop in Cambodia and has recently been included as one of seven priority crops in Laos. In both countries many farmers have been moving out of maize and into cassava due to biophysical and market conditions. The rapid growth has also been accompanied with various arrangements emerging between industry and smallholders, varying from large estates to smallholder-oriented models.

Increasing demand has been driving a process of commercialisation of cassava which smallholders are having to adapt to in response to these changing opportunities and constraints. Unlike in Indonesia and Vietnam, where smallholder production dominates, large land concessions have been a more common feature of industry growth in Laos and Cambodia, with often unfavourable impacts on smallholder livelihoods. As a result, while commercialisation has often seen average cash incomes rise, it is less clear how this translates into livelihood outcomes such as improved food security and poverty reduction, and how these benefits have been shared within communities (based on wealth, ethnicity, and gender). There are also concerns around the sustainability of soil management and the future income streams.

Cassava links to other commodities and global markets increasing volatility and risks to smallholders:

The market outlook for cassava remains strong, but is now coupled to the volatile energy market, with biofuel mandates changing regional market dynamics. This coupling has increased the connections to other commodity markets, notably for maize and sugarcane, where cassava is a substitute in both production (competing for land) and in a range of starch and feed commodity markets. In addition, its growing demand as a 'feedstock[1]' has seen significant investment by domestic and foreign companies from contract farming with selected smallholders through to large-scale land concessions and estates. As such, the future of the regional cassava market is heavily influenced by external factors, including agricultural policies for a wide range of commodities, especially Chinese policies impacting on the domestic maize sector. With the emergence of various cassava value chains, smallholders have been linked to global markets and exposed to associated risks crucially influencing livelihood outcomes; which are still poorly understood.

Cassava is an important crop for poor farmers, but its sustainability is under pressure from various internal and external factors:

Sustainable commercialisation of dryland farming systems, especially in the sloping uplands, is a policy priority for governments in the region but remains a challenge (Coxhead et al. 2010; Castella 2012; MSU and MDRI, 2013). Cassava production is in many ways an ideal activity for resource-poor farmers, which makes it potentially important for local livelihood development in marginal communities. However, in both countries it has attracted limited government investment relative to other crops and continues to face concerns over environmental sustainability. The livelihoods of producers and the environmental and economic sustainability of the industry are under increasing pressure from a number of internal and exogenous factors:

- changing global, regional, and national trade and market policies related to starch, feed and biofuel (for cassava and substitutes such as maize and sugarcane);
- infrastructure problems reducing the competitiveness of regions in the global market;
- soil erosion and decline in soil fertility in areas where the crop is not managed appropriately;
- emerging pests and diseases throughout Southeast Asia;
- rising labour costs and difficulty in mechanising the production system;
- continued underinvestment in cassava development by private and public institutions, relative to other crops such as maize.

The promise of new technologies and research directions to address existing and emerging issues with cassava

Governments in both countries want to increase smallholder productivity and improve livelihoods, while protecting the resource base, but conventional state-based research and extension approaches have had limited impact. However, there are opportunities for improving productivity with the adoption of a backlog of cassava technologies that are potentially suitable to different locations within the two countries. The adoption of new varieties and improved practices has markedly contributed to the increase in average yields of cassava in Southeast Asia from about 12 t/ha in 1984 to 21 t/ha in 2013, hence there is an expectation that these include "best-bet" technologies. However, it has become clear that progress in developing improved varieties and crop and soil management practices in many areas has been constrained by limited use of standard evaluation and demonstration trials for the selection of the best adapted varieties and practices with local farmers. Furthermore, impact pathways for new technologies and information products (particularly for pest and disease management) need to be evaluated in these different settings.

In order to address this void in research the project planned on focusing on three broad technologies – new varieties, soil and nutrient management, and pest and disease control. The rationale behind the choice of these technologies were (a) the backlog of research outputs from CIAT and national research partners providing suitable options for testing and demonstration in the case-study sites and (b) the ability of these technologies to address the major issues facing smallholders in the two countries. These technologies include improved crop management practices including selection of good planting materials, improved tillage practices, fertiliser application methods, soil fertility management and erosion control, efficient weed control, pest and disease management, and the proper use of improved cassava varieties within the context of existing farming systems. Thus, the project aimed at providing an opportunity to develop new impact pathways for CGIAR and national

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[1] *Feedstock refers to the raw material supplying and industrial process and should not be confused with stock feed (animal feed)*

research systems by linking this research with the interests of actors along the different value chains. Secondly, to identify technologies that have not scaled and unlikely to do so due to their inherent characteristics in the current livelihood and market context.

While the identification of suitable technology is necessary, it has been well acknowledged that solutions to increasing productivity need to be market driven, with the private sector playing an important role in linking technologies to farmers. As such extending potentially suitable technologies to farmers not only requires testing them in different agro-ecological zones, but also across different agro-economic zones representing a diverse range of production and value-chain settings. Identifying and evaluating new agribusiness models to increase the adoption of improved technologies is important to ensure research outcomes translate into development impacts and that the benefits are shared within the community.

To test technology adoption/ dissemination across different value chain structure to assess incentive structures:

The working hypothesis of the project was that there are incentives for cassava value-chain actors to work together to increase productivity and sustainability through the adoption of improved practices. In particular, agribusiness firms investing capital in processing facilities have a strong incentive to expand and maintain the supply of feedstock from the surrounding region. If farmers' yields are low and fluctuating, and at high risk of declining over time due to soil degradation, it is in the processor's interest to help promote improved varieties, better nutrient management, soil conservation, and pest and disease control. This will help to sustain an optimal throughput and reduce the processor's average costs and risks. However, if there are several processors in a region, there is also an incentive to free-ride on the efforts of others unless actors can be assured of sharing the costs and benefits of industry development.

The project intended to explore the potential for promoting adoption of a range of improved technologies (production, processing, resource management) in various cassava value chains by involving and linking primary value chain actors (farmers, traders, processors) and support actors (researchers, government agencies, industry bodies). The incentives for the involvement of private-sector actors was believed to vary between the different technologies, production locations, and value-chain settings.

4 Objectives

The overall aim of this project was to identify the socio-economic conditions under which improved technology and market booms in commercial crops such as cassava can be harnessed to increase the profitability and sustainability of smallholder farming systems in the poorer countries of Mainland Southeast Asia and thereby contribute to poverty reduction.

The research questions guiding the project focus on the potential for improving the profitability and sustainability of smallholder cassava production in Laos and Cambodia.

1. What is the role of cassava in smallholder livelihoods under different production, processing, and marketing systems (value chains), and how have these systems contributed to changes in livelihood outcomes (food security, income generation, resilience) at household and community levels?
2. How do alternative cassava production and marketing arrangements affect the adoption of better technologies, improvements in farm incomes and livelihoods, and the distribution of benefits within and between communities (including by wealth-class, ethnicity, and gender)?
3. What are the appropriate support services and policies to ensure that smallholders are involved in profitable and sustainable cassava-based farming systems and that poor and marginalised groups are not adversely affected by industry development?

The project objectives arising from these research questions are as follows:

Objective 1 – Assess the current production, marketing, and institutional arrangements for cassava in major agroeconomic zones and value chains in Laos and Cambodia.

1.1 Understand the macro-level drivers for the development of the local cassava industry in different agroeconomic zones in each country, including changing market conditions and policy settings.

1.2 Map the cassava value chains of inputs, outputs, and supporting services, including how benefits and costs are shared, how information moves along the value chain, and assessing the current capacity of value-chain actors (public and private) to provide information to farmers effectively.

1.3 Develop a practical typology of farm households in current cassava-growing regions, including their crop and livestock activities, livelihood strategies, decision-making, and constraints to adoption of improved technologies.

1.4 Understand local networks of social and economic relations affecting access to and collective management of farm resources, and access to input and output markets. Compare how factors such as gender and ethnicity impact these norms and implications for approaches in Objective 2.

Objective 2 – Increase the adoption of improved cassava production, resource management, and post-harvest practices by strengthening linkages between farmers and research, extension, and industry actors.

2.1 Assess current production systems for cassava as observed in the different household types and value chains identified under Objective 1, including varieties used, management of planting material, soil and nutrient management, intercropping, labour utilisation (including gender division), and post-harvest practices, and constraints to adoption of improved technologies.

2.2 Conduct participatory evaluation of new varieties, fertility management, pest and disease management, intercropping, and post-harvest practices (such as improved production of dried chips to meet alternative market demands) with farmers and industry stakeholders.

2.3 Identify incentives and business opportunities for value-chain actors to increase the adoption of improved technologies (e.g., processors interested in assuring their supply of cassava roots, producers of clean planting material, fertiliser dealers, markets for intercrops).

2.4 Develop and document successful models for supporting cassava smallholders in adopting improved practices, highlighting roles for farmer groups, industry stakeholders, and government research and extension services.

Objective 3 – Develop capacity for farming systems research and policy analysis and promote policy dialogue on the opportunities for industry development and livelihood enhancement through supported smallholder models.

3.1 Understand existing local and national policies and priorities and implications for scaling up research outcomes.

3.2 Facilitate dialogue between local actors to enable outcomes to inform provincial planning and policies aimed at supporting industry development and smallholder livelihoods.

3.3 Facilitate a learning alliance between national partners and industry associations to share lessons from the project between sites and inform national policy.

3.4 Develop local capacities for farming systems economics, value chain analysis, and evidence-based policy analysis and dialogue.

5 Methodology

5.1 Conceptual Framework

Within countries and communities, cassava is cultivated by heterogenous smallholder farmers who have diversified livelihood portfolios in which other a range of activities compete for land, labour and capital. Importantly, this includes the non-farm sector that provides attractive opportunities both within the country and abroad. Cassava producers in Laos and Cambodia include households of different socioeconomic, ethnic and cultural backgrounds. Finally, the biophysical conditions at the plot level vary greatly and will determine the suitability of different 'technologies' and the agronomic and economic impacts of their adoption.

The term "technology" as used here refers to the knowledge incorporated in farming systems, whether as farming practices (such as cropping patterns) or embodied in material inputs (such as crop varieties and fertilisers). It is recognised that technology has multiple sources and is not simply transferred uni-directionally from researchers to farmers (Biggs, 1990; Cramb, 2003; Williams and Cramb, 2020).

However, there is often a case for taking technologies that have been co-produced in a particular location by farmers, researchers, and others and transferring them to new locations where they appear to have potential for widespread adoption. Given the high degree of location-specificity of agricultural technologies, these transferred technologies still need to be tested and adapted before broad-scale adoption is likely to occur. It is this more nuanced process of technology transfer, adaptation, and adoption that is assumed within the project.

We argue that the discussion of value chains as conduits for the transfer of technology to farmers often lacks a nuanced appreciation of the varying incentives and capabilities of actors in different value chains. Not all value-chain actors will be aware of or interested in all technologies, or have an incentive to invest in adapting and transferring these technologies to farmers. Hence, in addition to the attributes or characteristics of the technology and of the population of potential adopters– it is necessary to consider the *characteristics of the value chain in which the potential adopters are embedded*. These characteristics will influence both the relative advantage of farm-level adoption to different value-chain actors and the learnability of the technology in question, that is, the ability of value-chain actors to learn about and communicate the technology.

Our approach was to expand on existing adoption/diffusion frameworks (for example the Smallholder Adoption and Diffusion Outcome Prediction Tool (Brown, Nidumolu et al. 2016)) to incorporate features, not only of the technology and the production system, but of the value chain and value-chain actors. We used this expanded three-dimensional framework to examine the potential level of engagement of value-chain actors with the development and diffusion of smallholder cassava technologies.

Technology: The *intrinsic characteristics of the technology* include the learnability of the technology and the relative advantage of the technology. Key elements of the *learnability characteristics* include (1) the observability of the technology itself and/or of the results of using it; (2) the complexity of the technology; and (3) the ease of trialling the technology. These variables contribute to the potential scale of diffusion of a technology. For a given commodity, the learnability characteristics of a technology would remain relatively constant across different communities. The key variables for the *relative advantage* of a technology include the upfront cost, the degree of reversibility, the profitability of the technology now and in the future, the costs and benefits to the community and their timeframe, the associated risks, and the ease and convenience of applying the technology.

Production System: The *production system characteristics* that influence the potential scale of diffusion of a given technology and the engagement of value chain actors include (1) agronomic characteristics; (2) socio-economic characteristics; and (3) political characteristics.

Value-Chain: The potential scale of diffusion of a given technology is influenced by the *value-chain characteristics*. The scope of linkages between actors in the value chain, the presence of well-functioning external support services, and high levels of existing skills and knowledge among value chain actors lead to an increased level of cohesiveness of value chains and effective transmission of information. These combine with the level of awareness of innovations within the value chain and the learnability characteristics of the technology to affect the scale of its diffusion among farmers. The *incentive for a value-chain actor* to engage with the technology is influenced by the actor's profit orientation and risk orientation, the degree of competition faced, the scale of the enterprise, the management horizon, and any short-term constraints.

Using this three-dimensional framework for analysing engagement and diffusion through value chains will enable better targeting of support interventions. An analysis of the different characteristics can assist in decision making around which technologies have potential, which value-chain actors could be potential partners, and where investments could be made to enhance engagement, diffusion, and adoption.

This conceptual framework is used to analyse the incentives for private value-chain actors to invest in the promotion of different technologies in contrasting cassava value chains. In the following section results and discussion are presented from activities conducted in Laos and Cambodia. These can be compared and contrasted to other cases in Vietnam and Indonesia (AGB/2012/078) for a richer analysis of alternative contexts that impact adoption and scaling of technologies in the cassava sector.

Box 1 - Publications on the conceptual framework

Can the private sector help deliver improved technology to cassava smallholders in South East Asia? Newby et al. Knowledge Management for Development Journal, Vol. 15 No. 2 (2020): The unusual suspect? The private sector in knowledge partnerships for agricultural and rural development

Developing value-chain linkages to improve smallholder cassava production in Southeast Asia; Dominic Smith, Jonathan Newby and Rob Cramb, Discussion Paper Number 3, May 2018

5.2 Research approach

The project aimed at identifying the potential for the adoption of a range of existing improved technologies (production, processing, resource management) by involving and linking farmers, farmer groups, traders, processors, researchers, government agencies, and industry bodies. This required a multiple case-study approach in which mixed methods were used to understand the various processes at work and action research was undertaken to experiment with alternative arrangements appropriate to each context. Hence the project established sites in each country which represented various production, processing, and marketing systems.

Within these case-study/action research sites a range of conventional quantitative and qualitative techniques were used, drawn from the repertoires of rural livelihoods analysis, agrarian systems analysis, and value-chain analysis (including primary actors, supporting actors, and the policy environment). The aim of these analyses were to understand the livelihood resources, strategies, and trajectories of cassava-based smallholders, the influence of the wider agrarian system on the opportunities and constraints faced by these smallholders (e.g., access to land, capacity for collective action, risks, poverty traps, policy constraints), and the attributes and incentive structures of the other actors in the cassava value chain(s) in each site (input suppliers, traders, processors, extension workers, local administrators). These analyses relied on structured and semi-structured face-to-face interviews with individual actors, small groups, and key informants along the value chain.

On the basis of these analyses, the project identified stakeholders (primary and supporting actors) and invited their participation in planning and implementing a range of improvements to the cassava value chain in each case-study area. These potential improvements were drawn from a pool of available and potentially adoptable technical innovations from ongoing international research activities (e.g., CIAT's cassava breeding and pest and disease management programs). A participatory research approach was used to select, adapt, and promote locally adoptable cassava technologies, centred on demonstration trials, field days, and participatory evaluations by farmers (men and women) and other industry actors. Where there were significant issues with existing technologies the project did not enter a technology redesign phase.

The participatory evaluation of demonstration trials helped assess the relative advantage and trialability of the technologies under local conditions and livelihood strategies. Economic analyses were also undertaken to quantify the returns and risks involved in adopting new practices. As these new arrangements and processes for technology adaptation and promotion were trialled at each site, viable models for improving the profitability and sustainability of smallholder farming systems were identified and described for a wider audience of end users.

In Cambodia, one case-study site was selected for the activities – Kratie, in the eastern part of Cambodia with strong links to the market in Vietnam. Activities were subsequently expanded into neighbouring Stung Treng Province as the market prices increased and the 'extensive margin' of production expanded.

In Laos, also, two case-study sites were selected – Bolikhamxai (where most production had occurred in the past), and Xayabouri (where there had been a recent swing from maize to cassava).

In each case-study site, the first phase involved value chain analyses to identify different product pathways (e.g., local production of raw starch for subsequent refining and export; production of dried chips for consumption), characterisation of the primary actors involved (e.g., small-scale local processors, cross-border traders, large-scale refiners), and an assessment of the capacity of support actors (researchers, extension services, input suppliers). These analyses were crucial in identifying and assessing potential modes of collaboration among value-chain actors.

In addition to the value-chain analyses, a number of villages were selected in each case-study site (i.e., 15 villages in three sites in each of Cambodia and Laos) for focus group discussions and farm household surveys. These provided detailed quantitative and qualitative information about agrarian institutions, livelihood strategies, farm types, the evolution of smallholder cassava systems, constraints to adoption of improved technologies and practices, contractual relations with value-chain actors, and potential for technical and institutional innovations. The surveys also provided a baseline for subsequent evaluation of localised, short-term project impacts.

Based on the analysis of the agrarian systems and associated value-chains, and consultations with key stakeholders, on-farm demonstrations of available cassava technologies were established, with support from relevant actors (government, business, development projects, and/or NGOs). These formed the basis of participatory evaluations by farmers and other actors in the value chains, both of the adoptability of the technologies and the potential benefits of industry promotion of improved production systems.

During the harvests of the final year's trials and demonstrations (October 2019 – March 2020), follow-up interviews with stakeholders were conducted to evaluate how the project interventions changed the knowledge, attitudes, skills, and aspirations (KASA) and led to changed practices of farmers and other actors within the different value chains.

The analyses of production and marketing systems and participatory evaluations of new technologies and institutional arrangements fed into a policy analysis and dialogue with key players in the cassava industry, including government planners and researchers, development project managers, industry actors and associations, farmer groups, and NGOs. The policy analysis involved quantification of identified improvements to cassava value chains and diagnostic appraisal of binding constraints to the realisation of those potential improvements (Hausmann et al. 2006). Spatial analysis of existing cassava production and marketing systems and potential sites for improvement was also undertaken. Formal opportunities were sought to present these analyses to policy advisors although experience had shown us that informal lines of communication can be more effective, along with a general readiness to insert specific policy advice into the policy process as opportunities arose (e.g., an unexpected ministerial request for policy options).

Until recently, cassava has not been a priority crop in the region. As such there are limited data available to policy makers on current area of production, yields, processing capacity, value chains, and market conditions. A final policy forum was to be jointly organised through this project and its sister project (AGB/2012/078) to present and discuss findings with key policy actors from each of the five countries participating in the two projects. Unfortunately, due to COVID-19 this did not occur and the information sharing was left at the national scale.

5.3 Research methods

The following research methods were utilised to understand the opportunities and constraints facing smallholder production and marketing of cassava within different value chains in Vietnam and Indonesia.

- A desktop review was undertaken to examine information on global and national cassava production, utilisation and trade, with particular reference to the main substitutes in production and final markets (e.g., maize, sugarcane, potato).

- Training was conducted in value-chain methodologies, economic analysis and gender analysis for personnel from this and other related projects. The project has had strong engagement with provincial governments in Xayabouly and Bolikhamsay in Laos, and Kratie in Cambodia. Provincial and national stakeholder meetings have been conducted in Laos with the participation of government and private sector actors. Private sector actors have been involved in the agronomic training activities and participated in value chain assessments in all sites.

- Cassava value chain assessments were conducted in each case-study area, including primary actors, supporting actors, and local policy environment. Additionally the role of gender in the functioning of the value chain was analysed.
- In Lao PDR, local value chain assessment was undertaken in Xayabouli Province. Within Xayabouli, this assessment included farmer focus groups and semi-structured interviews with value chain actors in Kenthao and Paklai Districts. The value chain assessments undertaken in Bolikhamsay, Xayabouly and Kratie have shown a large variation in production systems and household livelihoods within and between the sites.

- Diagnostic household surveys were carried out in identified feedstock supply zones to determine current farm-household types, livelihood activities, production practices, market linkages, decision-making, sources of information, risk profiles and constraints to adoption of improved practices baseline household surveys were developed in conjunction with partners in Laos and Cambodia. Surveys were translated into Lao and Khmer and loaded onto electronic tablets running the Commcare app. Training on the household survey and the use of electronic tablets for surveys was undertaken for the Laos survey team in Vientiane in April 2017. Household surveys were completed in Bolikhan and Viengthong districts of Bolikhamsay in May-June 2017, with a total of 180 surveys undertaken for the province. Surveys were undertaken in Xayabouly in July 2017 with total of 180 surveys. Household survey training and pre-testing were undertaken in Cambodia in late July 2017 and those in Kratie in August-September 2017.

- During the harvests of the final year's trials and demonstrations (October 2019 – March 2020) follow-up interviews were conducted to evaluate how the project interventions have increased the knowledge, attitudes, skills, and aspirations (KASA) and led to changed practices of farmers and other actors within the different value chains.

The following research methodologies focused on finding ways to increase adoption of improved cassava technologies through development of agribusiness models linking primary value-chain actors (farmers, traders, processors) and support actors (researchers, government and non-government agencies, industry bodies).

- Stakeholders identified in the value-chain assessments were invited to participate in project planning activities according to the circumstances and responses at each locale.
- Selected participants were trained by project staff in improved cassava cultivation practices, establishing demonstration trials, and participatory methods.

  Variety, fertiliser and intercropping trials were conducted annually through the course of the project in Kratie. Similarly, variety and fertiliser trials in Bolikhamsay, and variety, fertiliser and intercropping trials were conducted in Xayabouly annually.

- Participatory variety selection was conducted with farmers in identified supply zones and value chains, with varying levels of outside support from stakeholders and research institutions. A strong emphasis was placed on the involvement of private sector actors in facilitating this process with the view that they could continue the process beyond the life of the project.
- Discussions with stakeholders were used to identify opportunities for commercial production of healthy planting material where market demand exists in different value chains, and on-farm improvement where there is not potential market demand.
- Discussions with value-chain actors were undertaken to investigate cost-effective opportunities for them to communicate information on pest and disease management (identification, monitoring, and treatment) to farmers.
- Participatory evaluations were undertaken with value-chain actors (farmers, government, and industry partners) of improved soil and nutrient management practices and soil conservation systems (including intercropping) with a focus on assessing the economic returns and the constraints to adoption.
- Business plans were prepared to help evaluate opportunities for value-chain actors to promote adoption of appropriate fertiliser regimes (e.g., through the provision of credit or insurance).
- The effectiveness of linkages between value-chain actors were monitored and evaluated with stakeholders, and emerging agribusiness models were described and assessed in the form of business case studies. The evaluation was based primarily on “before-after” assessments, taking account of baseline data and external trends, rather than a “with-without” assessment.

The following research methodologies were used to disseminate and support more effective agribusiness models within the region

- A review was undertaken of local and national planning and policy timelines and procedures based on key-informant interviews to determine suitable entry points for developing continued support for the research outcomes.
- Stakeholder dialogues on the agribusiness models was organised in each of the four case-study regions to identify incentives for collaboration, problems, and solutions.
- A learning alliance was facilitated among key national stakeholders (national industry associations, government policy and research institutes, other development agencies) to share lessons and means of scaling out the successful project activities and identify constraints to collaboration.
- Evidence-based policy briefs were prepared on agribusiness models for improving cassava-based livelihoods, including opportunities for scaling out the approach and opportunities for industry collective action to increase and sustain smallholder productivity.
- A regional (Southeast Asian) dialogue was organised on cassava and related value chains and opportunities to support smallholder livelihoods and industry development (in collaboration with AGB-2012-078). While this was not able to go ahead, the results have been shared in the final project meetings. There remains good opportunity for sharing lessons learnt and challenges between different governments within the region.

6 Achievements against activities and outputs/milestones

Objective 1: Assess the current production, marketing, and institutional arrangements for cassava in major agroeconomic zones and value chains in Laos and Cambodia.

No.	Activity	Outputs/ milestones	Date Completed	Comments
1.1	Review information on global and national cassava production, utilisation, trade, and policies.	Review report	Annually	A database with updated information on regional and global cassava markets have been maintained through the duration of the project and updates on markets have been shared and discussed with stakeholders using the project website and via Facebook group updates. Results of the market analysis have also been presented at various workshops, symposia and conferences within Laos and Cambodia and internationally An interactive webpage has been developed with co-funding from RTB to continue to make data collected available https://cassavalighthouse.org/
1.2	Conduct value chain analyses in case study areas (primary and supporting actors, local policy environment).	Value chain reports	February 2017	Value chain assessments were undertaken in in Kratie, Bolkhamsay and Xayabouli. These assessments included farmer focus groups and semi-structured interviews with value chain actors in selected districts. Ongoing interviews were conducted with value chain actors with their inclusion in subsequent activities (field days, policy dialogues, symposium)
1.3	Conduct key informant and group interviews in case study areas to ascertain socio-economic relations affecting access to and collective management of farm resources and access to input and output markets.	Socio-economic analysis reports	April 2017	Key informant interviews and farmer focus groups were conducted in Kratie, Bolikhamsay and Xayabouly in conjunction with the value chain assessments. Ongoing farmers meetings occurred during farmer field days.

No.	Activity	Outputs/ milestones	Date Completed	Comments
1.4	Conduct household surveys in case study areas to determine current farm-household types, livelihood activities, production practices, market linkages, decision-making, and constraints to adoption of improved practices.	Household survey reports	July 2017	**Laos:** Household surveys were completed in Bolikhan and Viengthong districts of Bolikhamsay between May-June 2017, with a total of 180 surveys undertaken for the province. Surveys were completed in Xayabouly Province in July 2017. A total of 180 surveys were completed in Paklai and Kenthao Districts. **Cambodia:** A total of 311 surveys were undertaken in Kratie and Stung Treng **Reports and Presentations** The results of the household surveys have been included in project discussion papers and presented in various workshops, symposia and international conferences.

Objective 2: Increase the adoption of improved cassava production, resource management, and post-harvest practices by strengthening linkages between farmers and research, extension, and industry actors.

No.	Activity	Outputs/ milestones	Date Completed	Comments
2.1	Conduct workshops with identified stakeholders in each site to plan, prepare for, and review cooperative activities.	Workshops successfully conducted and reported.	March 2017	In Feb 2017 a small planning workshop was held in Vientiane with NAFRI, Province, and District staff, to plan activities and responsibilities. The team planning meeting was held at CARDI in March 2017 to plan activities and develop protocol.
2.2	Establish on-farm demonstration trials of improved cassava cultivation practices and conduct participatory evaluation of new varieties, fertility management, pest and disease management, intercropping, and post-harvest practices with farmers and other industry stakeholders. On-station research of key constraints, fertiliser balance and disease resistance (i.e. Cassava Mosaic Disease) to cassava production	On-farm trials successfully established Evaluation reports prepared Potassium balance in cassava production systems quantified; and partial resistances to CMD has identified	Establish Mar-Apr 2017 Harvest reports in Feb-March 2018-2019 April 2020	A total of 87 on-farm demonstrations (i.e. 64 in Laos and 23 in Cambodia) were conducted to disseminate project recommended technology (i.e. sowing method, timely weeding and fertiliser application) and use of high yielding varieties. In all demonstrations with very few exceptions; average yield of project recommended technology produced higher yield compared to framers' practice. Experiment on potassium balance was conducted. Result from the experiment was communicated to farmers via on farm demonstrations; commercially available fertiliser mix $N:P_2O_5:K_2O$ (14-5-35) and $N:P_2O_5:K2O$ (15-7-18) has been tested in Laos and Cambodia. Experiment on management of CMD was conducted in Cambodia. Best options from the results were communicated to farmers in on farm demonstrations (i.e. use of clean planting material, and variety KU50).

No.	Activity	Outputs/ milestones	Date Complete d	Comments
2.3	Develop business cases for value-chain actors to invest in adoption of improved technologies (e.g., production and supply of clean planting material, dissemination of information on pest and disease management, supply of suitable fertilisers and nutrient management information, provision of credit).	Business cases documented and discussed with stakeholders	April 2017 October 2017 July 2017-Jun2018	Economic Analyses and business case development was started in conjunction with the value chain analysis. Economic analysis of 2017-18, 2018-2019 and 2019-2020 trials have been conducted and have informed analysis of benefits and costs for different value chain actors.
2.4	Document successful models for supporting cassava smallholders in adopting improved practices, highlighting roles for farmer groups, industry stakeholders, and government research and extension services.	Working papers on smallholder models	July 2020	Working papers have been prepared on the role of value chains in disseminating technologies, including new varieties, fertilisers and improved soil management techniques. Potential models for cooperation between different stakeholder groups have been discussed at stakeholder meetings at both provincial and national levels Follow up interviews with farmers, government and industry stakeholders have been conducted in 2020.

Objective 3: Develop capacity for farming systems research and policy analysis and promote policy dialogue on the opportunities for industry development and livelihood enhancement through supported smallholder models.

No.	Activity	Outputs/ milestones	Completion Date	Comments
3.1	Review and document local and national policies with regard to smallholder cassava and identify opportunities for scaling up research outcomes.	Review report	Not completed as there were numerous existing reviews	A review of existing secondary information in both Cambodia and Lao PDR revealed that there are numerous existing reviews of agricultural and rural development policies which are directly relevant to cassava. It was decided that rather than replicate these existing documents in another report, that the project would concentrate on dialogue with stakeholders at local level on local policy settings impacting on cassava value chains. Frequent discussions have been held with stakeholders on this topic.
3.2	Conduct workshops to develop local capacities for on-farm research in cassava, farming systems evaluation, value chain analysis, and evidence-based policy analysis and dialogue.	Training workshops conducted, evaluated, and reported	February 2017	In both Lao PDR and Cambodia, training on sustainable cassava production with national, provincial, district staff, and the private sector have been conducted. Training on household survey implementation have also been conducted with local partner researchers. Training on value-chain analysis was conducted with partners. Training on economic analysis of agronomic data and scenario analysis was conducted.
3.3	Develop technical and policy briefs in local languages outlining the opportunities for improvement of a smallholder-based cassava industry.	Technical and policy briefs disseminated-ed	July 2020	Stakeholder briefs for both Cambodia and Laos have been developed and discussed with stakeholders. These stakeholder briefs cover key project topics including the cassava economy and status in each country, cassava variety use, fertiliser use, stakeholder linkages and pests and disease. Laos: Extension material made and distributed to DAFO, online, other projects. Featured in Ministry Magazine. A final policy brief was launched in 2021.

No.	Activity	Outputs/ milestones	Completion Date	Comments
3.4	Conduct dialogues between local actors to enable outcomes of research to inform provincial planning and policies aimed at supporting industry development and smallholder livelihoods.	Industry dialogues conducted	December 2019–January 2020 with final workshop and discussion in June 2020	District Stakeholder dialogues were undertaken in Xaybouly in August 2018 and in Bolikhamxay in November 2018. A National Stakeholder dialogue meeting was held in Vientiane, Laos during March 2019. Additional stakeholder discussions were held in 2020 at harvest field days involving farmers, DAFO, traders, processors, NGOs. Project staff contributed into existing dialogues organised by UNDP, CAVAC, GIZ, IFAD, IFC. No parallel national level workshops were initiated to duplicate these existing platforms. The national training and policy dialogue organised for 2020 was rescheduled and conducted in early 2021 with project participants from LURAS-Helvetas; CLEAN-Winrock; Local Development Program-LuxDev; FAO; Stakeholder discussion occurred during field days with farmers, government, processors and NGOs.

7 Key results and discussion

The production and marketing of cassava by smallholder farmers in Laos and Cambodia is part of a complex global value chain influenced by many factors outside the control of farmers or actors within these countries. However, despite fluctuation in price the sector provides a significant contribution the livelihoods of smallholder farmers engage in the industry, leads to economic development in rural communities and contributes significantly to the national economies of both countries.

The project posed the question of whether the productivity and sustainability of smallholder cassava production could be enhanced by strengthening market linkages to enhance the scaling of existing technologies. The results indicate that in reality the potential for scaling to occurred varies significantly between technologies and in the different production and value chain contexts.

The evidence outlined in the sections below indicate the higher likelihood of generating changed practices for new varieties; the importance of new models and partners to generate changed behaviour in the context of fertiliser; and the need for technology redesign together with farmers for technologies aimed at minimising land degradation to ensure that meet the current priorities and preference of farmers. That is, in some cases the binding constraint that need to be addressed are not directly related to the technology itself. In other cases, there is a clear need to continue to invest in technology development and refinement with farmers and other stakeholders.

Regardless of what technology or value chain context it was evident that the development of partnerships between public and private sector actors is required, and the need for better coordination between actors, ministries and development partners.

7.1 Objective 1

The following section presents some of the main factors influencing the trends and trajectories of the cassava sector and the livelihoods of cassava farmers. It is presented in four sections moving through the different scales: Market drivers and developments; value chain assessments; livelihood assessments; and cassava production.

7.1.1 Market drivers and developments

The regional cassava market experienced significant fluctuations during the project period. Both supply and demand were impacted by factors outside the control of farmers that influenced farm gate prices; the incentive for smallholders to change practices; and the incentive for different actors to engage in scaling.

On aggregate, cassava cultivation has remained relatively stable within the region in the past five year according to official statistics. The two notable exceptions are the continuing decline of production in Indonesia (-9.7%) and the significant increase in production in Lao PDR.

Table 2 – Cassava Production Area from 2015-2020

Country	2015	2016	2017	2018	2019
Cambodia	598,949	675,126	612,861	650,510	652,531
Lao PDR	75,465	75,810	70,930	71,010	101,494
Myanmar	36,234	36,609	34,703	31,278	33,387
Viet Nam	567,998	569,233	532,501	513,021	519,300
Indonesia	949,916	822,744	772,975	697,384	630,000
Thailand	1,433,815	1,377,553	1,338,957	1,385,817	1,386,655
Total	**3,662,377**	**3,557,075**	**3,362,927**	**3,349,020**	**3,323,367**

Collecting data on production and supply to inform decision making has a number of challenges. Production data was problematic to collect beyond the province level and with at least a year lag. In

Laos, the District level data was accessed through the individual year books of the Province. This data is held by DOA and was accessed via contacts in the Department of Policy and Law. Similarly, there is no central repository of district level data in Cambodia. GDA staff were able to consolidate some district level data for the main cassava producing provinces by contacting the PDAFF in each province. As such, the project has assembled the most comprehensive dataset of district cassava production that exists with the data made available online. Serious issues remain with the accuracy of data reported with informal discussion indicating that this could be underestimated by a factor of five is some districts depending what the official targets are. This is creating problems for priority setting and management of pest and disease, and has been discussed in different policy engagement meetings.

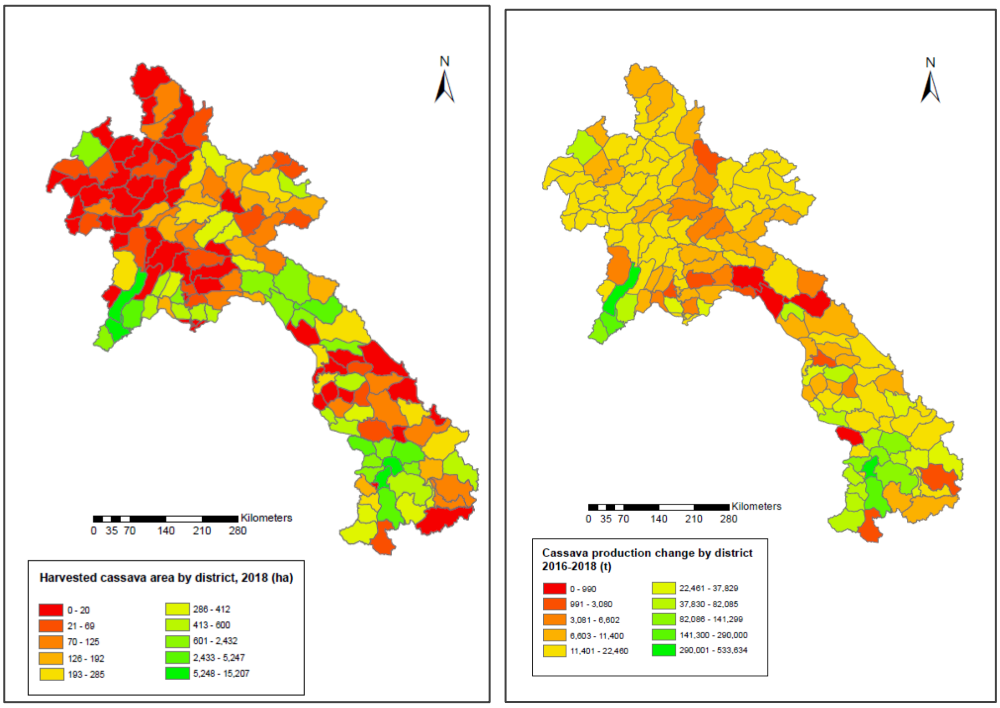

Figure 1: Example of district level data in Lao PDR. Panel a) District area in 2018; Panel b) Change in production 2016-2018

A comprehensive database has been created to monitor price and trade flows utilising published data, online national databases, and industry contacts. However, again price series data is more difficult to construct in Laos and Cambodia relative to Vietnam and Thailand. Import data from Thailand and Vietnam was initially used to understand the relative importance of each market and the seasonality of trade between countries. This showed the impact of market developments, policies and production changes due to pest and disease as well as floods and drought (although attribution is difficult).

Towards the end of the project, trade data from the Lao Ministry of Industry and Commerce was accessed, with a lag of around one year. However, this data was useful as it separated the export of cassava roots and cassava chips and also specified which port products were flowing. Data in Cambodia was also sourced by came with warnings on use due to well-known systematic errors to avoid tax.

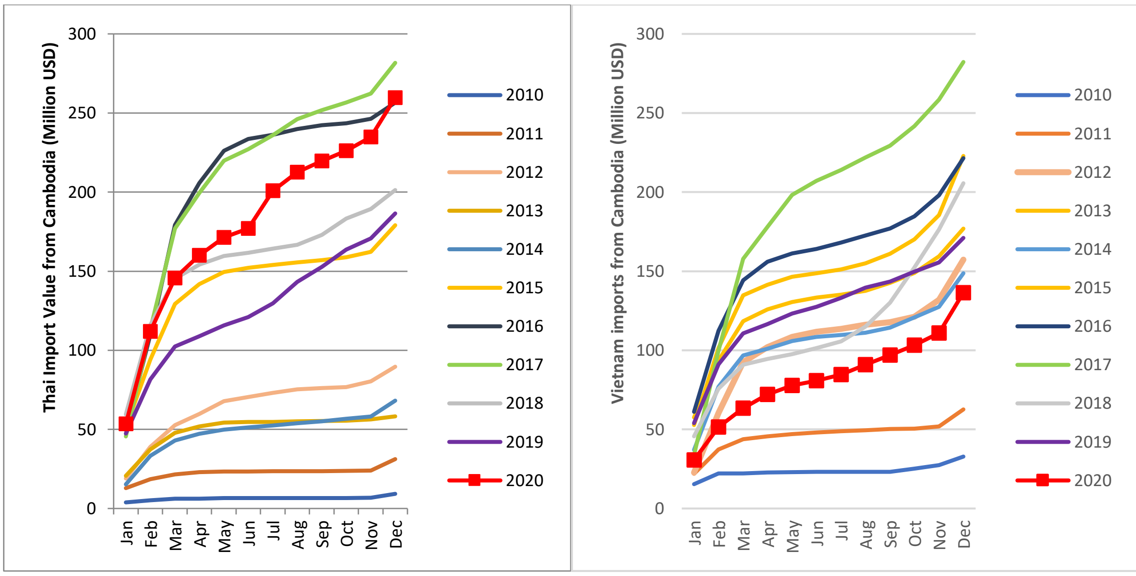

Figure 2: Example of trade data. Cumulative monthly value of Vietnam (left) and Thai (right) imports of fresh roots and dried chips from Cambodia

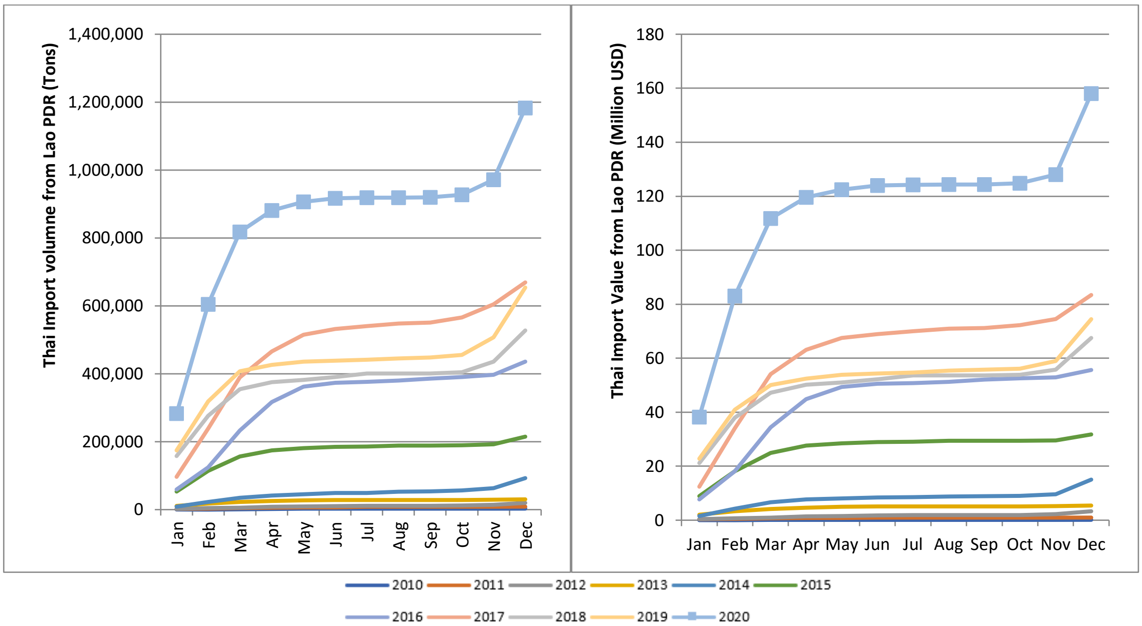

Figure 3: Volume and value of Thai cassava root and cassava chip imports from Laos (Source: Thai Ministry of Commerce)

Trade in cassava products includes cross-border trade in fresh roots; cross-border and regional trade in dried cassava chips; and global trade in cassava starch. While the global cassava trade remains a multi-billion-dollar industry, the aggregate value of traded roots, chips and starch declined by around 0.5 Billion USD from 2018-2019. This was largely driven by lower demand for cassava chips in China. The global trade in cassava products remains dominated by Asia as both the major source and destination. As can be seen in Figure 3, China remains the dominate market for both dried chips**2** and to a less extent cassava starch. However, the starch market still remains heavily geared towards East and Southeast Asia.

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[2]The 6-digit HS code 071410 aggregates both fresh roots and dried chips. Exports to China compose of dried chips while the total value includes the fresh roots traded between Cambodia and Laos into the Thai and Vietnamese market

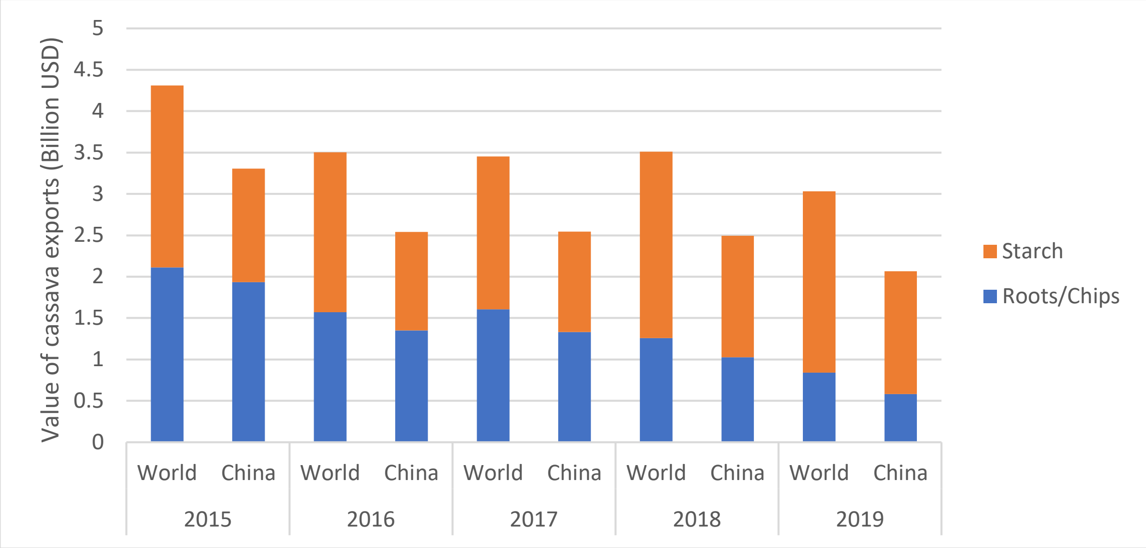


Figure 4 – Value of cassava exports by year to all destinations and China. (Source: Comtrade)

Cross border trade of fresh roots occurs within the Greater Mekong region, with roots sourced from Cambodia and Laos feeding starch and chip processing in Thailand and Vietnam. Thailand and Vietnam also import processed dried chips from its neighbouring countries largely for re-export given Laos landlocked nature and relative cost of exporting chips directly from Cambodia.

Table 3 – Value of cassava exports and imports from Thailand and Vietnam in 2019

Country	**Export**			**Import**
	Starch	Chips	Total	Root/Chips
Thailand	$1,219,667,300	$524,196,331	$1,743,863,631	$250,500,728
Vietnam	$870,353,340	$81,500,887	$951,854,227	$194,174,635
Total	$2,090,020,640	$605,697,218	$2,695,717,858	$444,675,363

Source: Comtrade

In 2020 there was some recovery in the export volume (27%) and value (33%) of cassava chips from Thailand into China. This trend is expected to continue into 2021 as the derived demand for cassava chips increased due to increasing maize prices in China. Starch exports declined slightly (2%) resulting in a reduction in export value by around 6.5 per cent. Higher starch prices have seen exports to Indonesia decline significantly as deep processor seek alternative feedstock for applications that are easier to substitute between starch types – i.e. toward maize.

Figure 5 – Value of cassava exports by year to all destinations and China. (Source: Comtrade)

As the project progressed the impact of cassava mosaic disease continued to spread within Cambodia, particularly in the project sites in the east of the country connected to the Vietnamese processing market and seed system. Shortages of roots in Vietnam resulted in a high price differential between Vietnam and Thailand, resulting in more roots flowing towards the Vietnam sector from deeper into Cambodia towards the Thai border. This re-orientation of roots and the extension of the 'extensive margin' changed the dynamics and potential for several partnerships in the project.

Table 4: Cassava Mosaic Disease by Country

	FIRST REPORTED	NUMBER OF PROVINCES	ESTIMATED CASSAVA AREA	IMPACTED AREA
Cambodia	**May 2015**	**14**	**587,120 ha**	**~205,500ha***
Vietnam	**May 2017**	**24**	**471,702 ha**	**~83,360 ha**
Thailand	**July 2018**	**32**	**1,048,660 ha**	**~80,785 ha**
Lao PDR	**July 2020**	**2**	**101,490 ha**	**20-50ha**
Myanmar	**NA**	**NA**	**33,390 ha**	**NA**
Total		**72**	**2,242,380 ha**	**~370,000ha**

These changes in global markets and supply impacted farm gate prices significantly over the project life. Root prices in 2016-2017 in project sites reached lows of less than $40 USD/t. The market went through a broad recovery in between 2017 and 2018 largely as a result of supply shortages in Thailand and Vietnam. Starch prices reached highs of $540 USD/t (FOB Bangkok) supporting the price of roots throughout the region. Farmers who continued to grow cassava after the price declines of 2016-17 enjoyed strong fresh root prices during this period, however disease pressure has started to impact yields, particularly in Cambodia where CMD has spread through the project province of Kratie. Prices have fallen steadily since mid 2018, and while the volume and value of chip production and export has declined markedly, the value of exports of starch from Thailand and Vietnam has reached record highs in 2019. (see Appendix 1 for more details).

Table 5 – Price used in calculations of economic impact of changed practices (Low, Medium, High) and the market high in 2020-21 season.

	Low Price	Medium price	High price	High Price 2020-2021
Bolikhan, Bolikhamxai (LAK)	300 ($35.30)	500 ($58.82)	600 ($70.59)	850
Viengthong, Bolikhamxai (LAK)	350 ($41.18)	500 ($58.82)	550	850
Paklai, Xayabouli (LAK)	400 ($47.06)	500 ($58.82)	580	850
Kenthao, Xayaboli (THB)	0.9	1.6	2	
Kratie Field (2018) (KHR)	60-80	230-240	340-360	

7.1.2 Value chain assessment in target regions

The value chain analysis conducted in the project took a holistic approach to analysis and includes consideration of direct actors, indirect actors and external influences. Direct actors are defined as those who are directly involved in the processes of bring the product from production to consumption – generally meaning those who take ownership and possession of the product. Indirect actors are those who have an influence on the value chain, but who so not take direct ownership and possession of the product. External influences that impact on the value chain include economic, environmental and socio-cultural forces.

In both Laos and Cambodia there were significant changes in the value chain structure and product flows during the course of the project, with new factories emerging to varying levels of success. A key feature in both cases was the cross-border trade and the tension between domestic processing and policies aimed at encouraging value-adding and the opportunity for higher prices for farmers by increased competition for raw material. This resulted in various ad hoc policies arising during the project, such as the ban of export of unprocessed roots from Xayabouli Province based on a provincial order.

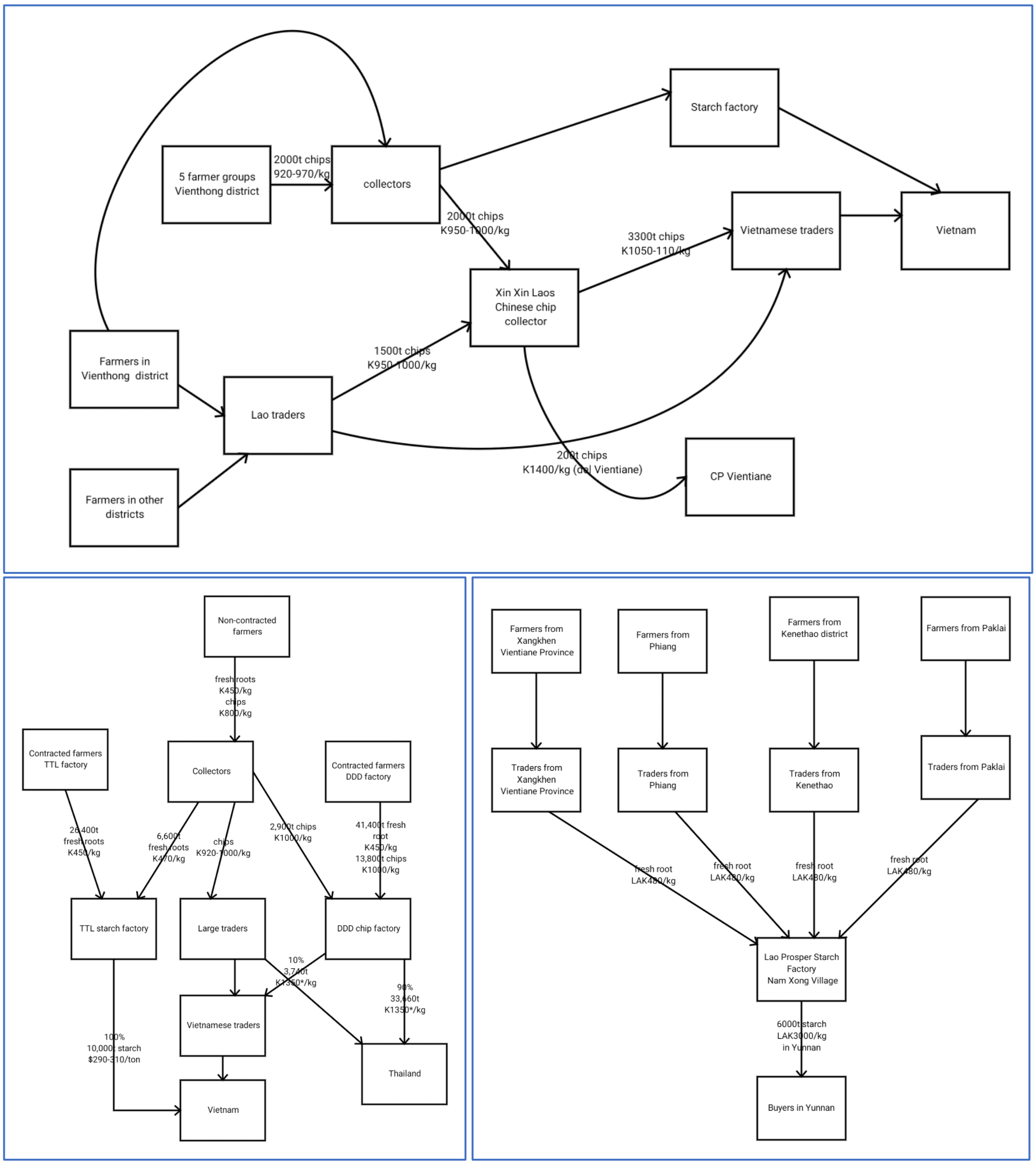


Figure 6 - Example of three different value chains in Laos highlighting why different entry points are required for stakeholder engagement.

The cross-border trade is required for the large majority of all cassava-based products from Cambodia and Laos, with the associated costs greatly impacting farm gate prices. For example, border costs between Cambodia and Vietnam were estimated to total USD7.27/ton, of which USD2.13/ton was incurred on the Cambodian side and USD5.14/ton on the Vietnamese side. For traders on both sides of the border, the cost of getting roots across the border far exceeded any other fixed or variable cost they incurred.

Based on the analysis of production and cross-border trade in cassava, spatial modelling was undertaken to predict the extent of the Cambodian supply zone providing cassava to Tay Ninh under relevant price and cost scenarios, including the elimination of border costs. The key to determining the supply zone is the relation between the price that traders can offer at the farm gate, allowing for transport costs, and the farmer's cost of production.

The value chain exercise was an important exercise to identity potential stakeholders to be consulted as activities in Objective 2 and Objective 3 progressed. It was also helped to explain to project partners the potential challenges of getting private sector partners to actively take a role in extension to farmers.

While the value chain mapping was not formally updated over the subsequent years, it became very apparent that the value chains in both Laos and Cambodia were very dynamic and it was important to continue to bring new stakeholders into the project activities where possible. There were a range of new market entrance in Cambodia and the rise and fall of companies in Laos.

Finally, the value chain mapping often presents a stakeholder as a company, e.g. Lao Prosper Starch Company. Whereas the project largely relied on forming relationships with individuals within these companies. This was often only made possible by having bilingual staff as part of the project team (e.g. Chinese speaking staff). This was particularly the case for foreign companies with head offices abroad that made it challenging to institutionalize any partnerships and progress interrupted if staff changed. Similarly, factory management often returned to their home country outside the processing season limiting the opportunities for engagement. Even when in the country, there were many decisions that needed to be determined by the management of the parent company.

Box 2 - Reports on value chain analysis in Laos, Cambodia and Myanmar

1. **Value Chain Analysis, Household Survey and Agronomic Trial Results – Lao PDR;** Vongphaphane Manivong, Laothao Youbee, Phantasin Khanthavong, Dominic Smith, Rob Cramb, Jonathan Newby and Lava Yadav, Discussion Paper Number 5, July 2018.
2. **Value Chain Analysis, Household Survey and Agronomic Trial Results – Cambodia;** Chea Sareth, Dominic Smith, Rob Cramb, Jonathan Newby and Lava Yadav, Discussion Paper Number 6, July 2018.
3. **Results of Cassava Processor Survey in the Ayeyarwady Region of Myanmar in 2018**; Tin Maung Aye, Nilar Aung, Kyaw Thura, Dominic Smith and Lava Yadav; Discussion Paper Number 13, September 2019.

7.1.3 Livelihood assessment of cassava farmers

It is important to recognize that farmers who grow cassava in the project sites in both Laos and Cambodia are not 'specialist cassava farmers' and are engaged in a range of other farm and non-farm activities that utilize resources (land, labour, capital) and contribute to the overall livelihood of the household. This is of particularly important when introducing technologies that require changes in labour and capital utilization. While agronomic and economic analysis at the field level may suggest a strong incentive for adoption – often there are other factors at the household scale which moderate these incentives.

In Laos, the production of paddy rice is an important contributor to livelihoods of households in all surveyed districts. Beyond this, rice production and self-sufficiency are import culturally and psychologically. The rhythm of the rice season dominates the planning of activities, and when labour is available for cassava production (planting, weeding and harvesting).

The importance of livestock varies significantly across districts with less than 5% contribution to household livelihood in Kenthao while this contribution is over 16% in Viengthong (where surveyed households were mainly Hmong). The importance of off-farm income is also quite variable across districts where it contributes to about 11% of household income in Kenthao while this contribution is slightly higher than 35% in Bolikhan. Tree crops on the other hand were not a significant source, contributing on average less than half a percent across all districts.

Once again, the livelihoods of households in were not static and households responded to a range of trends and shocks during the four years of the project. One example was the increased area of established forages in Kenthao during the period of low cassava price. These transitions were not universal and subject to ongoing research[3].

[3] *A PhD student from ANU selected project sites as case studies for their research on boom crops and livelihoods. Submission is expected in 2021.*

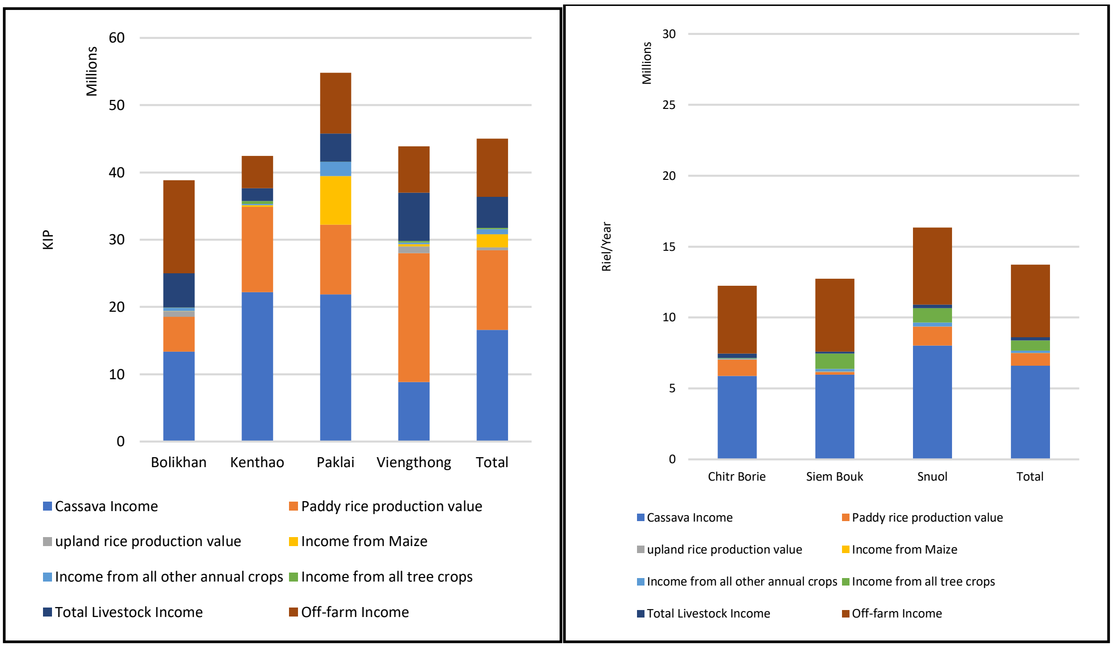


Figure 7: Source of Income, by District

On average, income from cassava production in **Laos** constituted slightly less than 37% of the overall household income. Households in Paklai district were most dependent upon cassava with income generated from cassava production contributing to over 52% of their household incomes. On the other hand, cassava production only constitutes about 20% of income for Viengthong households where it has been introduced more recently with a starch factory under construction at the time of the survey. Since that time, cassava area expanded sharply and prices increased significantly with the operation of the factory.

In **Cambodia**, across all surveyed districts cassava production was the most important source of income, contributing almost 50% of household income. Off farm income is the second most important source of income with a contribution between 30% to 40% to overall household income[4]. The importance of paddy rice varies across districts with a contribution of almost 10% to overall household income in Chit Borie while is it a low 1.5% in Siem Bouk. Tree crops on the other hand plays a more significant role in Siem Bouk contributing almost 9% to overall household income while they aren't a very significant source of income for Chit Borie where the investment is cashews had been less pronounced. Livestock production is not viewed as an income generating source with overall contribution of only 1.7% across all surveyed districts.

In Laos, the contribution of cassava to household incomes are quite consistent for the three lower income quartiles where it contributes between 45% and 48% of overall household incomes. However, for the highest income quartile this contribution falls to about 28%. While only about 10% of income is generated from off-farm work for the two lower quartiles, this proportion is roughly double (about 20%) for farmers in the third and fourth quartiles.

[4] *With COVID-19 impacting non-farm and migration sectors of the economy, a survey on the impacts of the pandemic on cassava producing household was underway in November 2020.*

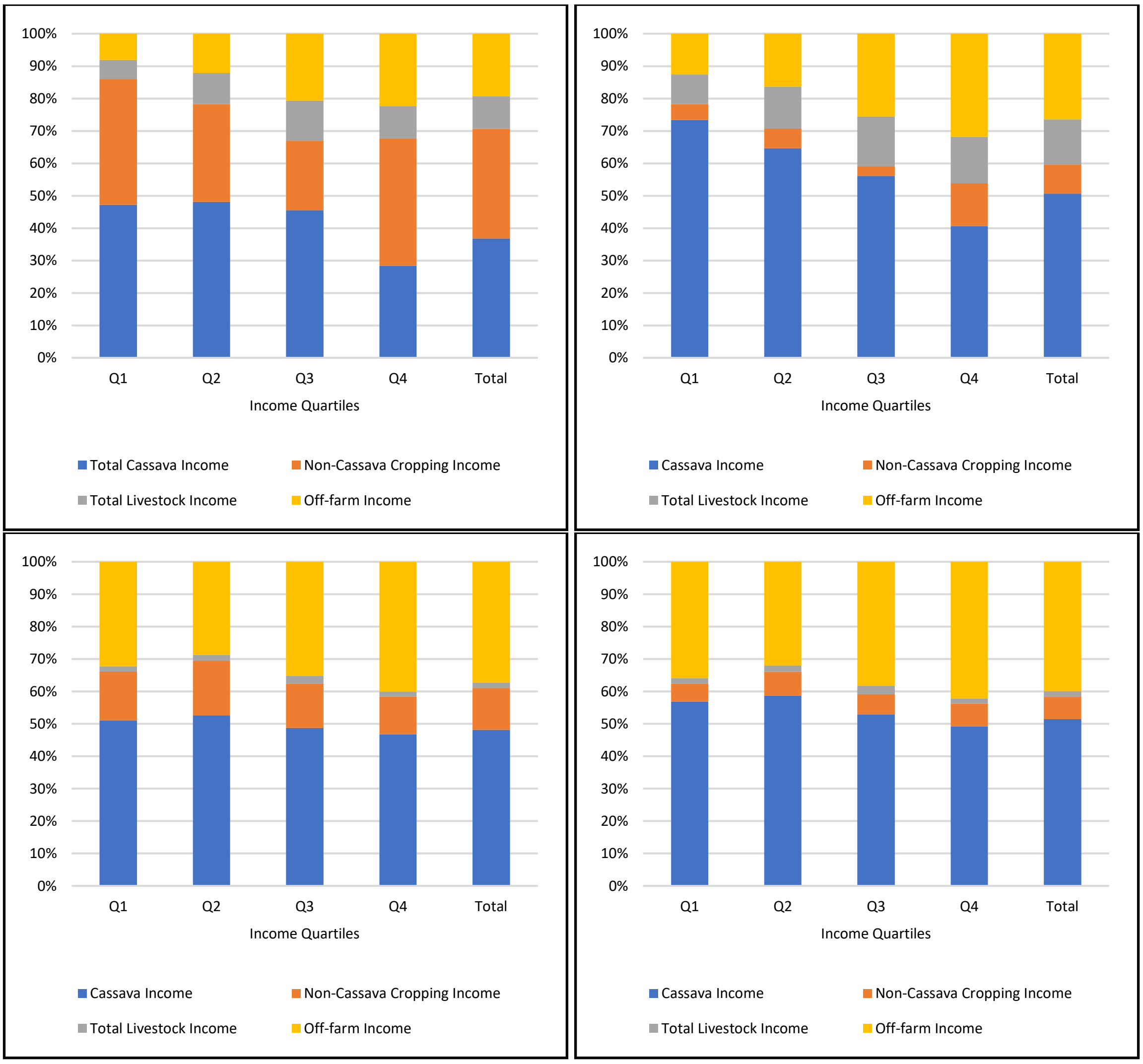


Figure 8: a) Laos - Sources of Livelihood, by Income Quartile; Panel b) Lao - Cash Income Source, by Income Quartile; Panel c) Cambodia - Sources of Livelihood, by Income Quartile; Panel b) Cambodia - Cash Income Source, by Income Quartile

The sources of cash income by income quartile are shown in Fig 8 panel b for (Laos) and panel d (Cambodia). This is derived by not including the value of the staple crop (paddy or upland rice) in the calculation of gross income. The figure highlights the importance of cassava as a source of cash income particularly to the lowest income households. Income from cassava constitutes 73% of household income for the lowest income quartile and 65% for the second income quartile. Cassava remains a dominant source of household income even for the wealthiest quartile supplying over 40% of their household cash income. The figure also shows the increasing importance of income from off farm sources as households become wealthier.

In **Cambodia**, across the major sources of income, cassava tops the list with slightly less than 50% contribution to overall household income. Income earned off the farm contributes to slightly above 37% which is followed by other non-cassava crops at about 13% and finally livestock which contributes less than 2% to household income. The importance of the various income sources is relatively consistent across all surveyed districts. The figure further highlights the importance of cassava as a source of cash income particularly to the lower income households where its contribution increases to almost 60% of overall household income. Cassava remains a dominant source of household income even for the wealthiest quartile supplying close to 50% of their household cash income.

In 2016, the average cassava production area per household in Laos was 2.15 hectares, varying between 1.36 hectares in Viengthong and 3.05 hectares in Kenthao. Average production was about

45 tons, giving a yield of 22.58 tons per hectare (Fig X). The yield per hectare ranged from a high of 27.34 tons per hectare in Kenthao to a low of 17.66 hectares in Bolikhan.

The average cassava production area per household in Cambodia was higher at 2.82 hectares, varying between 2.54 hectares in Siem Bouk and 3.16 hectares in Snuol. Average production is about 31 tons, giving a lower yield of about 11 tons per hectare. The yield per hectare was relatively consistent across the different districts in Cambodia and only ranged between 10.6 tons in Chit Borie to 11.8 tons in Siem Bouk.

Across both countries there was a recognition by many farmers that their cassava production was unsustainable. In Laos, farmers perceptions were that cassava yields were declining either moderately or rapidly for about 50% of farmers across all districts. The highest recognition of the problem was reported in Kenthao where almost 65% of farmers indicated a decline followed by Bolikhan with about 55% reporting a declining trend. On the contrary over 20% of farmers across all districts reported increasing cassava yields with over 28% of farmers in Paklai indicating either an increasing or rapidly increasing cassava yields.

In Cambodia, cassava yields are reported to be declining either rapidly or moderately for about 74% of farmers across all districts. The rate of decline in cassava performance is relatively even across the three districts. On the contrary about 15% of farmers across all districts reported increasing cassava yields with almost 20% of farmers in Chit Borie reporting such an increase.

Labour and gender roles

Across all surveyed districts in Laos, the average household size was 5.19. While an average of 2.51 household members were full time agricultural workers, an average of 4.23 members had at least some involvement in agriculture. The level of involvement with agriculture was similar across men and women. In Cambodia, the average household size was 4.69. While an average of 1.87 household members were full time agricultural workers, an average of 2.91 members had at least some involvement in agriculture. This implies that about 40% of household members in Cambodia are not involved in agriculture. The proportion of household members working off farm corresponds well with the proportion of income that come from off-farm sources which is also close to 40%. It also helps explain the relative higher adoption of labour-saving technologies such as herbicide, and limited interest in technologies requiring additional labour such as intercropping.

A greater amount of household labour is dedicated to cassava production in Laos relative to Cambodia. Specific gender roles do not seem to strongly exist in the production of cassava at broad level. The various tasks involved in cassava production shows an even distribution of person-days per year across male and female agricultural workers. Men do however have a dominant role in activities involving pest and disease control (particularly when chemicals are used) and transportation. While men and women do participate jointly in each of the cassava production activities, actual tasks within an activity may be different. For example, often during ‘harvesting’ men will pull or lever the roots from the ground which requires significant strength depending on soil type; women separate the roots from the stem and fill baskets; men carry the filled baskets to the loading point. These subtle differences become important during variety selection given things like root structure impact the ease of removal from the ground, and separation of the individual roots.

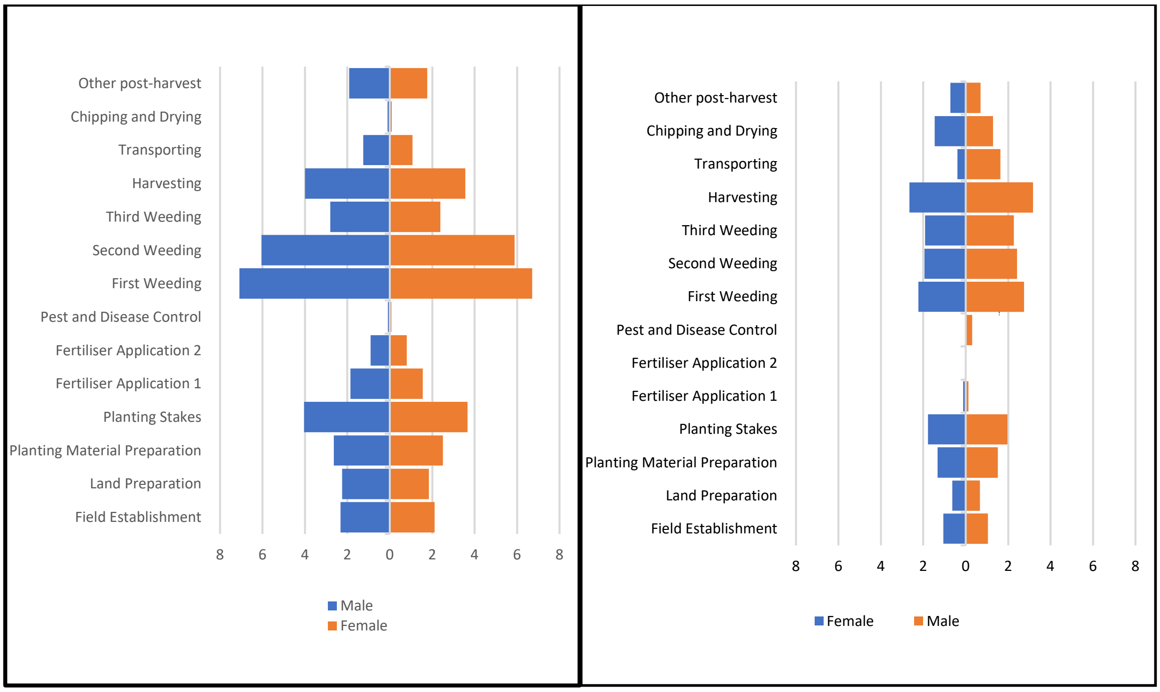


Figure 9: Household Labour Person-Days per hectare, by Gender

Access to credit

Access to capital was frequently identified during focus groups as a constraint to cassava production. Especially in Cambodia, this did not necessarily mean that there were no microfinance institutions working in the village, but often that farmers had reach a debt limit already and could not access any further loans. Loans were used for a wide range of agriculture and non-agricultural purchases, and often not the original intension.

In Laos, relatively few households (11% of all households) had taken a loan in the past 12 months, with almost all of them having taken out only a single loan. Quartile 2 reported the highest proportion of households with loans (almost 16%) while less than 8% of households in quartile 1 took out a loan in the last 12 months. In Cambodia, slightly over 40% of households had taken a loan in the past 12 months, with a majority of them having taken out only a single loan. Households in the highest income group were almost twice as likely to have taken a loan compared to those in the lowest income groups. The total value of loan of the highest income quartile was over four times that of the lowest income quartile.

In Laos, of those surveyed 58% indicated that their level of debt was either manageable or very manageable while the remaining respondents seemed to at least have some concerns. Slightly over 35% reported serious problems with their debt claiming they were ‘very unmanageable’. In Cambodia, those surveyed 71% indicated that their level of debt was either ‘manageable’ or ‘very manageable’ while the remaining respondents seemed to have at least some concerns. Slightly under 25% reported ‘some concern’ while about 4% said their level of debt was ‘worrying’. It is recognised that discussion around debt are sensitive and also can change very quickly.

The high levels of engagement with the micro-credit (debt) sector in Cambodia illustrate the potential issues around purchasing inputs such fertiliser where the agronomic and economic impact are uncertain and depend on both yield and prices. On the other hand, the purchase of chemicals that save labour (such as herbicides) are perhaps more tangible (amount of labour saved), despite the agronomic impact of less weeds also uncertain.

Access to information

In Laos, the most common source of information on agricultural production was through friends and neighbours within the village itself. A significant number of farmers pointed to cassava traders and processors as their sources of information for agricultural production, while only a handful regarded their information source to be the province or district government extension programs. In

Cambodia, the most common source of information on agricultural production was also through 'friends and neighbours within the village' which was closely followed by 'family' members. Beyond these two primary sources, only a few respondents indicated other options available for receiving information on agricultural production. Some sources of information reported by a handful of households were 'farmer groups', 'cassava traders' and 'government extension staff'.

In terms of market information, in Laos friends and neighbours were still regarded as the primary source of information, however cassava traders and processors also played a greater role in informing farmers about such markets. The role of government extension programs for marketing information on the other hand was almost non-existent. On the other hand, in Cambodia 'Cassava traders' were identified as the primary source of information on agricultural markets by a majority (95%) of respondents. This was followed by 'friends and neighbours in the village' (17%) and 'family' (5%). The role of government extension programs for marketing information on the other hand was almost non-existent.

These results highlighted difficulty on inserting information about sustainable cassava production into some pre-existing functional extension system that had the capability to engage in participatory demonstration at scale, if at all. Depending on the location there was some scope to work with traders to move information along the value chain, but the strength of these relationships was relatively weak.

Group membership

Group membership was also not a common feature of the households in both countries. In Laos, a total of 97 households (27% of all households) indicated that they had a household member participating in a group or a mass organization. While about half of these households were involved with only one organization, some households had memberships for up to six organizations. In Cambodia, only eight households (2.57% of all households) indicated that they had a household member participating in a group or a mass organization. As above, these results indicated the limited scope to engage with pre-existing farmer groups to disseminate information regarding sustainable cassava production.

Plans for growing cassava in the future

The survey asked respondents about their future plans in terms of growing cassava. Once again, this just provides a snap shot in time with the interest and area of cassava changing along with relative prices and other factors.

In Laos, only 40% of all farmers surveyed indicated that they intended to plant cassava into the future. A much smaller proportion of about 8% stated that they would not be growing cassava in the future while over 50% claimed to be unsure about their future decisions. The intentions for future cassava production varied across districts and income quartiles. Farmers in Viengthong indicated the highest likelihood of planting cassava in the future while it was lowest for Kenthao with only 24% stating such intent. Across income quartiles it was farmers in the first quartile that were most likely to keep up with cassava production into the future.

The intent of many farmers to cease cassava production in the future corroborates with their declining cassava yields. These intentions regarding future production are concerning given that up to 60% of household cash income is from cassava production.

Conclusion

The information from the diagnostic analysis conducted in Objective 1 illustrated several key factors and challenges.

At the household scale:

- The relatively high importance of cassava production for household livelihoods, particularly as a source of cash income for the poorest households.

- This exposed households to considerable livelihood uncertainty with large changes in prices determined by a range of external factors. Many farmers were uncertain about their future with cassava and would decide based on relative prices and other opportunities.
- There was limited recognition of problems and process of land degradation occurring, whilst yields declines had been noticed.
- There was low adoption of technologies that required additional labour
- There was low adoption of technologies that required cash payments to enhance productivity
- There was adoption of technologies and contracted services that reduced labour (land preparation, transport, herbicide)
- Farmers quickly adopt new varieties when they are made available through the informal seed system.

At the value chain scale:

- The structure and composition of the value chain varied considerable between sites, impacting potential enter points.
- The high reliance on cross-border trade and lack of domestic processing in the Cambodia sites made it challenging to identify entry points within the private sector with interest in scaling technologies;
- Within sites, the value chain structure and the individual actors (personalities) often changed altering the interest and incentives for scaling;
- Engagement with foreign companies was challenging with decision makers often not within the country and local management typically not present during the growing season. This often left ‘caretaker’ staff attending stakeholder meetings.
- Access to credit, working capital and financial literacy is an issue along the value chain, not only for smallholder farmers.

7.2 Objective 2 – Increasing the adoption of improved cultivation practices

Participatory research in the past had demonstrated that farmer-to-farmer learning could be successful model in generating adoption of new technologies and management practices. However, the key limitation of this approach was that this process typically needed to be facilitated by external partners (requiring funding) and had generated limited scaling of introduced practices beyond intervention villages. The notable exception has been the adoption of new varieties which were successfully scaled through the value chain, with the time of scaling dependent on a range of market and social factors.

The available production technologies to support improved livelihoods for cassava smallholders in the commercial cassava sector of Laos and Cambodia fall into four major categories:

Improved varieties specifically bred for desirable characteristics including increased fresh root yield, high starch content, drought resistance, pest and disease resistance. The adoption of new varieties and improved practices has markedly contributed to the increase in average yields of cassava in Southeast Asia from about 12 t/ha in 1984 to 21 t/ha in 2013 (Howeler and Aye 2014).

In Laos, a wide range of cassava varieties are reported by the farmers. Out of all the reported names given by farmers during the survey, none correspond to an actual official name. Several varieties had the same local name and often farmers were not aware of how many different varieties they were growing upon field inspection. Common varieties seen in the field during the start of the project included Rayong72. Others included Rayong5, Rayong11, KU50, HuayBong80.

The above problem is the same in Cambodia where the most common varieties reported by farmers were *Truoy svay* (meaning purple shoot) also known as Malay, and *Truoy sor* (meaning green shoot). Together these stated names accounting for almost 80 percent of the varieties planted by farmers. It is likely that Truoy Svay was KU50 in most instances, however there have been a wide range of new varieties entering Cambodia from Vietnam and Thailand. This included KM419, KM140, HL-S11, and Rayong72. Many of these newer released varieties from Vietnam are unfamiliar to farmers and cassava researcher. A range of new varieties were also beginning to appear that are non-released clones from Thai breeding programs. This posed a risk as farmers were often selecting them for their yield traits, unaware that they were not released due to susceptibility to pest and disease, for example. DNA fingerprinting was sometimes used to identify unfamiliar varieties especially when CMD was first emerging in the project sites.

Fertility Management including effective use of fertiliser to enhance production and profitability. Fertilisers are predominately inorganic, but treatments may include some use of manure. Balanced application of N, P, and K mineral fertilisers has increased root yields by 50 to 100 per cent in many areas and even more in very poor soils. The root starch content has also increased with the application of increased N, P, and K, but most markedly with additional K application.(Howeler and Aye 2014)

In Laos, cassava farmers typically reported not applying any fertiliser - either organic or inorganic. In fact, there was only one farmer that reported having applied any fertiliser to their cassava fields. As expected, less than 5% claimed to have seen a fertiliser trial on cassava. However, there is a good level of interest amongst farmers with about 50% indicating an interest in visiting a fertiliser demonstration trial and/or conducting such trials on their own lands.

In Cambodia, fertiliser application reported by respondents was also generally quite low with an average of 1.29% of total stating the use of organic fertilisers and 5.79% using inorganic fertilisers. Furthermore, only a handful reported having any knowledge about NPK values related to fertilisers that they used. Overall, there seems to be a positive attitude towards the use of fertilisers and significant interest from the farmers for learning more about them. Overall 82% expressed their interest in visiting a fertiliser demonstration trial while almost 65% indicated that they would like to conduct such a trial on their own lands.

Soil Management including intercropping and conservation agriculture techniques.

In Laos only about 6% of cassava farmers viewed soil erosion as a problem although this perception ranged from 12% in Bolikhan to a low of about 2% in Paklai. As a result, only a handful of farmers were aware of measures to reduce soil erosion or had received any training for mitigating soil erosion. Similarly, adoption of intercropping is also found to be extremely low in Laos with only 1% of farmers ever having grown intercrops with cassava and less than half a percent currently growing and form of intercrop.

In contrast, almost 66% of cassava farmers in Cambodia viewed soil erosion as a problem. Despite the severity of soil erosion, only 13% of all farmers were aware of any measures to reduce soil erosion. Only a handful of farmers across the surveyed districts (1.6%) had any previous training on soil conservation measures. Adoption of intercropping is found to be relatively high with almost 58% of farmers having grown intercrops with cassava and almost 50% currently involved in the practice.

Pest and disease management including methods for prevention and treatment. This can include biological control, “clean seed” protocols and control using pesticides.

Each of these major technology types has different learnability characteristics and relative advantage (Table 6). With the exception of some small differences, the learnability and relative advantage of each type of technology remains relatively constant across different project sites. As shown in Table 6, improved varieties and fertility management have relatively high learnability and relative advantage, while soil management and pest/disease management have longer timeframes to impact, less private benefits, and lower learnability.

Table 6 - Learnability characteristics and relative advantage of main technology types

Technology	Learnability characteristics	Relative advantage
Improved varieties	Easy to trial given access to stakes Low complexity – little change in farm practices Observability high at each stage but main evaluation at harvest. Observing starch content more difficult	Upfront cost low; farmers subsequently use own stakes through vegetative propagation High reversibility Impacts realised from first year of use No community benefit Relatively low risk; may have higher susceptibility to some pests and diseases No change in level of convenience
Fertility management	Moderately easy to trial – however there is low awareness of NPK fertilisers and appropriate rates. Moderately complex – fertiliser application depends on type of fertiliser, timing, and location. Observability is good at different stages, but main evaluation at harvest. Observing starch content more difficult.	Moderate upfront costs. Relatively good rate of return. Immediate impact can be high; long-term impact unclear. No community benefits – potential negative environmental externalities. More exposure to risk. Less convenient than no fertility management.
Soil management	Difficult to trial as may be long lag between implementation and observable impacts. Complex – many options including intercropping, soil conservation techniques. Low observability until critical threshold reached.	High labour input in initial years. Some benefits in first year of intercropping. Other impacts have long time horizon. Positive community benefits. Less convenient that no soil management.
Pest and disease management	Difficult to trial due to externalities requiring collective action (e.g., cannot treat one field if surrounding fields not treated). Complexity can be high. Observability may be low as often difficult to connect pest/disease control with yield; no ‘with’ and ‘without’ cases to observe.	Moderate upfront cost. Uncertain private benefits in first year. High community benefits if community-based treatment undertaken.

The aim of the activities under Objective 2 was to develop and test partnerships and models that could increase the adoption of the above practices. This was to be achieved by providing evidence of the relative advantage of the technologies at the farm level, and use the analysis from Objective 1 to demonstrate how benefits might accrue to different stakeholders in the value chain.

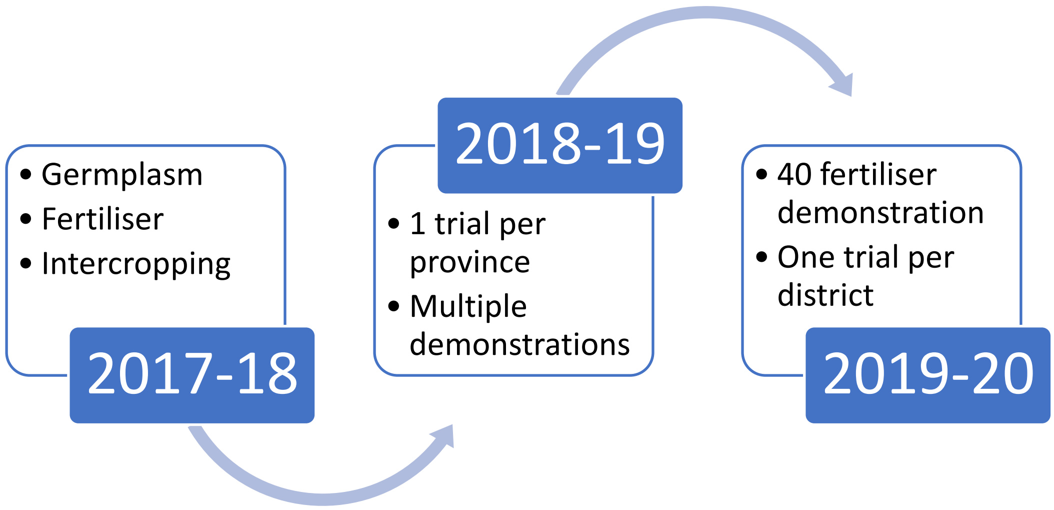
In the following section the present the results and discussion in five section for each of the main technology types.

1. Agronomic results (further detailed agronomic results are presented in Appendix **)
2. Economic analysis at the farmer level
3. Incentives for partnerships and business models
4. Changes in farmer KASA and Practices
5. Policies

As will be seen, there is a high level of interaction between the different technologies. For examples, cassava witches broom disease (CWBD) was impacted by both the variety planted and the fertiliser applied. Therefore, in the following sections the results and discussion of the results is presented on a country basis to better follow the sequence of events.

7.2.1 Lao PDR

The cropping season for cassava is relatively long with farmers typically harvesting their crop after 10-12 months, with limited time between harvest and the subsequent planting. The project managed three complete seasons of trials and demonstrations in Laos.



A. *Testing of different cassava varieties with stakeholders*

Agronomic results

During cropping season 2017-18, six high yielding cassava varieties along with farmers' variety were evaluated. Varieties did not differ significantly in fresh root yield (P=0.064). However, location (i.e. Paklai, Kenthao and Viengthong) had significant ($p<0.001$) effect on root yield. On an average Paklai District demonstrated highest and Viengthong lowest yield. Among the cassava varieties Rayong11 produced the highest fresh root yield (25.9 t ha^{-1}, average from three Districts) and KM-21-12 yielded the lowest (19.2 t ha^{-1}).

In these three trials farmers' variety[5] yielded 22.6 t ha^{-1}. In these trails all plots were infected by CWBD. Out of four trials, we managed to get data from three trails due to premature harvest by farmer from Bolikhan District as root price was higher compared to previous years and the farmer rushed to harvest.

[5] *The farmers were not sure of the variety names and were a range of Thai introduced varieties often with more than one variety found in the field.*

Economic impact at field level

There was a significant difference in the starch content between varieties. The value chain in all the Lao sites did not incentives the cultivation of varieties or management to improve starch content. However, farmers producing their own cassava chips would get a lower conversion of roots:chips. Processors indicated that measuring starch content of deliveries was time consuming and created confusion and conflict with farmers. They therefore paid a lower price for all roots based on starch recovery rates. As new varieties are released to deal with different diseases, it will be important that the tradeoff of starch yields and disease resistance are evaluated and communicated with stakeholders to get the correct incentives in place.

Partnerships and business models

The project plans for participatory variety selection with farmers and industry had to be re-evaluated. The original plan had been that farmer would be being able to take a selection of varieties for evaluation on their own land from the central demonstration, but this had to be revisited due to the widespread impact of CWBD. The findings on the susceptibility of KU50 to CWBD and the relative tolerance in Rayong 11 became an important project output that was shared with government and industry stakeholders.

The project arranged for a shipment of Rayong11 from TTDI in Thailand to NAFRI for multiplication and use in subsequent trials and distributed to some farmers for evaluation. At the same time, Rayong11 was also sent from TTDI to Cambodia where it was evaluated for resistance to CMD. The results of that trial, presented later, again gave cause for re-evaluating the promotion of Rayong11 which was found to be highly susceptible to CMD, whilst KU50 relatively resistant.

The extension activities and field days focused not only on what varieties are less susceptible to CWBD, but also how farmers could do positive and negative selection within their own fields, given no clean seed system was currently operating and farmers typically planted their own stems or purchased from the local area. This included how to recognise the disease in both the standing crop and harvested stems.

Changes in farmer KASA and Practices

In Laos one of the largest changes identified was in the increased awareness of CWBD and how to select healthy stems for planting. The Table below gives the result of a survey conducted at the end of the project. It shows large awareness of how to recognise CWBD and adoption of positive and negative selection. Conversely, it does show that at that stage farmers had not heard about CMD which was not yet reported in Laos.

Table 7: Farmer disease knowledge (Laos)

	Bolikan	Viengthong	Paklai	Kenthao	Total
Recognise CWBD in the field	90%	80%	70%	90%	83%
Recognise CWBD in harvested stems	95%	80%	65%	70%	78%
Have CWBD last year	100%	80%	70%	90%	85%
Remove CWBD infected plants	60%	50%	15%	25%	38%
Check stems before planting	100%	80%	55%	80%	79%
Heard of CMD	0%	10%	5%	10%	25%
Know symptoms	0%	5%	5%	0%	0%

Policies

The importance of addressing cassava disease and developing some form of a hybrid formal-informal cassava seed system was shared in policy meetings at the Province and National level (for example, see Lao Policy Brief). These activities are ongoing in AGB/2018/172. Information generated in this project has been important in demonstrating the potential impact on disease.

B. Fertiliser

Agronomic results

The agronomic benefit of fertiliser application against farmers' practice were demonstrated in four districts during 2017-18 cropping season. Varieties responded similarly to fertiliser application- no fertiliser treatment produced the lowest and high fertiliser produced highest yield.

The fertilize treatment X variety interaction was not significant. The average fresh root yield was 19.0, 27.1 and 17.9 for Paklai, Kenthao and Viengthong Districts, respectively, considering all varieties and all fertiliser treatment. Considering all three Districts and three varieties included in the trials, highest yield (25.1 t ha^{-1}) was achieved by highest fertiliser application. Moderate fertiliser application with manure also yielded (24.1 t ha^{-1}) very close to highest rate of fertiliser input. In general fertiliser application yielded 1.4- to 1.7-fold higher fresh root compared to Farmers' practice and without any fertiliser application. Fertiliser application did not show any effect on starch content.

To scale out of the results of previous year (2017-18) demonstrations of effect of fertiliser, large plot on-farm demonstrations were organised during 2018-19 that are more observable. The root yield was consistently low, ranged from 12.3 to 26.4 t ha^{-1} when grown without any fertiliser. The yield increase was 1.1 to 1.7-fold when fertiliser was applied

During the final year of the project, commercially available fertiliser blend with two different K:N ratio (i.e. 2:1 and 1:1) were tested in 4 districts and compared with without fertilize application. Fertiliser application increased cassava root yield compared to cassava grown without fertiliser by 1.5-fold and 1.4-fold while K:N ratio was 2:1 and 1:1 in fertiliser blend, respectively.

The importance of potassium fertiliser (K) was a vital factor to demonstrate, particularly to government officials who sometime promoted 'organic' production. We carried out an on-station experiment during 2018-19 season, to determine the growth response to K fertiliser and to examine the field's K balance over the cropping season We found a positive effect of K fertiliser (up to 39% yield increase compared to no K fertiliser at early harvest, 21% at late harvest) and a positive effect of late harvest (on average a 35% increase compared to early harvest) on cassava root yield. Low-K crops benefited more from a late harvest.

Economic analysis

The economic analysis of fertiliser application involved three aspects. Firstly, conducting a marginal analysis and determining the marginal rate of return (MRR). Secondly, participatory enterprise budgeting to determine the impact on criteria of interest to farmers – costs and income flows, net economic returns per hectare, returns to labour day. Finally, scenario analysis was conducted where prices and responsiveness of fertiliser application were varied to explore with farmers the stability of the results.

The results of 2017-18 in Kenthao and Paklai show the treatment of 80N-40P-80K produced the highest net return. However, the responsiveness and the rate of return varied significantly between the varieties due to CWBD. This would be even more pronounced if a price penalty was introduced for lower starch content.

The analysis of the trials in 2018-19 showed benefit of using the NPK blend in Xayabouli. The MRR when moving from 40-20-40 was 131% and is also less complicated for farmers. However, the results in Bolikhamxai due to other crop management issues, showed that the additional cost was not warranted. These results highlight the need for good management to justify additional expenditure.

The final year of demonstrations again showed on average attractive economic returns to the fertiliser application. However, these benefits became quite marginal under the low-price scenario, but extremely attractive under the high price scenarios. Farmers in Laos tended to have a very positive (optimistic) outlook for what future prices might be during interviews and focus groups.

Partnerships and business models

The agronomic analysis of the fertiliser application rates provided a strong economic case for adoption of fertiliser. Even under the lowest price scenario, on average farmers would make a reasonable return on their investment (36%) and at the high prices had at MRR of close to 300%. Economic feasibility in the context of purchased inputs for a cash crop should be viewed as a necessary, but not sufficient, determinant for adoption.

In sites with starch factories this would result in additional processing and the sale of starch and residue. For every hectare of adoption, a starch processor may process and additional 2-3 tons of starch and 0.6ts of residue. These potential benefits were discussed with the starch factories in the supply zones. In one case, a factory was already paying a ‘levy’ to the District Government for every ton of cassava processed. It was proposed that some of this funding could be directed to the DAFO for establishment of demonstration and provide training. This would result in additional processing revenue for the factory and an increase in levies collected for the District Government. In another case, a factory was interested to make large purchases of fertiliser and take the cost out of the income that farmers would receive after harvest.

In both situations that problem of ‘leakage’ from the system became apparent, especially when the price of cassava chips was high. Processors could not guarantee that they would receive the additional roots produced. The daily processing capacity of the factories remained the same, and if farmers could not sell their roots when they wanted then they would sell to other traders or produce their own dry-chips. This eventually saw the demise of the levy system in Paklai and the levy and control on export of roots to Thailand, was not resulting in the desired benefits to the factory – to be able to lengthen the processing season.

Recognising these issues of exclusivity of benefits, the project introduced a fertiliser importer and distributor into the partnership. The company was the sole licensed importer and distributor of some of the NPK fertilisers blended for cassava. The company provided free fertiliser for demonstrations in the last 2 years of the project. The concept was that since it didn’t matter where the roots were sold some of the issues of exclusivity over the benefits generated could be avoided. The company participated in many project stakeholder meetings and joined the research symposium to Indonesia. However, once again this partnership was not a silver bullet for several reasons:

1. Retailers frequently purchased fertiliser unofficially from Thailand meaning the company did not increase sales
2. The low existing use of fertiliser was not attractive for the company to invest
3. Low political support at the district level due to discussion of ‘green growth’ and organic production
4. Turnover of company staff. The relationships were largely developed with individual staff assigned to the partnership who were also subject to reallocation.

The involvement of fertiliser distributors to ensure that appropriate fertilisers and available in communities remains critical to increasing adoption. Despite the challenges the partnerships have been handed over to other development projects to continue. The factory in Viengthong was in negotiation with the fertiliser company during the last months of the project. NAFRI also continues to work with new development projects to establish similar trials and continues to engage with the company.

Changes in farmer KASA and Practices

Survey households in Laos at the start of the project did not use fertiliser on their cassava and had little knowledge of the appropriate types, rates or timing. The demonstrations in the project successfully changed farmer’s awareness of the importance of fertiliser for sustainable cassava production and there was an aspiration of farmers to be able to apply it to their crop. Knowledge regarding NPK remained low and calculations remain challenging even for DAFO staff. This is a reason why pre-blended NPK fertiliser are seen as more promising than asking farmers to mix their own individual sources of N, P, K for specific levels.

Despite these efforts, by the end of the project very few farmers had purchased fertiliser for their own crop. The most frequent answer was that the income from the previous harvest had already been spent and they could not afford to when the time for application arrived. This highlighted the need to work with financial institutions (formal or informal) to enable change to occur. Partnerships were being explored with development projects towards the end of the project that had village level savings as part of their activities.

Recognising the problem of district staff understanding and calculating NPK rates in 2021 (postponed due to COVID) a training was organised in Vientiane with DAFO and PAFO staff from all the main cassava producing regions of the country to share the results and provide practical training. However, given the high turnover of DAFO staff this is something that should be repeated frequently or other means of increasing capacity developed. Yet it is recognised that increased capacity at the DAFO is unlikely to generate large amounts of changed practices in villages in the absence of some form of facilitation (NGO or Industry).

Policies

Discussions on fertiliser at the District level were often complicated by the interpretation of national priorities. The was a process of change in the government strategic plan for agriculture towards promoting Laos as a source of 'clean agriculture'. This often got interpreted for organic agriculture and for all crops.

Organic fertiliser continues to be promoted to cassava farmers. The nutrient analysis of these products is extremely low (less than 1% of N, P, and K) whist the products are relatively expensive. This adds to the confusion of farmers and industry stakeholders with limited understanding of the nutrient extraction during cassava cultivation.

The policy brief provided to stakeholders at the end of the project had several aspects related to the findings above. There was no change in policy during the project, however final stakeholder meetings saw a clear call for the development of a cassava policy for Laos.

C. Intercropping

Agronomic analysis

During 2017-18 a demonstration of intercropping of cassava was established in Paklai Districts. The farmers involved were very enthusiastic about the potential to get extra income from the same field where cassava was growing. However, due to heavy rain during establishment period both intercrop and Cassava could not germinate due to soil waterlogging for extended period. Following intercropping systems were established- Cassava + mung bean 2 rows, Cassava + peanut 2 rows, Cassava + yard long bean 2 rows to compare with Cassava mono culture.

Economic analysis

No economic analysis could be carried out on the intercropping trial due to crop failure. Whilst farmers were initially excited about the potential for extra income, the additional labour required and the frequency was not attractive and finding willing farmers to participate in subsequent years was difficult.

Policy

The importance of addressing the sustainability issues around cassava production are very apparent to DAFO and PAFO staff that recognise the tradeoff in terms of economic development and environmental outcomes. This was made very clear during consultations and meetings.

Some projects continue to promote the practices of intercropping and contour grass strips despite the evidence provided from the project activities in the region – simply because they feel the need to show they are doing something. New systems to improve soil health need to be developed with farmers that provide a stronger incentive for adoption and the importance of sustainability highlight to factories who have invested in a particular supply zone.

7.2.2 Cambodia

A. Variety assessment

Agronomic analysis

During cropping season 2017-18, six high yielding cassava varieties along with farmers' variety were evaluated. Data from Snoul District demonstrated that varieties differed significantly in fresh root yield ($P < 0.05$) (Table 2.2.4). Among the cassava varieties KU50 produced the highest fresh root yield (30.2 t ha^{-1}) and farmers' variety was the lowest (16.0 t ha^{-1}). In this trail all the plots were infected by CWBD and infested by mealy bug. Presumably all the plants were equally affected by the pest and disease. Varieties differed significantly ($P < 0.05$) in starch content. Highest starch content was achieved by Rayong72 (i.e. 28%) and the lowest was 23% for SC9.

During 2018-19 season we conducted demonstrations in three districts in four farmers' field. Among the varieties across all locations 'farmer's choice[6]' variety yielded highest, ranged from 20.6 to 39.7 t ha^{-1} and Rayong 5 yielded lowest, ranged from 14.8 to 20.2 t ha^{-1}. While considering different locations, on an average for all varieties Snoul produced highest (i.e. 30 t ha^{-1}) and Chet borey produced the lowest (15 t ha^{-1}). Ranking of varieties following the criteria of the fresh root yield and starch content came out very different- considering fresh root yield Farmer's choice variety came out at the top; however, according to starch content the same variety came out at the bottom.

During 2019-20 experiment, plot root yield (calculated as t ha^{-1}) demonstrated clear advantage of clean planting material over symptomatic planting material (Figure 2.2.3A). Plot yield was1.2- to 2.2-fold higher in plants from clean and/or positive selection planting material than those from symptomatic planting material. The smallest yield difference (i.e. 1.2-fold) occurred in KU50 and Hauybong60, presumably due to their recovery ability from CMD, as many plants from symptomatic stakes remained asymptomatic during the experiment.

Economic analysis

The economic benefits of farmers planting less susceptible varieties to CMD and establishing their crop with disease free stems (or at least positively selected asymptomatic stems) is very significant. The results also highlight the need to avoid Rayong11 in areas with CMD – the variety the project had been promoting in Laos as being less susceptible to CWBD.

Even a very low rates of adoption, the potential aggregate farm level benefits from the four main provinces servicing Vietnam (Tbong Khmun, Kampong Cham, Kratie, Stung Treng) are very large. On top of this, there are the trading margins that were estimated to be around $6.20/t during the value chain assessment. However, again there are issues around exclusively of benefits generated with traders collecting from multiple sources and operating at close to full capacity on a daily basis. Therefore, it is unlikely that traders will be willing to invest large resources in promotion, but could distribute information they provided to them at a relatively low cost.

[6] *DNA fingerprinting indicated that the 'farmer's choice' was typically an elite Vietnamese variety, such as KM98-1 or KM140*

Partnerships and policies
The infection of the variety trials provided a unique opportunity to get early information on which varieties were more tolerant to CMD. This information was shared widely and reported to several projects and donors in multiple countries. Given the lack of private sector partner in the case study area a concerted effort was made to get information into various donor funded projects (IFAD, CAVAC, GIZ).

Additional resources were made available from CAVAC for a more systematic screening of varieties on station rather than the on-farm activities. This became an important activity for the region with information shared broadly and cross site visits from several countries and industry representatives. The information was reported to donors such as IFAD, UNDP, IFC, GIZ, FAO, ADB.

B. *Fertiliser*

As was the case in Laos, adoption of fertiliser in the project sites in Cambodia was relatively low. In 2017-18 the project demonstrated the benefit of fertiliser application against farmers' practice in 4 districts. Root yield was significantly different ($p<0.001$) between two locations (Table 2.2.5). However, there was no difference between the treatments in each location due to large variability caused by biotic (root rot, CMD and CWBD) stresses.

The average fresh root yield was 1.4- to 2.2-fold higher in the Snoul District compared to Chet Borei District. The highest yield (26.3 ± 6.7 t ha^{-1}, Snoul) was achieved with highest fertiliser rate, however, in Chet Borei District highest yield was 17.6 ± 1.0 t ha^{-1} with moderate fertiliser application. In general fertiliser application yielded higher fresh root compared to Farmers' practice and without any fertiliser application.

Fertiliser treatment responded similarly in both location and starch content was significantly different ($p<0.001$) between two locations. Application of fertiliser increased starch content in all treatments ranged from 22.1 to 28.9 %.
During 2019-2020 season, fertiliser demonstrations were set in large blocks on farmers' field who were willing to participate. There were two treatments with fertiliser $NP_2O_5K_2O$ (20:05:20) and without fertiliser. In these trials, disease incidences were recorded and by the end of the season number of symptomatic plants ranged between 49 -80% in all trials in both treatments; however, the severity of infection was low (Sareth C. personal observation). The lowest disease incidence was recorded for fertilised and un-fertilised plots was from same site (i.e. 49% fertilized and 67 % unfertilized); presumably, due lower disease pressure in that region (Annual report 2020).

Economic analysis of fertiliser application

Economic analysis demonstrates that the low adoption of fertiliser has little to do with the agronomic response or economic outcome. Low levels of fertiliser provide ample incentive for application on economic terms. As such, while a range of additional trials could be conducted to develop more accurate and site-specific recommendation – this is unlikely to overcome the current constraints to the adoption of fertiliser.

The uncertainty in expected returns has been made more complicated by the new disease situation. Furthermore, there was very significant price fluctuations during the life of the project. However, knowledge of appropriate fertiliser types and its availability in local markets remains a challenge.

Partnerships and policy

The potential farm level benefits from households adopting low levels of balanced fertiliser application are high. However, given the current value chain structure in eastern Cambodia there are few potential stakeholders that could invest in scaling recommendations to farmers.

During the project life a starch factory opened in Chet Borei District (SingSong) and they were consulted and invited to join project activities. The factory had limited interest in investing in their supply chain. The company was also under pressure as the rising price in Tay Ninh meant they could not effectively compete for cassava roots and were often not processing. Again, the exclusivity issues in working with processors. A second company (GreenLeader) was reported to be establishing a factory in Snoul District and staff did join field days. However, the factory was never built and the business model of establishing close to the Vietnamese border is very questionable given the analysis conducted in Objective 1 of the project. These examples again highlight the risk of working with companies even after they have invested in developing infrastructure in a particular supply chain.

The CAVAC program was developing partnerships with fertiliser companies to import Thai and Vietnamese fertiliser and promote them through their activities. The project provided input on these fertilisers and discussed the challenges in the East and West of Cambodia which were very different in terms of access to fertiliser and adoption. No attempts were made to create a parallel engagement with fertiliser industry stakeholders.

C. Intercropping

Agronomic

A total of 4 demonstrations of intercropping of cassava with short duration crops were established. Farmers were very enthusiastic about the potential to get extra income from the same field while cassava was growing. However, we could not capture data as farmers harvested cassava when the fresh root price went up early into the season. Following intercropping systems were established- Cassava + mung bean 2 rows, Cassava + peanut 2 rows, Cassava + corn 1 row to compare with Cassava mono culture.

Economic

The project team could not interest farmers to participate in additional intercropping trials in subsequent years due to the added labour required. Farmers were busy with other livelihood diversification outside the cassava farm – cashew nuts, pepper, rubber. While not all farmers were engaged in these activities they provided employment opportunities for some households.

There were other livelihood activities that produced significant contribution to livelihoods that were sensitive to discuss but competed for labour – the timber trade for example.

Conclusion

The agronomic and economic results together with farmer and other stakeholder reactions illustrate mixed results in terms of the plot and household level impacts and the development of viable business models. In all situations a mix of public and private sector actors are required, with the balance depending on the specific technology and value chain context.

Variety evaluation and dissemination

- Changed practice in terms of identifying disease symptoms and selecting healthy planting material has a significant impact on yields and is highly adoptable when farmers can access sufficient disease-free stems from within their own field. Farmers involved in the project indicated changed practices. However, in some cases, this is no longer possible due to the rapid expansion of diseases.
- There is strong interest by farmers in access to new varieties that are less susceptible to emerging disease problems. Private sector stakeholders are interested to play a role in awareness raising and variety distribution, but issues around exclusivity to the benefits limit investment in most value chain contexts unless they had their own land where the value of the roots offset other costs.

- Different models for producing and disseminating varieties will need to be developed based on the findings in objective 1 and objective 2 involving both public and private sector.

Fertiliser

- The application of a relatively low rate of a balanced NPK fertiliser produces on average a yield response that provides a high return on investment, even at low prices.
- Poor management of other stress (disease and weeds) reduces the response and can lead to low or negative returns, especially at low cassava root prices
- While developing more site-specific recommendations may improve the response in different locations, this is unlikely to improve the levels of adoption or enhance scaling. Efforts should continue to focus on addressing other constraints in the 'innovation package' such as extension, availability, and changing saving and expenditure behavior.
- Issues of exclusivity of benefits for processors was somewhat overcome by engaging actors in the fertiliser distribution business, rather than the core cassava value chain actors. However, this relationship needs ongoing support.
- There is some policies and agricultural strategies that impact the willingness of actors to invest in the dissemination and promotion of fertiliser, particularly in Laos.

Sustainable soil management

- The current technologies being promoted to improve soil health such as intercropping and contour grass-strips are of limited interest to farmers in Laos and Cambodia.
- Given the high awareness of productivity decline and the ongoing expansion in market demand, investment in the codesign of alternative production systems to address soil degradation need urgent attention.

7.3 Objective 3

7.3.1 Review and document local and national policies with regard to smallholder cassava

Cassava in Lao PDR has become one of the national ‘priority crops’. However, there are very few direct policies supporting this and there is limited experience on the government side regarding the cultivation of the crop. The high-profile failure of a starch factory in Vientiane Capital Prefecture has received the attention of MAF. The NAFRI project team has been involved in ongoing research and briefing MAF on problems and potential interventions.

Fertiliser, herbicide and organic production

The use of agrochemicals including fertiliser became increasingly political during the project cycle as MAFF developed the sectors “Green Growth Strategy. The interpretation of this change in strategy varied considerably between the Districts in Laos. Some directors of DAFO started out very concerned with fertiliser demonstrations, however the project was able to clarify many aspects about cassava and fertiliser.

Seed and varieties

At the beginning of the project there was no seed law in Laos. However later in the project the National Seed Law was developed. As is the case in most Asian countries the law was written with rice and maize mostly in mind, and vegetative propagated crops were not well covered.

Import of cassava planting material from Thailand was possible with import and export permits from both countries meeting the phytosanitary requirements. In practices there was a large informal trade of stems coming into Laos from both Vietnam and Thailand. This was often facilitated by industry stakeholders.

Cambodia

Similar to Laos, at the start of the project there were no specific policies related to cassava, with the sector influenced by general agricultural and trade policies. During the project UNDP facilitated the development of the Cambodia Cassava Policy. The project team provide considerable input into the policy design, both directly on aspects around production, and indirectly with presentations and reports provided to FAO and UNDP. This is covered later in the report.

7.3.2 Conduct workshops to develop local capacities for on-farm research

Lao PDR

Training on sustainable cassava production was conducted in Vientiane with national, provincial and district staff which also included some private sector participation. Practical value chain training was conducted in Vientiane with key stakeholders to map value chains in target provinces in Lao PDR. Training on household livelihood surveys and use of electronic tablets for gathering information were conducted with partners in Vientiane in April 2017.

Training material on cassava production has been distributed to DAFO, made available online, and shared with other development projects. It was featured in the MAF magazine in July 2020.

The project organized a national level training on sustainable cassava production seeking participants from DAFO, farmers organizations, NGOs, and industry. The event was initially postponed due to COVID and held in 2021. The event received some level of co-funding from several NGOs (Winrock, Helvetas, LuxDev) and industry (Lao Cassava Association).

Training material from these events can be found online in Lao language.

Cambodia
Training on sustainable cassava production was conducted in Kampong Cham with national, provincial, and district staff which also included some private sector participation. Practical value chain training was conducted in Kratie Province with stakeholders to map value chains.

Training on household livelihood surveys and use of electronic tablets for gathering information was conducted with partners in Kratie in July 2017.

7.3.3 Develop technical and policy briefs

Engagement with policy makers occurred throughout the project and different pollical scales. A policy brief in Lao and English was developed and provided to government stakeholders at the end of the project. This was the basis for discussion on the next steps for addressing the concerns around the sustainability of the industry.

In Cambodia the project team developed two main outputs. Cassava: Facts and Fiction was developed and provided to UNDP in the policy dialogue process. The second brief focused on priorities for a sustainable cassava system.

7.3.4 Conduct dialogues between local actors

In addition to the regional research symposia conducted in Vientiane review) and in North Sumatra in July 2019, project results have been discussed with key stakeholders in January 2018 (in conjunction with the mid-term in local and national stakeholder meetings in both Cambodia and Lao PDR.

Lao PDR
Local stakeholder meetings
Local stakeholder meetings were held on the 14th and 16th of August 2018 in Paklay and Kentao District, Xayabouly province and on the 6th and 8th of November 2018 in Bolikhan and Viengthong District, Bolikhamxay province.
The topics of discussion involved:

- Overview of cassava production and marketing,
- Review of marketing systems and production value chain research results for provincial, district and household level,
- Review of agronomy research activities and progressive results in 2017
- Farmer adaptation on agronomy technologies, especially, soil fertility improvement with application of suitable fertiliser rates and compound chemical fertilisers, intercropping systems, selection of appropriate varieties and the importance of utilising clean seeds.
- Stakeholder's perceptions, challenges and recommendations of cassava cultivation.

National stakeholder meeting:

The National stakeholder meeting was held on the 6th of March 2019, in Vientiane. The meeting was chaired by Dr. Bounthong Bouahom, DG of NAFRI and included a number of presentations and discussions.
Additional and less formal stakeholder dialogues occurred during harvest field days. Farmers, traders, processors and government joined field days and discussed the results and other concerns. A few lessons learnt were that timing is important with foreign owned factories – as management are typically absent during the growing season. Secondly, decisions are typically made by management abroad.

Cambodia

Cassava became a crop of interest to several International Organisations (UNDP, FAO, IFAD, IFC) and INGO (CAVAC, GIZ, SwissContact). The project did not seek to replicate a crowded space with additional dialogues, instead provided technical expertise into the existing platforms. All resources and reports were made available and Cambodia made up a large percentage of the Facebook group (416 member from Cambodia) that included high level government, NGOs, Local government and farmers.

UNDP commission the development of the Cambodian Cassava Policy in 2017 which remains ongoing. CIAT lead the component on raising the productivity of the cassava sector in Cambodia and the project passed on all the value chain assessments to FAO who coordinated the input of value chains. A workshop was held with stakeholders to gather inputs and presented at a Workshop in December 2017.

8 Impacts

8.1 Scientific impacts – now and in 5 years

There are three main thematic areas where scientific impact of the project would be reasonably expected within 5 years:

Methods of working with private sector actors in development and research projects
The overall ACIAR Cassava Value Chains Program (including this project and AGB/2012/078) afforded a unique opportunity to look at the incentives and potential modalities for involving private sector as a partner in disseminating technologies in support of improved smallholder livelihoods in a range of sites across 4 countries.

One of the key conclusions was that the potential role of private sector and incentives for their support of development outcomes is highly dependent on the context, specifically the typologies of value chain, technology and socio-economic conditions that the private sector operates under. This implies that there is no one size fits all approach for working with the private sector within value chain type projects.

The outcomes of the project have enabled the rapid implementation of activities in AGB/2018/172 aimed at addressing cassava disease in Asia. This includes the methods of working across scales (from global to plot) and identifying the incentives for public and private sector actors to engage in different interventions in the different production and value chain contexts.

Lessons learned from the cassava program experience of private sector linkages have been included in the Making Value Chains Work Better for the Poor Toolbook, which has had widespread uptake in the development community. This is a potential pathway to wider scientific impact within the coming 5 years as other development projects and programs could adapt approaches based on these lessons learned.

The project team leader is now also utilising a flexible approach to private sector involvement in value chain support (based on the experience from ASEM/2014/053) in his current position as Conservation Friendly Enterprise Development Team Lead on the USAID Biodiversity Conservation Activity in Vietnam. This activity will cover around 40 value chains in 6 provinces of Vietnam. There is good opportunity for wider impact through aligning approaches with the sister USAID program “Sustainable Forest Management” covering an additional 50 value chains across Northern Vietnam. Together these projects represent an investment of more than USD70 million in sustainable livelihood improvements to support positive biodiversity outcomes.

Inclusion of economic analysis in decision making around promotion of conservation agriculture techniques within crop production systems
Results across the majority of sites in both ASEM/2014/053 and AGB/2012/078 show that conservation agriculture techniques, including intercropping and planting of grass contour strips as part of an integrated crop/livestock system had significant potential positive impacts on sustainability, but had very low adoption rates due to the high labour requirements, especially in areas with steeply sloping fields.

SMCN/2014/049: *Improving maize-based systems on sloping lands in Vietnam and Lao PDR* is drawing on experience from ASEM/2014/053 and AGB/2012/078 in exploring the trade-offs between improved sustainability and economic benefits in introducing conservation agriculture practices in maize based farming systems, especially in the context of rising opportunity costs for labour and increasingly diversified livelihood strategies at farm level.

Disease screening
While it was unfortunate that participatory variety trials in Cambodia were impacted by CMD in the first year of evaluations in the project, this unplanned screening of existing varieties was quickly used by breeding programs and industry in the region and has informed seed system development in Laos, Cambodia, Vietnam, and Thailand. Screening and degeneration trials have continued under AGB/2018/172. The susceptibility of KU50 to CWBD identified in Laos has also informed the

screening and breeding activities in the new project, whilst the susceptibility of Rayong11 discovered in in Cambodia has informed the seed system interventions being developing in Laos.

8.2 Capacity impacts – now and in 5 years

One of the key features of the project was capacity building of project staff, local government partners, and private sector partners. Training of district staff and value chain actors was undertaken through stakeholder meetings, training and focus groups at the District level.

Baseline household surveys of cassava farmers were developed in conjunction with partners in Laos and Cambodia. This was followed by training on the household survey instrument and the use of electronic tablets for the Laos and Cambodia survey teams. These engagements have provided project staff with valuable knowledge for developing and conducting household surveys successfully using state of the art research methods.

Both CARDI and NAFRI have a long history of conducting socio-economic research in rice-based systems. However, to date there has been very limited research conducted by these institutions on the marketing aspects of cassava. Some staff from the agronomy related research sections participated in the value chain assessments and focus group discussions. The involvement of both technical cassava researchers and social scientists in this part of the study has increased the knowledge related to cassava markets and value chains. Such cross-disciplinary knowledge is of critical importance for developing more comprehensive research capacities.

The program of capacity building within the project is expected to have long term impacts in the project areas – especially with the building up of a cadre of young researchers who will be able to contribute to cassava development across the region well into the future. Both NAFRI and CARDI have used the approach and methods in expanding studies within the cassava sector to other region or in different value chains. The challenge has been the high turnover of staff, however some staff have moved into policy development oriented departments and continue to draw on the information produced during the project.

The project outputs have been extensively used by next users. This has included organisations such as FAO, UNDP, IFAD, IFC, WorldBank, ADB, USAID, AustralianAID, Khmer Enterprises, Helvetas, Winrock International, LuxDev.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Adoption of new varieties and selection of healthy planting material

The adoption of more suitable varieties for different situations, especially under disease pressure will generate substantial economic benefits in terms of avoided losses.

The case in Cambodia with the identification of more resistant varieties to CMD and the importance of positive selection of asymptomatic stems for replanting an average price would deliver over $11m USD per year if the adoption rate was only 10% in the four main provinces in eastern Cambodia. Again, at only 10% adoption the avoided losses to traders would be $0.9 million per year. There would be additional benefits generated for starch processors and intermediaries in Vietnam.

Table 8: Economic Analysis of new variety adoption, Cambodia

Cassava root price (KHR/kg)	100	300	500
Benefit of positive selected stems ($/ha)	225	675	1125
Benefit of 'clean' stems @ $3 bundles($/ha)	-20	540	1100
Farmer benefit from positive selection ($)	36,918,675	110,756,025	184,593,375
*10% adoption	3,691,868	11,075,603	18,459,338
*25% adoption	9,229,669	27,689,006	46,148,344

In Laos the planting of varieties less susceptible to CWBD would also result in significant economic benefits, but should not be viewed in isolation from the application of fertiliser, which also is critical for maintaining the health of future stems.

Adoption of fertiliser and fertility management

The potential economic impact of the adoption of appropriate fertiliser is large. The Table below provides an example of if the average 8t/ha gain was realised across the four project districts in Laos. Assuming the additional roots produced were subsequently processed within the country there would be additional processing margin and additional sales of processing residue.

The total benefits to industry are significant, but there is no exclusively over the benefits that would be generated, as roots flow outside the starch sector if farmers cannot sell when they want.

Table 9: Economic Analysis of fertiliser adoption, Laos

	Bolikhan	Vangthong	Kenthao	Paklai	Total
Area of cassava (ha)	2,027	1,149	15,207	11,206	29,589
Increase production (8t/ha)	16,216	9,192	121,656	89,648	236,712
Value of increase	$696,021	$394,538	$5,221,704	$3,847,860	$10,160,123
Added starch production (tons)	4,633	2,626	34,759	25,614	67,632
Additional processing margin ($25/t)	$115,829	$65,657	$868,971	$640,343	$1,690,800
Additional residue (tons)	1,158	657	8,690	6,403	16,908
Additional residue sales	$156,369	$88,637	$1,173,111	$864,463	$2,282,580
Total benefit Industry	$272,197	$154,294	$2,042,083	$1,504,806	$3,973,380
Total Benefit	$968,218	$548,832	$7,263,786	$5,352,666	$14,133,503
- 10% adoption	$96,822	$54,883	$726,379	$535,267	$1,413,350
- 25% adoption	$242,055	$137,208	$1,815,947	$1,338,166	$3,533,376

In Cambodia an additional 8.2t/ha at average prices of 300 KHR/kg would produce $9.2 million USD of net benefits at 10% adoption. However, again this result assumes that farmers have access to at least asymptomatic cassava stems for planting. Without the disease-free planting material or even access to more resistant varieties the benefits of fertiliser application may not be realised.

Table 10 – Economic Analysis of fertiliser adoption, Cambodia

Cassava root price (KHR/kg)	**100**	**300**	**500**
Benefit of positive selected stems ($/ha)	155	565	975
Farmer benefit from positive selection ($)	25,432,865	92,706,895	159,980,925
*10% adoption	2,543,287	9,270,690	15,998,093
*25% adoption	6,358,216	23,176,724	39,995,231

Intercropping and grass strips

There is very limited expected adoption or benefits to be generated from promotion of existing technologies to address soil fertility decline. The economic benefits from adoption would come from avoided losses.

8.3.2 Social impacts

The project design did not seek to have any major transformative social impacts within communities. Cassava is grown by a wide range of rural households that have dynamic livelihoods and on a range of trajectories. The analysis in the project demonstrated the importance of the cassava sector for the livelihoods of many of the poorest households living in regions outside the main rice producing regions of Cambodia and Laos and with less capacity to make a rapid transition into other systems due to high upfront costs and lags.

This was communicated with evidence to policy makers and a range of development projects that often identify the concerns around the sustainability of cassava production and use this as a reason not to engage in the sector. Demonstrating the livelihood and economic contributions of the sector with evidence has kept these households growing cassava in the development of polices and development programs.

8.3.3 Environmental impacts

Despite the high livelihood benefits attributed to the cassava production; the economic development and employment generation along local value chains; and the substantial contribution to national economies; the cassava sector continues to carry the stigma related to the cultivation leading to deforestation and land degradation.

Within the life of the project, the activities and partnerships were not at a scale to lead to any significant environmental impacts – positive or negative.

The research conducted in the project did not seek to measure changes in erosion under different management practices. However, previous studies have shown the importance of a healthy crop to increase canopy cover together with other management practices to either reduce runoff (such as contour grass strips) or provide additional canopy cover early in the cropping cycle (such as intercropping).

The project activities showed high economic incentive for the adoption of healthy planting material of less disease susceptible varieties and the use of a balance level of inorganic NPK fertiliser. The combination of these two practices, while not the primary aim, have been shown to reduce erosion.

Information regarding which varieties were less susceptible to CWBD and how farmers could assess their own planting stems was being adopted in project villages. This information is being made available to industry partners and extension information (written and audio visual) has been shared and continues to be developed under the new ACIAR project focused on cassava pest and disease.

The potential environmental benefits of the application of low levels of NPK fertiliser (in terms of reduced erosion) are unlikely to be realised without some ongoing external support and facilitation. The research showed that farmers are unlikely to receive direct support or extension advice from either the government or industry in the majority of contexts without some level of facilitation. The information regarding appropriate fertiliser management has been shared with several development projects who have taken up the recommendation and continue to work with farmers. Therefore, some benefits may arise in the future.

On the other hand, the existing technologies directly aimed at reducing soil erosion and degradation are unlikely to be adopted or scaled. As such, the trade-off in terms of the economic and livelihood outcomes of cassava production and the sustainability of the sector continues to be a cause for concern. The research has shown that in the current context of increasing opportunity costs of labour, systems designed for past context face increasing constraints to adoption.

8.4 Communication and dissemination activities

Website

The project website (now archived at https://research.aciar.gov.au/cassavavaluechains/index.html) contains all key documents of the project and serves as the main repository of project outputs and reporting. The website also includes information and presentations from key project activities, including MTR, Final Review and the regional Research Symposium.

Facebook Group and Stakeholder engagement

The Facebook group "ACIAR Cassava Value Chain and Livelihoods Program" now has more than 1300 members. Members include key national policy makers, national level researchers, Provincial and District staff, private sector actors (processors and traders), and farmers. At the moment the content is in English, but it will provide a useful way to point stakeholders to results as they become available in different languages. https://www.facebook.com/groups/1462662477369426/

Research Symposia

The project convened two large regional research symposia, bringing together private sector, government and development sector to discuss cassava value chain and livelihood related topics. The first symposium was held in conjunction with the project mid-term review in 2018 in Vientiane, Lao PDR. Information is available at https://research.aciar.gov.au/cassavavaluechains/mid-term-review/index.html

The second regional research symposium was held in 2019 in North Sumatra. Details of the symposium are here and the proceedings (published as ACIAR Proceedings 148) can be downloaded here.

Key Conferences and Workshops where project results were presented:

- World Roots and Tuber congress (China)
- Starch World (HCMC)
- CIAT Cassava Retreat (Hanoi)
- Agribusiness Master Class (Mandalay)
- FAO workshop for the Capacities Development for Agriculture Innovation System (CDAIS)
- NAFRI 20th Anniversary Symposium, April 25th, 2019
- Lao PDR Cassava Industry Stakeholder Meeting, Vientiane, Lao PDR, 6 March 2019
- GCP21 IVth International Cassava Conference, Contonou, Benin, June 2018
- International Tropical Agricultural Conference, Brisbane, November 2017
- International Conference on Root and Tuber Crops for Food Security - Malang, October 2017
- North-West Research Symposium, Hanoi, November 2017.

9 Conclusions and recommendations

9.1 Conclusions

The area of cassava has expanded rapidly in Cambodia and Laos in the last decade. The current strong market prices continue to drive expansion, resulting in changing landscapes and communities. This has created significant livelihood benefits for producers, contributed to economic development within communities, and become a major part of the national economies. Despite all these benefits, the underlying issues of sustainable production continue to place the sector under a cloud concern, leading to neglect by many stakeholders.

This project sought to understand the structure and nature of a range of external and internal factors that incentivise and constrain both the adoption and scaling of existing technologies aimed at improving the sustainability of the sector. The degree of private-sector interest and involvement in the project's research agenda in each case varied with the characteristics of the technology, the farming population, and the value chain structure.

Both farmers and value-chain actors were most interested in utilising cassava varieties that gave higher tuber and starch yields and, to a lesser degree, in managing soil fertility through application of appropriate fertiliser doses. These technologies had high learnability and relative advantage. Despite the benefits at the farm level, there remain issues of exclusivity over benefits generated which limited value chain actors actually taking an active role in promotion of technologies – beyond joining field days and stakeholder meetings. That is, without some form of external facilitation many of the potential farm and value chain benefits would never eventuate.

Technologies for soil conservation were also characterised by low learnability and (individual) relative advantage; hence there was little or no interest in these technologies. Government stakeholder, particularly in Laos, recognised the importance of addressing these issues. The ongoing expansion of cassava in districts created a conundrum for DAFO and PAFO who could not contain the expansion given the strong economic benefits that farmers were generating.

The case in Cambodia illustrates the additional problems associated with value chains that span borders, reducing the informal ties between processors, traders, and farmers. This can be characterised as a "disarticulated value chain". The Vietnamese processors saw no relative advantage in disseminating technology to Cambodian farmers, with whom they had no relationship, formal or informal. Likewise, the traders on both sides of the border were only interested in making spot transactions in a volatile market. Hence the project could not identify a private-sector knowledge partner, and government and non-government agencies were ill-equipped to step in.

To meet the urgent need for a supply of disease-free planting material will require a public agency to take the lead, perhaps then linking to private-sector technology suppliers who would thus have an interest to increase farmers' awareness and knowledge about disease control.

The comparison of cases shows that different incentive structures for engaging in knowledge partnerships exist within each value chain, depending on the type of technology, the farming population, and the potential for value-chain actors to capture benefits from the dissemination of the technology. This potential is in large part a function of the structural characteristics of the value chain, though the personal attributes and relationships of individual actors played an important role. This implies that private-sector actors can be powerful partners in technology dissemination if the incentive structure is in place, but in other cases the private sector has little or no incentive to get involved.

It is important to note that the research did not find a case where the private sector had spontaneously become involved in research-based technology dissemination. Hence, even where there is an underlying business case for such involvement, there needs to be facilitation by a public-sector (or NGO) actor. Successful knowledge partnerships can often be traced to the activities of one or a few local "champions" in business, government, and/or research who spark the process and keep it going.

Moreover, the private-sector partner may face constraints due to lack of knowledgeable staff, high turnover of staff, lack of capabilities to undertake participatory research, or language and cultural barriers (especially with foreign ownership), again pointing to the need for public-private partnering.

Also, it cannot be assumed that private-sector actors will have the necessary sensitivity to equity issues.

A further point that underscores the need for public-sector involvement is the need to coordinate contributions from value-chain actors that benefit the whole industry, as in the case of distributing disease-free planting material. While there are some examples of spontaneous coordination, it is likely that government regulation is needed so that participants are assured of mutual compliance.

These requirements for partnering with the private sector are summarised in Table 3. The "key conditions" listed can be regarded as provisional generalisations arising from the cross-case analysis and are not intended as a simple recipe for knowledge partnerships. As we have emphasised, there are many case-specific factors that restrict our ability to make such firm generalisations. Nevertheless, these key conditions can serve to delimit situations where private-sector partnerships are more likely to succeed.

Table 11. Key conditions for effective knowledge partnerships with private-sector actors, based on results of cassava case studies

- A fund of adoptable technologies (i.e., with moderate to high relative advantage and learnability) requiring no more than local adaptation
- A commercially-oriented farming population, experienced in repeat-dealing with stable agribusinesses
- An articulated value chain that establishes strong, enduring links between farmers, traders, and processors
- A market structure OR industry regulation that assures agribusiness actors of capturing the benefits of investing in improved farm productivity
- Absence of policy constraints such as distortions in fertiliser pricing or sudden changes in cross-border trade restrictions
- Involvement of a knowledge broker to catalyse and support the partnership (e.g., a public agency, a university, a development project, or an NGO)
- Individual actors with the interest and capabilities to pursue these partnerships

9.2 Recommendations

Review incentive structure for projects with private sector partners identified as central to the impact pathway

Many projects emphasis the role of the private sector as part of their impact pathway to scale technology development to smallholder farmers. The research conducted as part of this project demonstrates that this approach has several limitations depending on the specifics of the technology and value chain context.

It recommended that technical projects that identify the private sector as a key partner in scaling innovations utilise a similar approach understand context is which this may achieve the planned impacts and where it may either result in limited impacts or perverse environmental and social impacts. In these cases, the role of public sector and non-government actors should be emphasised and fostered. It would also be beneficial if these arrangements are in place during the design of a project and mechanisms for learning alliances and scaling included in budgets. The value of networked staff within countries cannot be understated.

Working closer with development projects that can incentives activities, particularly those with link to finance sector and development projects

Stemming from the above, in the context of cassava in Laos and Cambodia the project highlighted that in many situations there is an absence of appropriate private sector partners or lack of incentive for them to engage with scaling technologies to smallholder.

Access to credit was often identified by farmers as a constraint to adopting practices like purchasing fertiliser. This is not just a case of providing access to micro-finance tools that were often present. However, providing technical advice to projects or institutions in the finance space could go towards households changing saving and loan practices.

Financial services and financial literacy throughout the value chain.

The value chain assessments and discussions with farmers illustrated both the lack of financial services available to actors to manage their business and often a lack of financial literacy. Activities around access to financial services (traditional or e-services) should seek to include other value chain actors.

Behavioural change and nudges.
In some cases, the agronomic results and the economic analysis showed very high economic returns to changed practices. The case of fertiliser is a good example where a relatively small outlay produced a significant return. Yet, follow up interview showed many farmers although recognising the benefits of fertiliser and interest in receiving free fertiliser (or on credit) that they would not purchase fertiliser on their own accord.

The project identified situations in which processors may bridge the gap by providing fertiliser on credit. However, this situation is not always relevant either due to the lack on processor (Cambodia) or strong competition and uncertainly between processors (Laos). Therefore, models for engagement with support value chain actors need further development. A number of 'nudges' rather than incentives could be explored. This could include exploring various pre-commitment mechanisms and links to financial services – nudging savings at harvest time, rather than loans and credit.

Establishing cassava innovation working group and multi-donor activities

In both countries there are several projects and donors working either on cassava or with farmers in which cassava is an important activity for households.

There have been attempts to coordinate activities in Cambodia with the Cassava Working Group. Notwithstanding the politics between different organisations and groups greater coordination in activities and investments would enable efficiencies and scaling. Multiple projects seek technical advice from project staff on an adhoc basis – often with no resources to ensure sustainability of critical resources (germplasm collections etc.)

Similarly, in Laos there are informal collaboration between different organisations that this project has taped in to. However, there remains strong potential for more strategic collaboration to ensure efficiencies and sustainability. The National level training facilitated in 2021 partly supported by multiple projects is an example.

Seed system development to manage cassava disease
The importance of farmers having access to disease free planting material has been highlighted during this project. This project has provided the justification and established initial partnerships for this to occur. This recommendation has been taken forward in the new ACIAR project AGB/2018-172.

Investment if research on sustainable cassava systems for the context
The research conducted in this project aimed to evaluate existing technologies and develop partnerships for their scaling. The pre-existing technologies that have been developed and promoted in the past (intercropping and grass strips) have not been widely adopted anywhere and farmers continue to express a lack of interest once the additional labour requirements become apparent.
This is common to many sectors with livestock forage systems such as cut-and-carry becoming increasingly unpopular with farmers who now prefer to establish pastures for grazing.

Given the sustainability concerns of cassava production, it is critical that new technologies are developed that address both the sustainability concerns and farmers interests. This is likely to include exploration of rotational systems, the role of mechanisation, forage-livestock integration. This work needs to be conducted both on-station (also currently not managed sustainability) and on-farm. It should engage a multidisciplinary team of physical and social scientists.

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11 Appendix 1: Key Maps

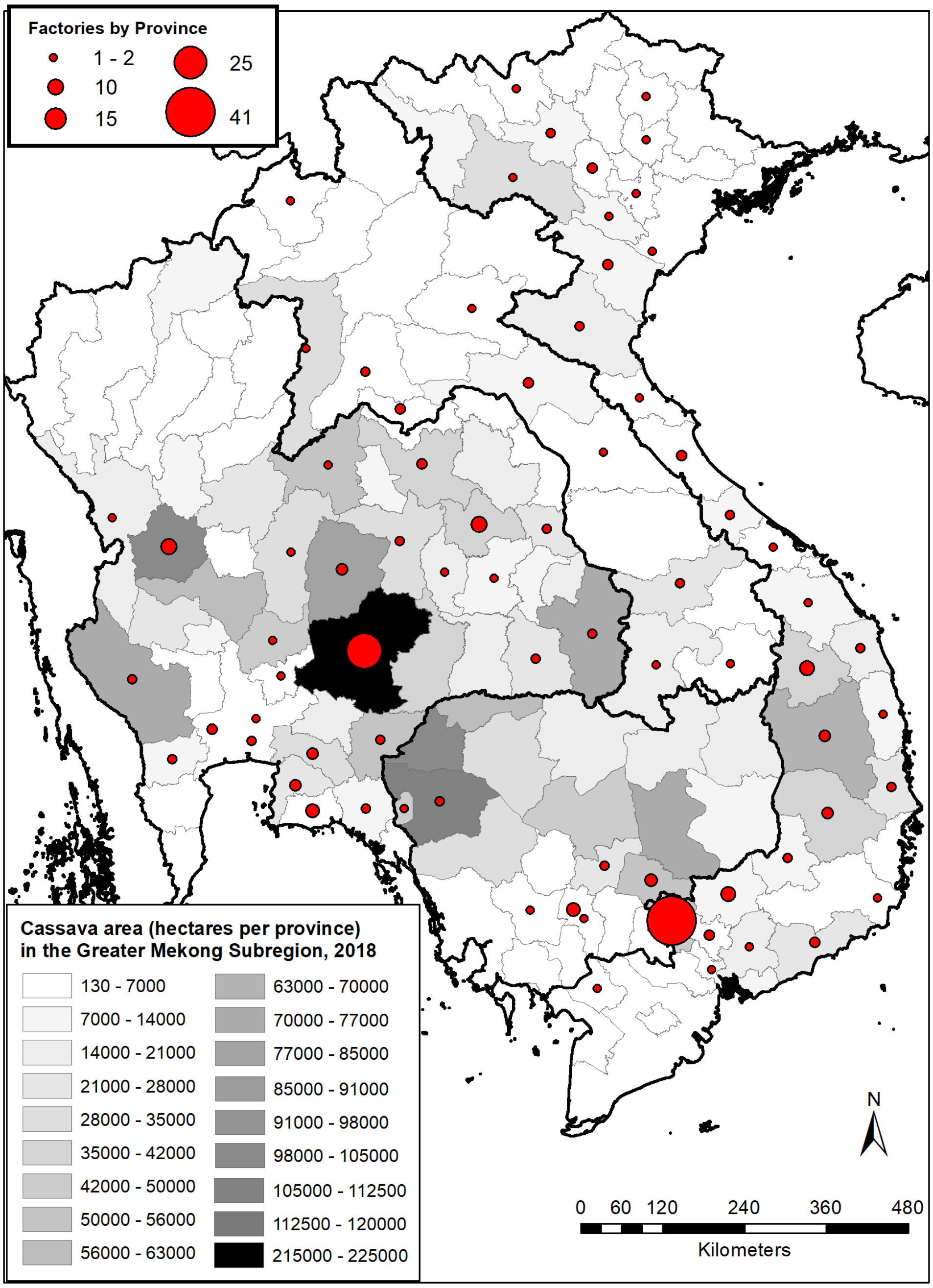

Figure A1.1 – Province production of cassava in Thailand, Vietnam, Cambodia and Laos (Map - E.Delaquis)

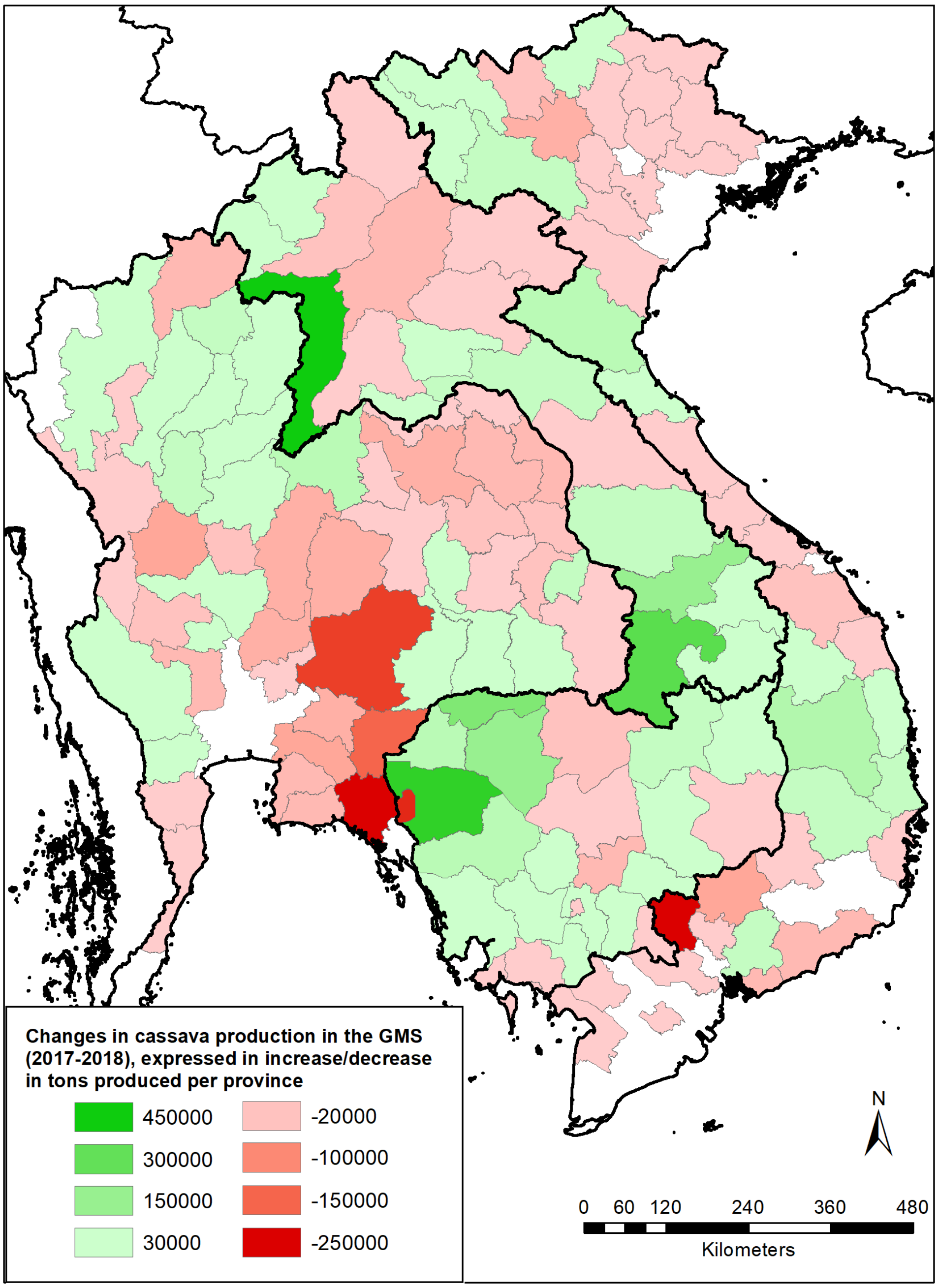

Figure A1.2 – Change in production of cassava in Thailand, Vietnam, Cambodia and Laos 2017 to 2018 (Map - E.Delaquis)

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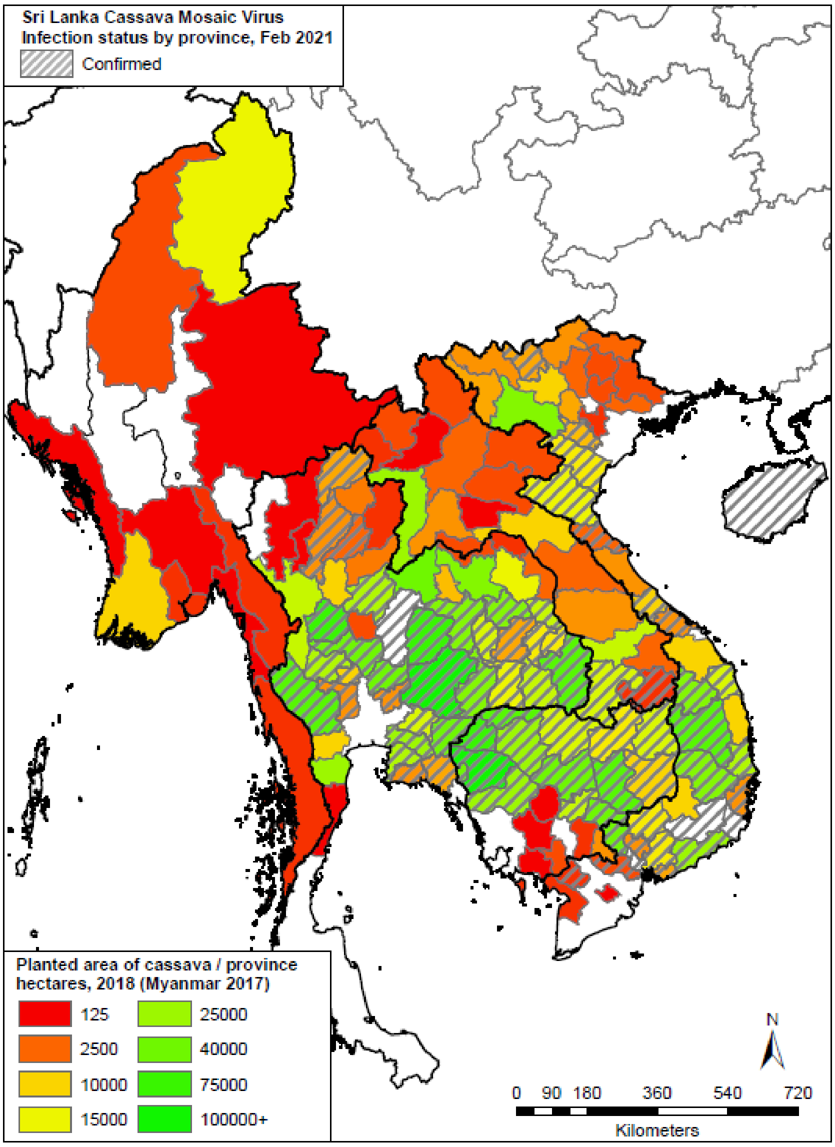

Figure A1.3 – Planted Area of Cassava/province, Myanmar 2017. (Map - E.Delaquis)

12 Appendix 2: Key Information from Household Survey

Table A2.1: Proportion of households having taken loans by income quartile

Access to Credit	Q1	Q2	Q3	Q4	Total
Lao PDR					
Percent of households that received a loan in the past 12 months	7.9%	15.7%	8.9%	11.6%	11.0%
% households with 1 loan	7.9%	15.7%	8.9%	10.5%	10.7%
% households with 2 loans	0.0%	0.0%	0.0%	1.2%	0.3%
Average value of total loans received (KIP)	9,916,667	8,807,847	9,562,500	14,200,500	10,608,298
Average value of total loans received (USD)	1,239.58	1,100.98	1,195.31	1,775.06	1,326.04
Cambodia	**Q1**	**Q2**	**Q3**	**Q4**	**Total**
Percent of households that received a loan in the past 12 months	30.77%	30.77%	44.87%	57.14%	40.84%
% households with 1 loan	25.64%	24.36%	42.31%	51.95%	36.01%
% households with 2 loans	2.56%	5.13%	2.56%	5.19%	3.86%
% households with 3 loans	2.56%	1.28%	0.00%	0.00%	0.96%
Average value of total loans received (Riel)	4,437,500	7,305,208	7,171,428	18,335,909	10,548,070
Average value of total loans received (USD)	1,109.38	1,826.30	1,792.86	4,583.98	2,637.02

Table A2.2: Manageability of debt

	Lao PDR		Cambodia	
How manageable is the current level of debt	Frequency	Percent	Frequency	Percent
Very unmanageable	22	35.5%	6	4.35%
Some concern	4	6.5%	34	24.64%
Manageable	25	40.3%	72	52.17%
Very manageable	11	17.7%	26	18.84%
Total	62	100.0%	**138**	**100.00%**

Table A2.3: Sources of Production Information

	Laos		**Cambodia**	
Source of Information	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Friends and neighbours in the village	**260**	**72.20%**	**229**	**73.63%**
Family	72	20.00%	**225**	**72.35%**
Cassava Traders	**77**	**21.40%**	13	4.18%
Friends and neighbours outside the village	57	15.80%	8	2.57%

	Laos		**Cambodia**	
Cassava Processors	**58**	**16.10%**	1	0.32%
Other	24	6.70%	6	1.93%
District government extension	23	6.40%	3	0.96%
Farmer Group	5	1.40%	13	4.18%
TV	13	3.60%	2	0.64%
Province government extension staff	3	0.80%	11	3.54%
Radio	3	0.80%	7	2.25%
Non-Government Organizations	1	0.30%	8	2.57%
Researchers	1	0.30%	3	0.96%
Internet	0	0.00%	0	0.00%

Table A2.4: Sources of Market Information

	Laos		Cambodia	
Source of Information	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Cassava Traders	**158**	**43.90%**	**296**	**95.18%**
Friends and neighbours in the village	**243**	**67.50%**	52	16.72%
Cassava processors	**97**	**26.90%**	10	3.22%
Family	48	13.30%	16	5.14%
Friends and neighbours outside the village	38	10.60%	3	0.96%
Other	17	4.70%	2	0.64%
Farmer group	4	1.10%	13	4.18%
Radio	2	0.60%	3	0.96%
Province government extension staff	1	0.30%	2	0.64%
District government extension	2	0.60%	0	0.00%
TV	2	0.60%	0	0.00%
Internet	0	0.00%	1	0.32%
Non-government organisation	0	0.00%	1	0.32%
Researchers	0	0.00%	0	0.00%

Table A2.5: Asset ownership by income quartile

Assets	Q1	Q2	Q3	Q4	Total
Laos					
Truck	1.1%	1.1%	4.4%	11.1%	4.4%
car	10.0%	3.3%	17.8%	22.2%	13.3%
motorbike	86.7%	92.2%	92.2%	93.3%	91.1%
Lot sing	17.8%	15.6%	26.7%	31.1%	22.8%
two wheel tractor	58.9%	75.6%	75.6%	83.3%	73.3%
four wheel tractor	8.9%	3.3%	2.2%	11.1%	6.4%
water_pump	5.6%	3.3%	2.2%	6.7%	4.4%
generator	1.1%	3.3%	5.6%	2.2%	3.1%
mobile phone	93.3%	88.9%	92.2%	93.3%	91.9%
smart phone	23.3%	18.9%	28.9%	34.4%	26.4%
tv	83.3%	85.6%	92.2%	96.7%	89.4%
dvd player	17.8%	26.7%	26.7%	47.8%	29.7%
radio	23.3%	26.7%	32.2%	36.7%	29.7%
refrigerator	82.2%	80.0%	90.0%	96.7%	87.2%
Cambodia	**Q1**	**Q2**	**Q3**	**Q4**	**Total**
truck	0.00%	0.00%	3.85%	7.79%	2.89%
car	0.00%	2.56%	0.06%	2.60%	1.29%
motorbike	87.18%	94.87%	93.59%	94.81%	92.60%
lot sing	17.95%	30.77%	42.31%	40.26%	32.80%
two wheel tractor	1.28%	1.28%	2.56%	3.90%	2.25%
four wheel tractor	5.13%	15.38%	8.97%	19.48%	12.22%
water pump	6.41%	6.41%	12.82%	12.99%	9.65%
generator	1.28%	1.28%	5.13%	5.19%	3.22%
mobile phone	84.62%	78.21%	88.46%	84.42%	83.92%
smart phone	12.82%	20.51%	15.38%	28.57%	19.29%
tv	26.92%	29.49%	30.77%	50.65%	34.41%
dvd player	12.82%	11.54%	10.26%	14.29%	12.22%
radio	24.36%	25.64%	26.92%	25.97%	25.72%
refrigerator	0.00%	1.28%	0.06%	0.14%	0.32%

13 Appendix 3: Stakeholder feedback on project activities and outreach

Cassava industry has been proven successful by collaboration and sharing of knowledge and resources among stakeholders. I believe our community is unique with these core values and I am pleased to see we deploy all available technologies and platforms to communicate and work together to enhance livelihood of farmers and all stakeholders.
Over a thousand of members in this FB group are extraordinary and reflects high interest and enthusiasm to learn and share. We see a number of rapid changes in the world and the challenges going forward. Hope the strong relationship and close collaboration will get us through the situation and re-establish strength and competitiveness of cassava Industry. Lastly I wish all members be happy, strong and healthy
Boonmee Wattanaruangrong,
Vice President of TTSA

This is a very helpful page to connect with every actor who is involved in cassava sector. To me, I come to Facebook mainly to check on this FB page as to see updates and news feeds as the resources here are quite informative. The coverage of cassava related-info with regional and global focus is an essential part of this page that I like the most. This is because, for a transboundary disease like CMD, it requires a platform with transnational focuses for audience to comprehend the issue with a more reliable sources so that we how to could work individually and collaborate with one another to solve the problems.

Neng Por
CAVAC Cassava Program

A really informative webinar that gave a good overview of regional developments in the cassava sector. A must watch for all market participants.
Michael Y. Yoong, Business Development Manager, Hung Duy Starch – Vietnam

The material produced by the ACIAR Value Chains Project provided the most comprehensive data set and analysis available and the Facebook site also gave timely updates for on trade and prices, disease management and field trials. As a Policy Officer largely operating at the national level, the interactions with the ACIAR Program provided opportunities to visit the field with an expert team and to learn a great deal about practical aspects of cassava production and disease management. In addition, the Facebook site provided regular updates on progress with field trials, brief statements of the results and a great deal of information relating to trade and prices. This was a valued source of information for me and for others at FAO Cambodia.
Iean Russell
Senior Policy Officer. FAO-EU FIRST Programme, Cambodia

I have followed this web site on Facebook for more than a few years now. I read their posts with great interest both to follow their approach and activities and also to learn of what they were doing - much of which was and is applicable in West Africa. A most useful site and a model for others to follow

Louw Burger,

FOUNDER Thai Farm International and former CEO, Nigeria

I am Clair Hershey, former global leader of CIAT's Cassava Program (retired), and currently private consultant. I rely on the cassava value chain discussion group to stay up to date on a wide range of cassava-related issues and research progress. I feel that there is special value in the sharing of innovative approaches to arising major challenges such as the mosaic virus, along with the more general day to day management strategies and techniques of research that can make each program more efficient and more effective. The forum provides up-to-date and on-the-ground understanding of how each country of the region is faring in production, processing, marketing and use of cassava.

Unlike other projects with limited timeframe, ACIAR funded cassava program is kind of long lasting program, ensuring continuity of the research activities, exploring and providing up-to-date solution for sustainable cassava production. Multiple years field trials in Chamkar Leu Upland Crop Research Station have been well set up, and provided a lot of benefits including solutions to the challenges in cassava production (nutrient, pest and disease management, varieties etc.) and capacity building to the national research institution and extension. The fact that it is a regional program, the program also brings coordination and collaboration between countries.

Another important achievement by the program is the organization of a Regional Workshop for a Cassava Mosaic Disease Control Plan in Mainland Southeast Asia in September 2018. The workshop has gathered top experts around the world, policy makers, practioners to interact, discuss and identify immediate, medium and long-term solutions for CMD management in SEA.

As a development worker being involved in the cassava works, I value the ACIAR cassava program, and collaboration between the ACIAR cassava program and FAO project. Last but not least, I appreciate good personality (Jono and Rith) and you both quick responses to my enquiries/questions.

Proyuth Ly,

FAO Cambodia

The group provides experience, knowledge related to the value chain of cassava, especially to management of diseases and pests. It's very useful for my business and it's very good to meet new friends around the world. Thank you everyone.

Mr. Attapol Lerdvanichdilok

Manager, Thai Tapioca Starch Association (TTSA)

The Facebook group is a useful and needed tool to connect experts and implementers to discuss technical topics and share information on cassava. It likes a hub which directly contributes to build knowledge on cassava regional value chains.

Reathmana Leang – Project Manager
Accelerating Inclusive Cassava Market Development
UNDP Cambodia

I have always been a great believer in free discussion and exchange of information. Farmers always like to know what their neighbours are doing. Researchers and technical assistants also like to know what is happening on the farm and in the real world and to learn from those experiences. Traditionally there has been a communication gap in this area. The cassava pages set up by Jono on Facebook do a wonderful job of keeping everyone in the picture. The danger of false claims being pushed to someone's advantage are managed through the free and easy commentating on the posts, whilst good ideas can get a boost when several people show their appreciation. Whilst this page does not replace more formal communication methods, it does a magnificent job of keeping a diverse range of people from growers to researchers and policy makers of what is happening and possible solutions. In these days when people are questioning social media, this is an excellent example of how they can be used to improve peoples lives.
James Cock.

I am pleased to express my sincere gratitude and large thanks to you and the team for bringing important data and discussions on Cassava forward in a very constructive format
It is encouraging to see how this forum brings together so many different interest parties to support the common theme on improving the cassava value chain and farmers well fare
I have recommended the site to other people with interest in the subject and we are all looking forward to continue the open dialogue
Best regards,

Gerd Frank Pedersen
Regional Lead Texturants, Asia Pacific
Tate & Lyle

11. Appendix 4: Agronomic Results and Economic Analysis

13.1 LAO PDR

13.1.1 Varieties

Agronomic results

During cropping season 2017-18, six high yielding cassava varieties along with farmers' variety were evaluated. Varieties did not differ significantly in fresh root yield (P=0.064). However, location (i.e. Paklai, Kenthao and Viengthong) had significant ($p<0.001$) effect on root yield. On an average Paklai District demonstrated highest and Viengthong lowest yield (Annual report 2018).

Among the cassava varieties Rayong11 produced the highest fresh root yield (25.9 t ha^{-1}, average from three Districts) and KM-21-12 yielded the lowest (19.2 t ha^{-1}) (Table X).

In these three trials farmers' variety[7] yielded 22.6 t ha^{-1}. In these trails all plots were infected by CWBD. Presumably, all the plants were equally affected by the disease. Out of four trials, we managed to get data from three trails due to premature harvest by farmer from Bolikhan District as root price was higher compared to previous years and the farmer rushed to harvest.

Table A4.1 Mean fresh root yield (t ha^{-1}) and Starch content (%) of all three districts. Values are the means of three districts, Paklai, Kenthao and Viengthong, and values within a column followed by different letters are significantly different (*P* < 0.05).

Variety	Fresh Root yield (t ha^{-1})	Starch content (% fresh root weight)	Starch yield (**t** ha^{-1})
Rayong11	25.91^{a}	30.67^{a}	7.9^{a}
KM140	23.59^{ab}	23.54^{bcd}	5.5^{b}
Rayong72	23.19^{ab}	23.60^{bcd}	5.6^{ab}
Local	22.58^{ab}	25.57^{bc}	5.7^{ab}
Rayong9	22.19^{ab}	26.70^{b}	6.3^{ab}
KU50	20.12^{ab}	21.65^{d}	4.7^{b}
KM21-12	19.16^{b}	22.76^{cd}	4.7^{b}

Economic impact at field level

The agronomic results from the trial show that there was no significant difference in the fresh root yield (FRY) for the main elite varieties available in Laos for multiplication and distribution. However, the trials conducted in the project began with positive selected stems (no disease symptoms) from the NAFRI research station. It is clear that over time some varieties would become seriously infected by CWBD which could impact the subsequent FRY.

[7] *The farmers were not sure of the variety names and were a range of Thai introduced varieties often with more than one variety found in the field.*

There was a significant difference in the starch content between varieties. The value chain in all the Lao sites did not incentives the cultivation of varieties or management to improve starch content. However, farmers producing their own cassava chips would get a lower conversion of roots:chips. Processors indicated that measuring starch content of deliveries was time consuming and created confusion and conflict with farmers. They therefore paid a lower price for all roots based on starch recovery rates. With the spread of disease and the release of new varieties factories would be advised to change their pricing structure to incentives early adoption of high and stable starch content varieties. This would improve the efficiency of processing and the price that factories could pay to farmers.

In Thailand the advertised benchmark price is for roots with a 25% starch content. A premium of 0.05 THB/kg (S1.70 USD/t) is paid for roots above this until a maximum of 30% when no additional premium is paid. In Vietnam the advertised price is for roots of 30% starch content and a deduction is made for roots of lower starch content. The deduction in Tay Ninh is 90VND/kg ($3.90USD/t). Roots below 25% are not desired and are often rejected as they approach 20%.

13.1.2 Fertiliser

Agronomic results

The agronomic benefit of fertiliser application against farmers' practice were demonstrated in four districts during 2017-18 cropping season. Varieties responded similarly to fertiliser application- no fertiliser treatment produced the lowest and high fertiliser produced highest yield (Table 2.2.2).

The fertiliser treatment X variety interaction was not significant. The average fresh root yield was 19.0, 27.1 and 17.9 for Paklai, Kenthao and Viengthong Districts, respectively, considering all varieties and all fertiliser treatment. Considering all three Districts and three varieties included in the trials, highest yield (25.1 t ha^{-1}) was achieved by highest fertiliser application. Moderate fertiliser application with manure also yielded (24.1 t ha^{-1}) very close to highest rate of fertiliser input. In general fertiliser application yielded 1.4- to 1.7-fold higher fresh root compared to Farmers' practice and without any fertiliser application. Fertiliser application did not show any effect on starch content.

Table A4.2 Fresh root yield (t ha^{-1}) of KU50 and Rayong11 while applied different fertiliser rate in three districts, Paklai, Kenthao and Viengthong Districts. **P_0** No fertiliser, **P_1** 40N-10P-0K, **P_2** 40N-10P-40K, **P_3** 40N-10P-40K + Manure (5t ha^{-1}), **P_4** N-P-K (15-15-15), **P_5** 80N-40P-80K.

	Fertiliser					
Variety	P_0	P_1	P_2	P_3	P_4	P_5
KU50	17.2	18.8	18.6	21.4	19.7	23.7
Rayong11	18.1	22.3	25.1	27.9	23.9	28.2
Variety	P<.001	L.S.D.= 2.51				
Fertiliser	P=0.005	L.S.D.= 4.34				
Variety x Fertiliser	P=0.808	L.S.D= 6.14				

Data for Rayong72 not presented and kept out of calculation as it was only used as replacement for KU50 in one district (i.e. Viengthong).

To scale up of the results of previous year (2017-18) demonstrations of effect of fertiliser, large plot on-farm demonstrations were organised during 2018-19. The root yield was consistently low, ranged from 12.3 to 26.4 t ha^{-1} when grown without any fertiliser. The yield increase was 1.1 to 1.7-fold when fertiliser was applied (Annual report 2018). Bolikan district had the lowest yield for both treatments compared to other districts; however, demonstrated highest yield increase with fertiliser application. By contrast, Vienthong district demonstrated list yield increase with fertiliser; however, yielded highest (26.4 t ha^{-1}) without any fertiliser application. The district x fertiliser treatment interaction was not significant for fresh root yield.

During the final year of the project, commercially available fertiliser blend with two different K:N ratio (i.e. 2:1 and 1:1) were tested in 4 districts and compared with without fertilize application. Fertiliser application increased cassava root yield compared to cassava grown without fertiliser by 1.5-fold and 1.4-fold while K:N ratio was 2:1 and 1:1 in fertiliser blend, respectively. Highest yield increase (i.e. 1.8-fold) and lowest yield increase (i.e. 1.2-fold) was observed in Viengthong and Bolikan district, respectively, with K: N 2:1 ratio.

Cropping history of the farmers' field presumably contributed to the response of the fertiliser application on cassava root yield. At Paklai the cropping history was the oldest, ~11 years, of continuous cassava without any fertiliser inputs (data not shown), where lowest yield was observed when grown without fertiliser application (13 t ha^{-1}), however, yield increase with fertiliser was high (1.7-fold). Bolikan district had the highest yield (24.1 t ha^{-1}) compared to other districts when grown without fertiliser had the cropping history of 6.5 years of continuous cassava without any fertiliser inputs (data not shown). Kenethao and Viengthong district had the cropping history of 4 and 5 years of cassava cultivation without fertiliser, demonstrated similar response to fertiliser application, average 1.7-fold increase in yield (calculated from Table 2.2.3). Furthermore, when analysed all 40 demonstrations fertiliser application increased yield by ~38% compared to without any fertiliser application.

Table A4.3 Fresh root yield (t ha^{-1}) and starch content in four districts of Laos during the season 2019-20. Values are the means of trails in each district (2 trials in each district. n.s., non-significant.

District	Fresh root yield (t ha^{-1})			Starch content (%)		
	No Fertiliser	With Fertiliser $N:P_2O_5:K_2O$ (14-5-35)	With Fertiliser $N:P_2O_5:K_2O$ (15-7-18)	No Fertiliser	With Fertiliser $N:P_2O_5:K_2O$ (14-5-35)	With Fertiliser $N:P_2O_5:K_2O$ (15-7-18)
Kenethao	15.3 ± 8.03	25.2 ± 6.40	25.3 ± 6.69	28.0 ± 1.03	27.6 ± 0.64	27.8 ± 2.16
Paklai	13.0 ± 3.57	21.6 ± 1.53	20.1 ± 1.57	23.1 ± 1.43	26.7 ± 1.14	26.7 ± 1.88
Viengthong	18.4 ± 5.95	32.5 ± 2.78	28.7 ± 3.97	30.6 ± 0.58	33.5 ± 0.07	32.3 ± 0.34
Bolikan	24.1 ± 0.10	28.9 ± 3.68	36.7 ± 3.26	26.9 ± 3.13	29.9 ± 1.87	26.6 ± 1.32
Fertiliser	n.s.			n.s.		
Fertilize X Location	n.s.			n.s.		

The importance of potassium fertiliser (K) was an vital factor to demonstrate, particularly to government officials who sometime promoted 'organic' production. We carried out an on-station experiment during 2018-19 season, to determine the growth response to K fertiliser and to examine the field's K balance over the cropping season We found a positive effect of K fertiliser (up to 39% yield increase

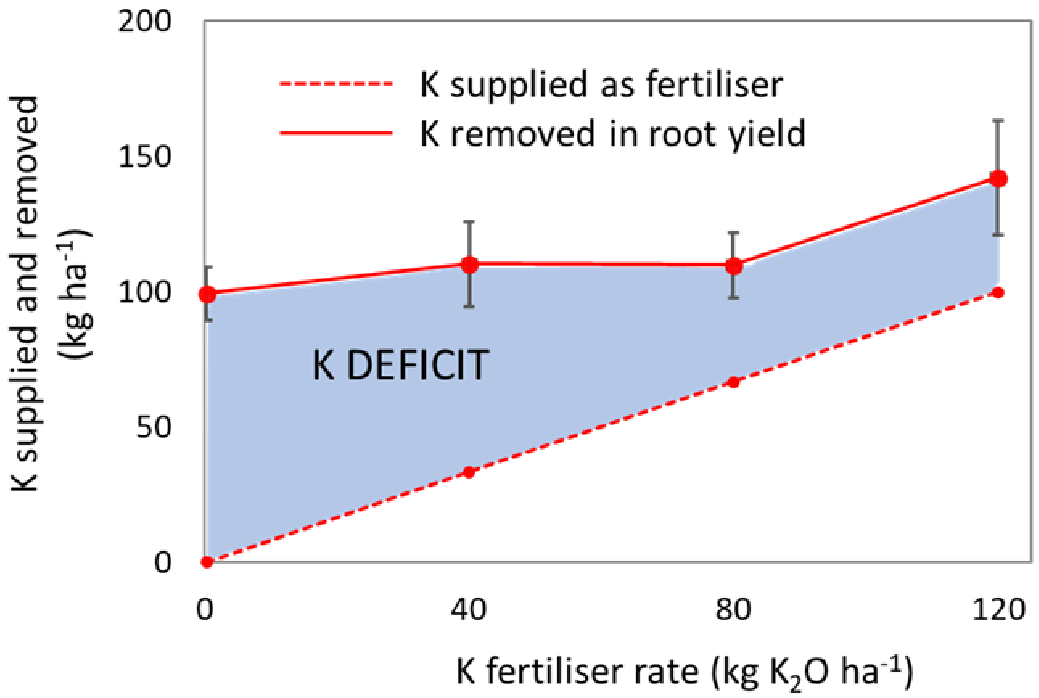

Figure A4.1 K balance of the cassava crop. The graph shows amounts of K supplied as fertiliser (doted, line) and removed in tuber yield (solid line) at the harvest 2, for treatments N-P_2O_5-K_2O (kg ha^{-1}) T_2 40-20-0, T_3 40-20-40, T_4 40-20-80 and T_5 40-20-120. Values are means of three replicates ± s.e. for K removed in tuber yield.

compared to no K fertiliser at early harvest, 21% at late harvest) and a positive effect of late harvest (on average a 35% increase compared to early harvest) on cassava root yield. Low-K crops benefited more from a late harvest. At 10 months, the harvested cassava contained 99-142 kg K ha^{-1}, indicating that there was a net removal of K from the fields, even at high K fertilisation levels. This experiment was carried out in comparatively fertile soil with relatively high background K levels, yet yield benefits of K fertilisation were observed and soil K reserves were depleted by the harvest. We concluded that K fertilisation of cassava is advisable for better yields and to avoid progressive depletion of the soil K capital.

Economic analysis

The economic analysis of fertiliser application involved three aspects. Firstly, conducting a marginal analysis and determining the marginal rate of return (MRR). Secondly, participatory enterprise budgeting to determine the impact on criteria of interest to farmers – costs and income flows, net economic returns per hectare, returns to labour day. Finally, scenario analysis was conducted where prices and responsiveness of fertiliser application were varied to explore with farmers the stability of the results.

The results of 2017-18 in Kenthao and Paklai show the treatment of 80N-40P-80K produced the highest net return. However, the responsiveness and the rate of return varied significantly between the varieties due to CWBD. This would be even more pronounced if a price penalty was introduced for lower starch content (that would happen in Thailand or Vietnam).

Table A4.4 – Net returns of fertiliser trials in 2017-18

District/Treatment	Both	KU50	Rayong 11	Rayong 72
Kenthao				
Control	11,234,722	10,522,222	11,947,222	
40N-10P-0K	11,601,324	11,233,963	11,968,685	
40N-10P-40K	12,686,026	11,462,415	13,909,637	
N-P-K (15-15-15)	13,142,578	11,995,356	14,289,801	
80N-40P-80K	**13,686,220**	**12,296,637**	**15,075,803**	
40N-10P-40K+Manure (5t/ha)	11,229,081	9,181,859	13,276,304	
Paklai				
Control	7,432,639	6,668,056	8,197,222	
40N-10P-0K	8,963,824	6,261,740	11,665,907	
40N-10P-40K	8,124,915	5,197,137	11,052,692	
N-P-K (15-15-15)	6,632,856	5,234,245	8,031,467	
80N-40P-80K	9,718,859	**7,454,970**	**11,982,748**	
40N-10P-40K+Manure (5t/ha)	8,456,165	6,237,415	10,674,915	
Viengthong				
Control	3,732,500		4,215,000	3,250,000
40N-10P-0K	3,642,713		4,478,963	2,806,463
40N-10P-40K	5,032,415		**5,441,581**	**4,623,248**
N-P-K (15-15-15)	4,399,245		5,327,578	3,470,912
80N-40P-80K	4,208,720		4,800,803	3,616,637
40N-10P-40K+Manure (5t/ha)	3,334,915		4,169,915	2,499,915

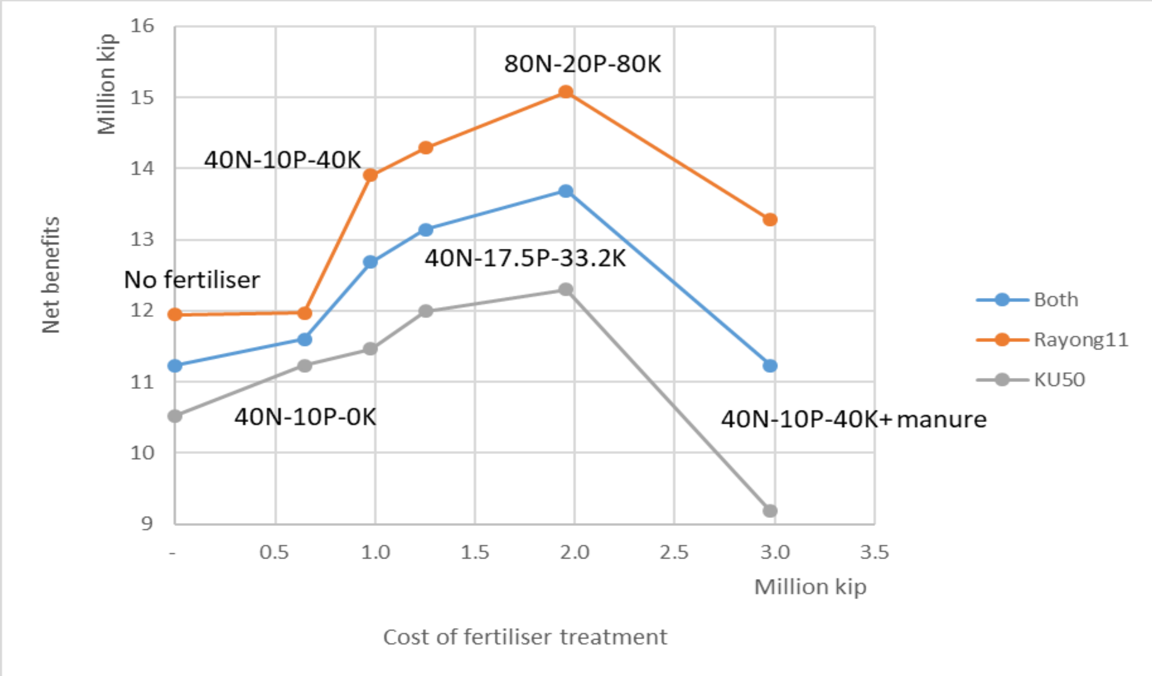

Fig A4.2 Marginal analysis of trial 2017-2018 in Kenthao

The application of manure application on cassava is often promoted. Manure has a significant cost and also requires larger amounts of labour to collect and apply to the field. Based on the one year trial, the economics of manure application reduces farmer returns and provides a negative return.

The analysis of the trials in 2018-19 showed benefit of using the NPK blend in Xayabouli. The MRR when moving from 40-20-40 was 131% and is also less complicated for farmers. However, the results in Bolikhamxai due to other crop management issues, showed that the additional cost was not warranted. These results highlight the need for good management to justify additional expenditure.

Table A4.5: Economic analysis of results from 2018-19

		Xayabouli		**Bolikhamxai**	
Treatment	**Cost**	**Net Benefits**	**MRR**	**Net Benefits**	**MRR**
Control (No fertiliser)	0	10,156,944		3,662,500	0
N:P2O5:K2O (40-20-40)	814,157	16,287,232	753%	**5,401,120**	**214%**
N:P2O5:K2O (15-5-30): 300 Kg/ha = (45-15-90)	**1,320,000**	**16,950,833**	**131%**	3,216,806	D
N:P2O5:K2O (80-20-80)	1,401,172	14,709,939	D	3,761,328	D

The larger demonstrations conducted in each district show the variation in agronomic responses and the economic implications. In all districts there are positive net benefits at the current prices when the analysis conducted. However, the MRR is relatively low (23.8%) in Viengthong and is unlikely to induce much practice change. Indeed, when the lower price scenario is used the yield response in Viengthong would result in negative returns.

Table A4.6 - Economic analysis of demonstrations in 2018-19 in Laos

District	Paklai	Kenthao	Bolikan	Viengthong
Yield without fertiliser (t/ha)	27.8	24.8	12.3	26.4
Yield with fertiliser (t/ha)	37.2	36.8	21.1	29.7
Difference (t/ha)	9.5	12.0	8.8	3.3
Current price (kip/kg)	540	540	540	500
Cost fertiliser (kip/ha)	1,320,000	1,320,000	1,320,000	1,320,000
Current cassava root price				
Marginal Net Benefits (kip/ha)	3,785,333	5,140,667	3,428,240	313,796
MRR (%)	286.8%	389.4%	259.7%	23.8%
Low cassava root price: 300 kip per ton				
Marginal Net Benefits (kip/ha)	1,516,296	2,269,259	1,317,911	- 339,722
MRR (%)	114.9%	171.9%	99.8%	-25.7%

A harvest field days partial budgets were constructed with farmers to look at the costs and returns of cassava production – with and without fertiliser. The results in the Table below are just indicative from one village. This was a useful activity for farmers to see all the costs (including the opportunity cost of their own time) for cassava production. A range of scenarios were explored around different prices and yields. Threshold were identified where specific criteria were met or failed to be met. The net-returns to labour day became an interesting indicator where participants could identify that at particular price and yield combinations the returns per day invested – and compare to their own alternatives.

Table A4.7 – Example of scenario analysis results from focus group after harvest

	Without fertiliser	**With fertiliser**
Material costs (A)	1,600,000	2,920,000
Labour costs (B)	6,420,000	6,660,000
Total costs (A+B = C)	8,020,000	9,580,000
Revenue (D)	16,114,691	21,598,198
Net returns (D-C)	8,094,691	12,018,198
Net returns to household resource (D-A = E)	14,514,691	18,678,198
Labour days (F)	152	158
Net returns per labour day (E/F)	95,491	118,216
Low price scenario		
Revenue	8,335,185	11,171,481
Net returns	315,185	1,591,481
Net returns to household resource	6,735,185	8,251,481
Labour days	152	158
Net returns per labour day	44,310	52,225

Presentation of results of participatory budgeting comparing different scenarios and also maize production – Xayabouli Province.

The final year of demonstrations again showed on average attractive economic returns to the fertiliser application. However, these benefits became quite marginal under the low-price scenario, but extremely attractive under the high price scenarios. Farmers in Laos tended to have a very positive (optimistic) outlook for what future prices might be during interviews and focus groups.

Table A4.8: Economic Analysis of Fertiliser Application (Laos)

Row Labels	Net benefits (Low price)	Net benefits (Medium price)	Net benefits (High price)	Net benefits (2020-21)	MRR (Low price)	MRR (Medium price)	MRR (High price)	MRR (2020-21)
Bolikhamxai	662,787	1,820,681	2,438,224	4,908,397	40%	110%	148%	297%
Bolikhan	185,019	1,104,028	1,594,167	3,554,720	11%	67%	96%	215%
Viengthong	1,140,556	2,537,333	3,282,281	6,262,074	69%	153%	199%	379%
Xayabouli	540,684	1,637,526	2,222,509	4,562,439	33%	99%	134%	276%
Kenthao	361,667	1,369,000	1,906,244	4,055,222	22%	83%	115%	245%
Paklai	739,593	1,935,889	2,573,914	5,126,012	45%	117%	156%	310%
Average	603,301	1,731,452	2,333,132	4,739,853	36%	105%	141%	287%

13.1.3 Intercropping

Agronomic analysis

During 2017-18 a demonstration of intercropping of cassava was established in Paklai Districts. The farmers involved were very enthusiastic about the potential to get extra income from the same field where cassava was growing. However, due to heavy rain during establishment period both intercrop and Cassava could not germinate due to soil waterlogging for extended period. Following intercropping systems were established- Cassava + mung bean 2 rows, Cassava + peanut 2 rows, Cassava + yard long bean 2 rows to compare with Cassava mono culture.

Economic analysis

No economic analysis could be carried out on the intercropping trial due to crop failure. Whilst farmers were excited about the potential for extra income, the additional labour required and the frequency was not attractive and finding willing farmers to participate in subsequent years was difficult.

Farmers in Laos tend to have large areas of cassava and the labour requirement to intercrop the whole area is a significant constraint and would require the hiring of labour. This cash outlay would expose farmers to the risk of debt should crop failure occur.

After consultation with stakeholders and the research team the continuation of intercropping did not continue into subsequent years. The technology did not meet the demands of labour scarce farmers and there were no partnerships that could be developed to incentives it. Having said that, if there was strong market demand for one of the proposed intercrops may have more attraction. One particular Thai starch processor also processes mungbean and has expressed interest investment in Kenthao District.

13.2 Cambodia

13.2.1 Variety assessment

Agronomic analysis

During cropping season 2017-18, six high yielding cassava varieties along with farmers' variety were evaluated. Data from Snoul District demonstrated that varieties differed significantly in fresh root yield (P < 0.05) (Table 2.2.4). Among the cassava varieties KU50 produced the highest fresh root yield (30.2 t ha^{-1}) and farmers' variety was the lowest (16.0 t ha^{-1}). In this trail all the plots were infected by CWBD and infested by mealy bug. Presumably all the plants were equally affected by the pest and disease. Varieties differed significantly (P < 0.05) in starch content. Highest starch content was achieved by Rayong72 (i.e. 28%) and the lowest was 23% for SC9 (Annual report 2018).

Table A4.9 Fresh root yield (t ha^{-1}) of seven popular Cassava varieties of Cambodia from atrial in Snoul district, Kratie province during the season 2017-18. Values are means of three replicates and within a column followed by different letters are significantly different (*P* < 0.05)

Variety	Fresh root yield (t ha^{-1})
KU50	30.17^{a}
Hauybong60	25.94^{ab}
Rayong72	25.41^{ab}
KM-98-1	24.91^{abc}
SC8	22.29^{abc}
SC9	19.44^{bc}
Farmer variety	15.97^{c}

During 2018-19 season we conducted demonstrations in three districts in four farmers' field. Among the varieties across all locations farmer's choice variety yielded highest, ranged from 20.6 to 39.7 t ha^{-1} and Rayong 5 yielded lowest, ranged from 14.8 to 20.2 t ha^{-1}. While considering different locations, on an average for all varieties Snoul produced highest (i.e. 30 t ha^{-1}) and Chet borey produced the lowest (15 t ha^{-1}). Ranking of varieties following the criteria of the fresh root yield and starch content came out very different- considering fresh root yield Farmer's choice variety came out at the top; however, according to starch content the same variety came out at the bottom. Although when ranking was calculated following starch
yield farmer's choice variety came out as second precede by variety KM98-1 (Figure 2.2.2). Ranking on the disease susceptibility (i.e. % of symptomatic plants), Farmer's choice variety ranked the top and Rayong60 bottom (Annual Report 2019).

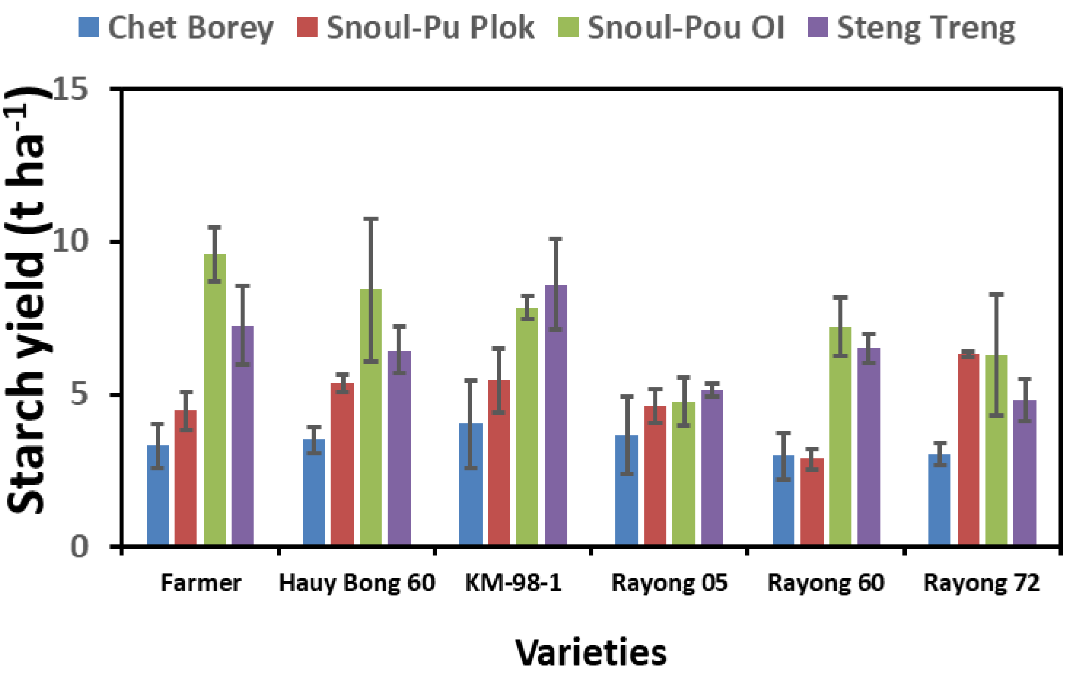

Figure A4.3 Starch yield (t ha^{-1}) of six cassava varieties grown in four farmer's field in three districts. Values are means ± standard error (n=3).

During 2017-18 season we first notice presence of disease (CMD) in our trials. However, in December 2015, Sri Lankan cassava mosaic disease (SLCMD) was first reported in a single isolated plantation in Eastern Cambodia (Wang et al., 2016)[8]. Consequently, project started focusing on infection of CMD and its consequences on farmers' livelihood. In the established demonstrations during 2018-19 infection rate (i.e. number of symptomatic plants) on different varieties were recorded. Number of CMD symptomatic plants differed among 6 varieties across all locations (Annual report 2019). Percentage of CMD symptomatic plants was highest (i.e. 29.3%) for Rayong60 and lowest for Farmer's choice variety (i.e. 5%). Among 4 locations percentage of CMD symptomatic plants were on average highest in trails Snoul-Pou Ol and Steng Treng for all the varieties, 20 and 19.3%, respectively (Annual report 2019).

Screening for disease (i.e. CMD) tolerances among popular varieties were carried out during 2018-19 and 2019-2020 cropping season. During 2018-19 experiment, there was no effect of fertiliser application on disease symptoms (i.e. infection). Fresh root yield on both sites was similar ranging from 24.1 to 42.9 t ha^{-1} at site 1 and 17.1 to 46.0 t ha^{-1}. Variety SC8 yielded highest in both treatment at site 1, however, in site 2 KM 98-1 produced highest. Rayong11 yielded lowest in both treatment and both sites. Among the varieties, SC8 and Rayong11 showed the highest symptom (i.e. 100%) and KU50 the least at the end of the experiment (Annual report 2019).

[8] *Wang H. L., Cui X. Y., Wang X. W., Liu S. S., Zhang Z. H. & Zhou X. P. (2016) First Report of Sri Lankan cassava mosaic virus Infecting Cassava in Cambodia. Plant Disease 100:129.*

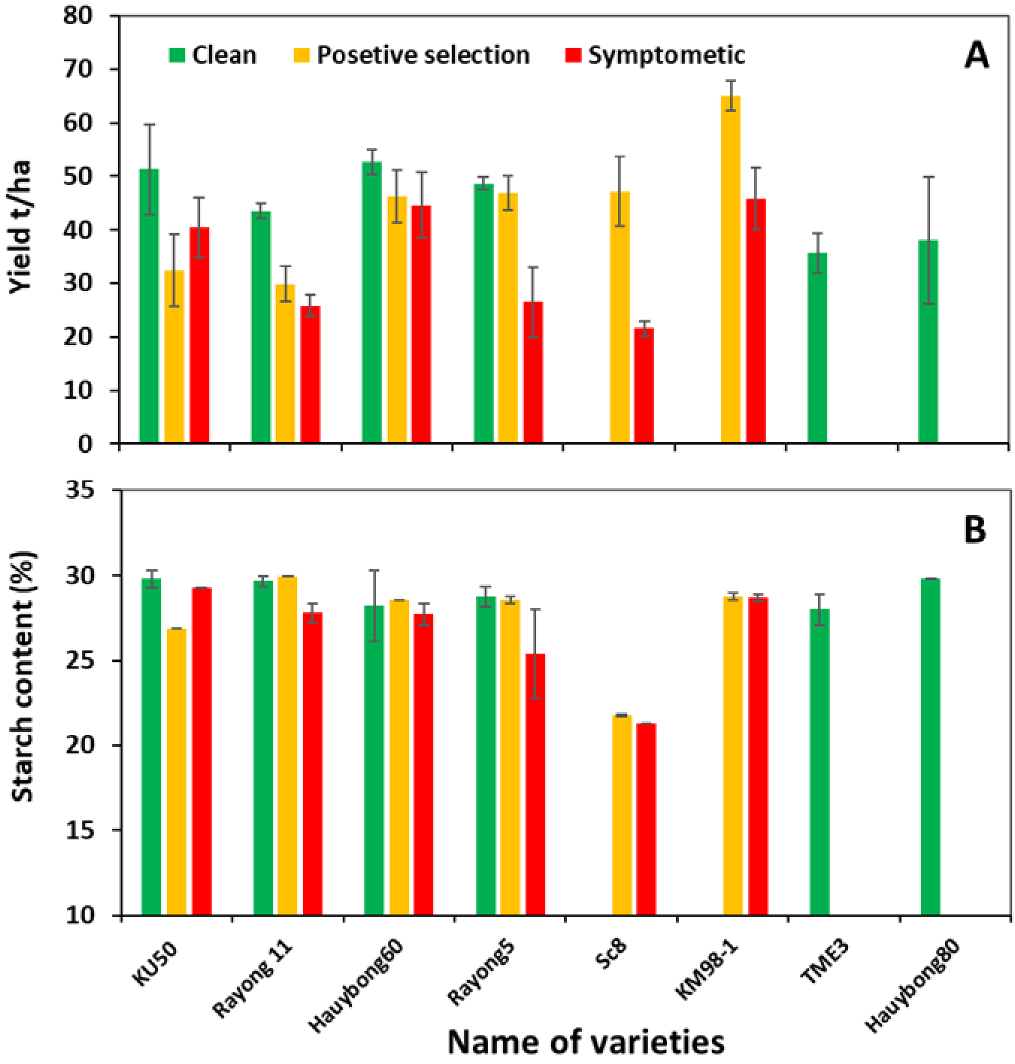

Figure A4.4 Fresh root yield (t ha^{-1}) and starch content (%) of cassava roots in plants infected with cassava mosaic disease (CMD) of six popular cassava varieties in Southeast Asia using disease-free stakes (clean), positive selected stakes from diseased fields (positive selection) and stakes selected from symptomatic plants (symptomatic). Twelve plants were harvested from each plot. In some plots, 2 to 6 plants were missing due to termite damage. Yields were adjusted for missing plants following Perez et al. (2010)[9]. Bars are standard errors of the mean (n=3 to 4). TME3 and Huabong80 were planted as clean planting material due to the scarcity of clean planting material of SC8 and KM98-1(6), respectively.

During 2019-20 experiment, plot root yield (calculated as t ha^{-1}) demonstrated clear advantage of clean planting material over symptomatic planting material (Figure 2.2.3A). Plot yield was1.2- to 2.2-fold higher in plants from clean and/or positive selection planting material than those from symptomatic planting material. The smallest yield difference (i.e. 1.2-fold) occurred in KU50 and Hauybong60, presumably due to their recovery ability from CMD, as many plants from symptomatic stakes remained asymptomatic during the experiment.

[9] *JC Pérez, H Ceballos, IC Ramírez, JI Lenis, F Calle, N Morante, G Jaramillo, M Lentini (2010) Adjustment for missing plants in cassava evaluation trials. Euphytica 172:59–65. doi:10.1007/s10681-009-0039-9*

Economic analysis

The economic benefits of farmers planting less susceptible varieties to CMD and establishing their crop with disease free stems (or at least positively selected asymptomatic stems) is very significant. The results also highlight the need to avoid Rayong11 in areas with CMD – the variety the project had been promoting in Laos as being less susceptible to CWBD.

With the current level of disease pressure in the area where trials were conducted positive selection remained possible and would result in around $225/ha even at the lowest prices farmers had received. The economic benefits increased significantly at the higher price points experienced later in the project.

Whilst the planting of disease-free stems further increased the agronomic performance, it was assumed in the table below that farmers would need to purchase these stems – and they may cost $3/bundle. In this case, there was no net benefit on purchasing stems at the lowest price. The benefits at higher prices was less than under positive selection – but assumes that farmers could actually source asymptomatic stems from their own field. Also, farmers could not easily source KU50 as it hard fallen in popularity in Vietnam prior to the outbreak with farmers switching over to the newer released Vietnamese varieties (HLS-11 and KM419) that are more susceptible.

Table A4.10: Economic Analysis of Variety Adoption (Cambodia)

Cassava root price (KHR/kg)	300	500	800
Benefit of positive selected stems ($/ha)	225	675	1125
Benefit of 'clean' stems @ $3 bundles($/ha)	-20	540	1100
Farmer benefit from positive selection ($)	36,918,675	110,756,025	184,593,375
*10% adoption	3,691,868	11,075,603	18,459,338
*25% adoption	9,229,669	27,689,006	46,148,344

Even a very low rates of adoption, the potential aggregate farm level benefits from the four main provinces servicing Vietnam (Tbong Khmun, Kampong Cham, Kratie, Stung Treng) are very large. On top of this, there are the trading margins that were estimated to be around $6.20/t during the value chain assessment. A 9-ton/ha yield increase (avoided losses) has a value to traders of more than $9 million USD per year from the above four provinces. However, again there are issues around exclusively of benefits generated with traders collecting from multiple sources and operating at close to full capacity on a daily basis. Therefore, it is unlikely that traders will be willing to invest large resources in promotion, but could distribute information they provided to them at a relatively low cost.

Village level collectors joined harvest field days and could see benefit in promoting the use better planting material. However, the main issue is that farmers in many parts of Cambodia now have no access to source disease-free or even asymptomatic planting material from their own farm or from surrounding farms. This has become a major focus of the ACIAR project AGB/2018/172.

13.2.2 Fertiliser

Agronomic Results

As was the case in Laos, adoption of fertiliser in the project sites in Cambodia was relatively low. In 2017-18 the project demonstrated the benefit of fertiliser application against farmers' practice in 4 districts. Root yield was significantly different ($p<0.001$) between two locations (Table 2.2.5). However, there was no difference between the treatments in each location due to large variability caused by biotic (root rot, CMD and CWBD) stresses.

The average fresh root yield was 1.4- to 2.2-fold higher in the Snoul District compared to Chet Borei District. The highest yield (26.3 ± 6.7 t ha^{-1}, Snoul) was achieved with highest fertiliser rate, however, in Chet Borei District highest yield was 17.6 ± 1.0 t ha^{-1} with moderate fertiliser application. In general fertiliser application yielded higher fresh root compared to Farmers' practice and without any fertiliser application.

Fertiliser treatment responded similarly in both location and starch content was significantly different ($p<0.001$) between two locations. Application of fertiliser increased starch content in all treatments ranged from 22.1 to 28.9 % (Annual report 2018). Out of four trials, we managed to get data from two trails due to premature harvest by farmers from other two trials.

Table A4.11 Fresh root yield (t ha^{-1}) with different fertiliser rate in districts of Kratie province. Values are means of three replicates.

Treatment	Chet Borei	Snoul
No fertiliser	9.7	14.0
N40 P10 K0	14.2	21.2
N40 P10 K40	17.6	20.3
N40 P10 K40 + CM 5t ha^{-1}	11.0	24.2
N80 P20 K80	12.9	26.3
Farmer practice*	11.8	19.3
Fertiliser	P= 0.172, L.S.D.= 6.31	
Location	P<0.001, L.S.D.=3.64	
Fertiliser x Location	P=0.403, L.S.D.=8.92	

*(20:20:15=100kg/ha), CM, cow manure.

During 2019-2020 season, fertiliser demonstrations were set in large blocks on farmers' field who were willing to participate. There were two treatments with fertiliser $NP_2O_5K_2O$ (20:05:20) and without fertiliser. In these trials, disease incidences were recorded and by the end of the season number of symptomatic plants ranged between 49 -80% in all trials in both treatments; however, the severity of infection was low (Sareth C. personal observation). The lowest disease incidence was recorded for fertilised and un-fertilised plots was from same site (i.e. 49% fertilized and 67 % unfertilized); presumably, due lower disease pressure in that region.

Economic analysis of fertiliser

Economic analysis was conducted on the fertiliser demonstration and farmers were involved in participatory budgeting and scenario analysis.

Table A4.12 Economic Analysis of Fertiliser treatment (Cambodia)

		Net Benefits		
Treatment	**Cost of treatment**	**Snuol**	**Chit Borei**	**Both**
No fertiliser	0	4,911,667	3,409,259	4,160,463
N40 P10 K0	191,987	7,224,124	4,779,309	6,001,717
Farmer practice (20:20:15=100kg/ha)	210,000	6,545,000	3,925,185	5,235,093
N40 P10 K40	338,661	6,774,117	**5,818,746**	**6,296,43**1
N80 P20 K80	677,322	**8,539,344**	3,853,233	6,196,289
N40 P10 K40 +CM5T/ha	838,661	7,619,672	2,995,135	5,307,404

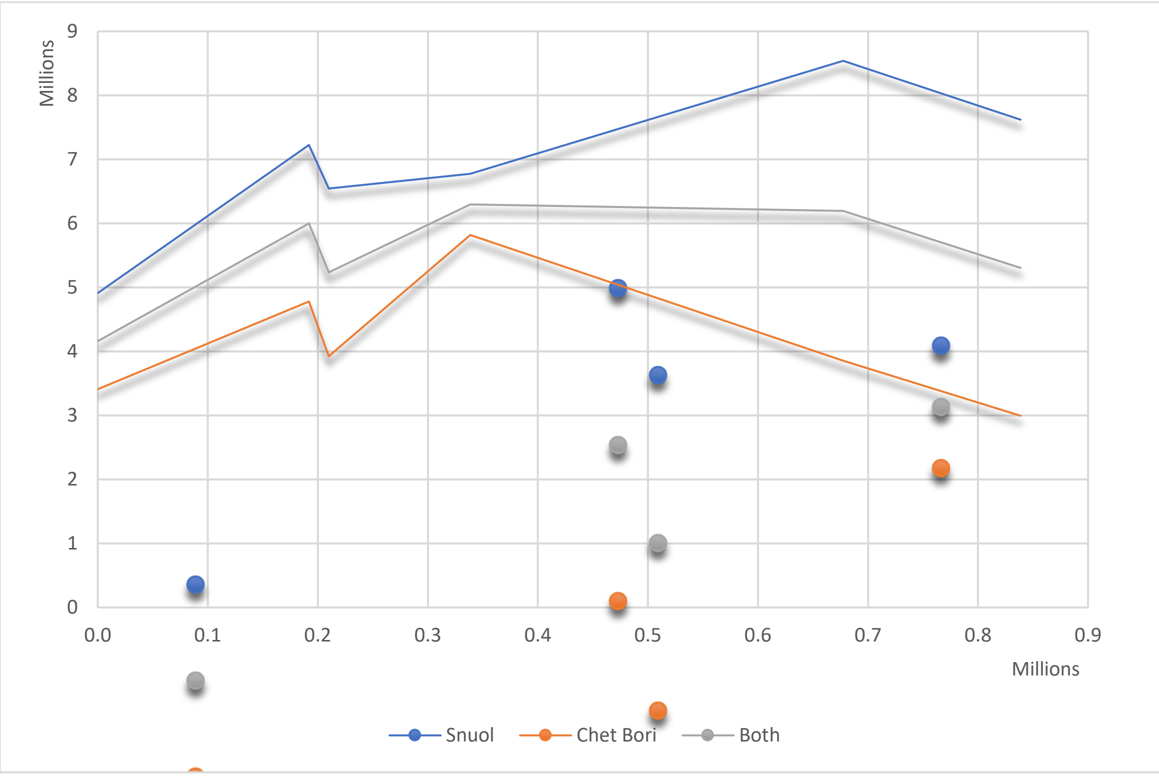

Figure A4.5: Marginal analysis of fertiliser trial in 2017-18

Based on the results of the first year significant uncertainty remained surrounding fertiliser application when biotic and abiotic stresses are present. Given that there was no significant difference between fertiliser rates, the least expensive rate would be recommended, however given it is only one year of result no recommendation were made at that stage.

If average responses are considered, a $50 USD investment in fertiliser produced a marginal net benefit (MDB) of over $570 for N40 $P_2O_5$10 K_2O 0. At all probable root prices the MRR would be above 200%. An additional $120 USD investment ($170 USD total) required for the high balanced rate produced a MNB of $329 USD equivalent to a MRR of 270%. This would remain above 200% for prices above 280 Riel/kg (analysis done at 350 Riel).

In Chet Borei District, once again the cheapest rate (N40 P2O510 K2O 0) produced a high MRR (714%), while the additional of potassium (N40 P2O510 K2O 40) also produced a high MRR (709%).

The table below presented the marginal analysis from the second year of trials. There were some inconsistent results, however in general the MRR for the low rate (20-5-20) was very high. In some cases, there was economic support for the medium or high rate of application.

Table A4.13: Marginal Analysis of Fertiliser Trials (Chet Borei)

Chet Borey	Yield (t)	Returns	Net return	Marginal benefits	MRR	MRR2
N00-P00-K00	19.46	6810882	6810881.5			
N20-P05-K20	28.06	9821436	9628115.7	2,817,234	1457%	
N40-P10-K40	28.10	9835409	9449009.4	D		
N80-P20-K80	26.76	9367635	8597154.7	D		
Snoul (1)						
N00-P00-K00	21.38	7484681	7484681.4			
N20-P05-K20	24.43	8549048	8355728.3	871046.9	451%	
N40-P10-K40	22.58	7903277	7516877.1	D		
N80-P20-K80	29.90	10463934	9693454.4	1337726		232%
Snoul (2)						
N00-P00-K00	26.68	9337222	9,337,222			
N20-P05-K20	27.69	9690139	9,496,819	159,597	83%	
N40-P10-K40	18.28	6397222	6,010,822	D		
N80-P20-K80	31.67	11085278	10,314,798	817,979		142%
Stung Treng						
N00-P00-K00	19.64	6873611	6873611.1			
N20-P05-K20	18.33	6416667	6223346.7	D		
N40-P10-K40	24.44	8555556	8169155.6	1295544		335%
N80-P20-K80	26.11	9138889	8368408.9	199253.3		52%
Average						
N00-P00-K00	21.79	7626599	7626599.1			
N20-P05-K20	24.63	8619322	8426002.4	799403.3	414%	
N40-P10-K40	23.35	8172866	7786466.1	D		
N80-P20-K80	28.61	10013934	9243453.9	817451.6	142%	

Once again participatory budgeting was used to look at all the costs and returns and the resulting returns to the household. This process included analysis under different prices and yield scenarios. The results in the table below demonstrate the benefits of fertiliser application at the farm level, and how cassava production without fertiliser and low prices was leading to negative net-returns when a value was placed on all family labour. That is, the returns to household labour fell below the opportunity cost that farmers decided to use in the calculation.

Table A4.14 – Example of budget Scenarios in Kratie Province

	Snoul		**Chet Borei**	
	Without fertiliser	With fertiliser	Without fertiliser	With fertiliser
Material costs (A)	1,070,000	1,840,480	1,830,000	2,023,320
Labour costs (B)	755,000	795,000	700,000	740,000
Total costs (A+B = C)	1,825,000	2,635,480	2,530,000	2,763,320
Revenue (D)	7,484,681	10,463,934	6,810,882	9,821,436
Net returns (D-C)	5,659,681	7,828,454	4,280,882	7,058,116
Gross Margin (USD)	1,415	1,957	1,070	1,765
Net returns to household resource (D-A = E)	6,414,681	8,623,454	4,980,882	7,798,116
Labour days (F)	32	34	23	25
Net returns per labour day (E/F)	200,459	253,631	216,560	311,925
` **Low price scenario**				
Revenue	2,138,480	2,989,696	1,945,966	2,806,124
Net returns	313,480	354,216	-584,034	42,804
Gross Margin (USD)	78	89	-146	11
Net returns to household resource	1,068,480	1,149,216	115,966	782,804
Labour days	32	34	23	25
Net returns per labour day	33,390	33,800	5,042	31,312
Net returns per labour day (USD)	8.35	8.45	1.26	7.83

In the final year of demonstrations when trials were established on a large scale and with asymptomatic stems, the net benefits and MRR were attractive in all cases. This was case even at the low-price scenario. At the high price scenario the return of applying fertiliser at the low levels used to disease free cassava are extremely beneficial. Again, the issue becomes access to disease free planting material within villages.

The results also demonstrate that the low adoption of fertiliser has little to do with the agronomic response or economic outcome. Low levels of fertiliser provide ample incentive for application on economic terms. As such, while a range of additional trials could be conducted to develop more accurate and site-specific recommendation – this is unlikely to overcome the current constraints to the adoption of fertiliser.

Table A4.15 – Revenue and Net Benefits (thousand KHR) and MRR (%)

		Site 1	Site 2	Site 3	Site 4
Price Scenario	**Yield Increase**	3.9	4.9	8.2	15.8
100 KHR/kg	**Revenue**	390	490	820	1,580
	Net Benefit	190	290	620	1,380
	MRR	95%	145%	310%	690%
200 KHR/kg	**Revenue**	780	980	1,640	3,160
	Net Benefit	580	780	1,440	2,960
	MRR	290%	390%	720%	1480%
300 KHR/kg	**Revenue**	1,170	1,470	2,460	4,740
	Net Benefit	970	1,270	2,260	4,540
	MRR	485%	635%	1130%	2270%
400 KHR/kg	**Revenue**	1,560	1,960	3,280	6,320
	Net Benefit	1,360	1,760	3,080	6,120
	MRR	680%	880%	1540%	3060%

The uncertainty in expected returns has been made more complicated by the new disease situation. Furthermore, there was very significant price fluctuations during the life of the project. However, knowledge of appropriate fertiliser types and its availability in local markets remains a challenge.

13.2.3 Intercropping

Agronomic Results

Demonstration for intercropping of cassava with short duration crops: A total of 4 demonstrations of intercropping of cassava was established. Farmers were very enthusiastic about the potential to get extra income from the same field while cassava was growing. However, we could not capture data as Farmers hurriedly harvested cassava when fresh root price went up early into the season. Following intercropping systems were established- Cassava + mung bean 2 rows, Cassava + peanut 2 rows, Cassava + corn 1 row to compare with Cassava mono culture.

Economic analysis

The project team could not interest farmers to participate in additional intercropping trials in subsequent years due to the added labour required. Farmers were busy with other livelihood diversification outside the cassava farm – cashew nuts, pepper, rubber. While not all farmers were engaged in these activities they also provided employment opportunities for some households.

There were other livelihood activities that produced significant contribution to livelihoods that were sensitive to discuss but competed for labour – timber trade for example.