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Contents

1 Acknowledgments 3

2 Executive summary 5

3 Background 8

4 Objectives 11

5 Methodology 13
5.1 Conceptual Framework 13
5.2 Research approach 15
5.3 Research methods 16

6 Achievements against activities and outputs/milestones 19

7 Key results and discussion 25
7.1 Objective 1 25
7.2 Objective 2: 44
7.3 Objective 3 67

8 Impacts 72
8.1 Scientific impacts – now and in 5 years 72
8.2 Capacity impacts – now and in 5 years 73
8.3 Community impacts – now and in 5 years 74
8.4 Communication and dissemination activities 78

9 Conclusions and recommendations 80
9.1 Conclusions 80
9.2 Recommendations 82

10 References 85
10.1 References cited in report 85
10.2 List of publications produced by project 85

11 Appendix 1: Key Agronomic Activities and Results 95
11.1 Conduct training in improved cassava practices, demonstration trials, and participatory research methods 95
11.2 Activity: Conduct participatory variety selection with farmers with varying levels of outside support from research institutions. 96
11.3 Identify opportunities for on-farm improvement and commercial production of clean planting material 100
11.4 Investigate opportunities to communicate information on pest and disease management to farmers through value-chain actors 101
11.5 Evaluate opportunities for value-chain actors to promote adoption of appropriate fertiliser regimes 102

12 Appendix 2: Key Agronomic Result Tables 103
12.1 Dak Lak 103
12.2 Son La 107
12.3 Indonesia 111

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List of acronyms

ACIAR	Australian Centre for International Agricultural Research
AGB	Agribusiness Research Program, ACIAR
BPTP	Balai Pengkajian Teknologi Pertanian
CCAFS	Climate Change, Agriculture, and Food Security
CIAT	International Centre for Tropical Agriculture
CGIAR	Consultative Group on International Agricultural Research
CMD	Cassava Mosaic Disease
CRP	CGIAR Research Program
CWBD	Cassava Witches Broom Disease
DARD	Department of Agriculture and Rural Development (Vietnam)
HCMC	Ho Chi Minh City
HT	Humid Tropics
ICFORD	Indonesian Center for Food Crops Research and Development
ILETRI	Indonesian Legumes and Tuber Crops Research Institute
IBM	Inclusive Business Models
ICAS	Indonesian Cassava Association
IFAD	International Fund for Agricultural Development
IPM	Integrated Pest Management
K	Potassium
MOCAF	Modified Cassava Flour
MOST	Ministry of Science and Technology
N	Nitrogen
NAFRI	National Agriculture and Forestry Research Institute of Lao PDR
NGO	Non-Governmental Organisation
NOMAFSI	Northern Mountainous Agriculture & Forestry Science Institute
NTA	Nusa Tenggara Association
NTT	Nusa Tenggara Timor
P	Phosphorus
PIM	Policy Institutions and Markets
PPC	Provincial People's Committee
RTB	Roots, Tubers and Banana
R4D	Research for Development
SRA	Small Research and Development Activity
TNU	Tay Nguyen University
UB	Brawijaya University
UNIPA	University of Nusa Nipa
USD	United States Dollar
UQ	University of Queensland
VICAAS	Vietnam Cassava Association

2 Executive summary

The overall aim of this project was to increase the profitability and sustainability of smallholder cassava production in Vietnam and Indonesia by developing effective linkages between value-chain actors to increase the adoption of improved technologies.

To achieve this aim, the project had 3 interrelated objectives:

Objective 1 – Assess opportunities and constraints for smallholder production and marketing of cassava within different value chains

Objective 2 – Increase the adoption of improved cassava production and processing technologies by strengthening linkages between primary value-chain actors (farmers, traders, processors) and with support actors (researchers, government agencies, industry bodies)

Objective 3 – Develop policy recommendations and facilitate learning alliances for the development of a sustainable cassava industry and improvement in rural livelihoods through improved agribusiness arrangements

Key Project Findings and Recommendations

1. ***The need to strengthen public-private partnerships in support of R&D***

The results showed that the incentive for individual companies to engage in the extension of technologies to smallholders was highly variable depending on several factors related to the characteristics of the technology, the value chain structure, and the production systems (and livelihoods) of target farmers. Nevertheless, individual value chain actors continue to benefit from the limited public and non-government investments in the sector. Funding models to formalise public and private contributions to R&D need continuing facilitation and support. This is critical in areas with high levels of externalities and non-exclusivity over benefits generated. Communicating the potential benefits (or avoid losses) across the value chain of increasing investment in the sector is essential.

The current disease situation in Vietnam may provide a unique opportunity for the industry to see the potential losses that no action will cause. Developing public-private partnerships is a key feature of the new project AGB2018/172. A system of R&D levies could support both the extension of technologies within specific supply zones and contribute to national level research. It is important that such as system does not distort the flow of roots to the highest value market segment (eg. Domestic v export; starch vs dry chips).

The situation in Indonesia is much more complicated with several market segments and large on-farm consumption and utilisation. For the large-scale commercial starch market segment there is potential for similar engagement however would create some issues with small-scale processors who compete for roots within the same supply zone.

2. ***Importance of engagement with National level agencies***

The project initiated and facilitated stakeholder consultation and dialogues at the Regency scale in Indonesia and Province scale in Vietnam. Large national consultation meetings planned for 2020 were interrupted by COVID-19 but were held in Indonesia. Cassava still remains a secondary crop in terms of national priorities in both countries, often due to poor access information about its contribution to food security, rural livelihoods, economic development and national trade balance. Lifting the profile of cassava is essential for supporting the industry development and sustainability.

3. ***The importance of policy Engagement on fertiliser subsidies and availability***

The awareness, knowledge and current use of fertiliser in cassava production system in both Indonesia and Vietnam is resulting in sub-optimal outcomes and inefficiencies. The availability of fertiliser most suitable for cassava production (either as Urea, TSP and KCL or suitable blends) varies between sites. In Indonesia the existing fertiliser subsidy system are distorting what fertiliser farmers apply to their crop. Engagement around policies impacting the availability and use of fertiliser should continue at the same time as engagement with the fertiliser value chain; cassava value chain and extension providers.

4. ***Need for investment in data gathering and reporting***

Invest in more accurate and real-time reporting of crop production data to allow stakeholders to make strategic decisions. Understanding the short-term supply within specific supply chain would help value chain actors make decision. The current area of production would also assist governments in planning and approving new investments in processing. This would include using remote sensing data to understand cropped area of cassava and other crops. A regional investment would also enable actors to evaluate overall supply and how it may impact prices.

At the same time, ongoing efforts to understand changes in demand should be develop at the national scale. The interpretation of supply and demand with some forecast of impact on prices should be communicated to value chain actors and farmers.

Within the harvest seasons, collation and reporting of spot prices at different locations would also aid farmers in making decisions around harvest and marketing. The same platform could incorporated into information regarding the geographic availability and price of new varieties or disease-free cassava stems.

5. ***The need to strengthen and modernise cassava breeding programs***

During the project life new diseases (CMD) became a serious issue within Vietnam. ACIAR has already responded to this problem through the investment in the project "Sustainable Solutions to Cassava Disease in Mainland Southeast Asia". This project includes capacity building in cassava breeding in Vietnam.

The project in Vietnam and Indonesia highlighted the strong connection between the industrial sectors of mainland southeast Asia and Indonesia. It also highlighted how quickly pest and disease can spread from the industrial sector into the food sector in the outer islands (eg. Cassava mealybug in Flores). This highlights the urgent need to introduce sources of resistance to CMD into Indonesia for introgression into breeding pipelines for both the starch sector (bitter high starch content varieties) and direct food sector (sweet varieties).

6. ***The need to develop national cassava seed systems***

During the project access to adequate volumes of planting material was a constraint to the speed at which activities could be scaled. This was particularly the case in Indonesia with high costs associated with transferring stems to different parts of the archipelago.

The challenges of multiplication and dispersal of new varieties to farmers also now need to confront the arising disease situation in the region.

- Investment in in-vitro facilitates and capacity to receive germplasm
- Training in in-vitro at regional universities

- Introduction of rapid multiplication centers in key provinces in partnership with private sector

7. ***Importance of investment in research on sustainable cassava systems meeting farmer needs***

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.

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 NOMAFSI, TNU, UB and ILETRI, 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 used by next users including DINAS in Flores (NTT) and the University of Nua Nipa. In Vietnam the outputs of the project are informing partnerships and implementation approaches under AGB/2018/172.

Key potential *economic impacts* of the project include potential gains at the farm and processor scale. The scale and likelihood of these benefits being generated varied considerably between technologies and site. Introducing new varieties in all sites had a significant economic impact and is likely to be widely adopted. Even at 10% adoption this was estimated to have a potential aggregate impact of $1.9 million per annum in Sonla; to $2.6m USD in Daklak. These results assumed minimal impact of CMD, which would necessitate the introduction of different varieties, although the partnerships and capacity generated during the project would also speed up the adoption of these varieties.

Improved fertility management practices also showed high economic potential at the farm level. Given the high levels of adoption of fertiliser in Vietnam, it was assumed that 25% adoption of improved practices could be achieved in 5 years. This would result in farm level benefits of 4.18m USD per annum in Sonla and $6.5 m USD in Daklak. In Daklak we also accounted for increased starch processing and residue sales adding $382,000USD and $560,000 per annum respectively. In North Sumatra we assumed only 10% change in practices within the two main regencies the project worked which resulted in an increased benefit at the farm level of $1.4million USD per annum and additional starch processing revenue of $415,000 USD. The high ratio of economic benefits arising at the farm level relative to the processing level highlight the need for public support for scaling, particularly when there are multiple processors and issues around exclusivity over benefits generated.

In Sikka and East Flores potential benefits are around $580,000 USD per year from changing the intercropping configuration and fertility management, recognising that there would be additional support and policy changes to realise these benefits.

3 Background

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

The production, processing and use of cassava 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 valued at around USD 3.79 billion in 2017 (Commtrade). Both production and consumption of traded cassava are concentrated in Asia, which accounts for over 95% of global exports. With rising household incomes in Asia and a range of new applications continuing to be developed for cassava starch, the outlook for demand for cassava-based products remains strong with smallholders well positioned to be the primary source of raw material.

Increasing levels of Cassava production in Vietnam and Indonesia:
Vietnam currently grows over 500,000 ha of cassava, generating over USD 1 billion per year in export earnings, making it the world's second largest exporter of cassava products (starch and dried chips). In Indonesia, on the other hand, cultivated area has fallen over the past 5 years to around 630,000 hectares (Table 1). In addition to its own significant production levels, Indonesia remains the second largest importer of cassava starch in the world. The volume of Indonesia starch imports varies depending on the price differential between the domestic and Thai market, as well as the competitiveness of cassava starch relative to other feedstock (eg. Maize).

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**

Cassava's links to other commodities and global markets increasing volatility and risks to smallholders:
The market outlook for cassava remains strong, but is given it connection to the global carbohydrate market is 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. As such, the short-term outlook 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 poorly understood.

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

Cassava has been an ideal crop for resource-poor farmers, which has made it an important activity for local livelihood development, provided farmers have options to manage the yield and price risks. However, in both countries cassava 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 competiveness 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.

Expansion into fragile landscapes means that sustainable production remains challenging:

The increase in demand for feedstock has also seen production move into more fragile landscapes, typically without the adoption of best management practices. This is leading to concern regarding the environmental impact of the cassava boom, particularly in Vietnam. Thus, the Government of Vietnam is seeking to maintain or reduce the current production area, while investing in research and development efforts toward productivity gains. In Indonesia there is also a strong focus on increasing productivity. With cultivated area in decline in the traditional zones of Java, expansion into new areas (including the eastern province of Nusa Tenggara Timor (NTT)) is considered possible but presents a range of trade-offs in terms of food security and environmental outcomes. In both Vietnam and Indonesia, interest in developing the biofuel sector will create additional opportunities for smallholders but also add to the concern over sustainability if expansion is not well managed, particularly if 'green-field' sites are considered. The demand for biofuel also adds to the competition for feedstock with the food and the industrial sectors.

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 mixed impact. However, there have been good opportunities for improving productivity with 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, namely, low yields, soil degradation, pests and diseases, and the risk that the industry was unsustainable. Thus, the project aimed at providing an opportunity to develop new impact pathways for CGIAR and national research systems by linking this research with the interests of actors along the different value chains.

While the identification of suitable technology is necessary, governments of both countries have 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 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 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 is to increase the profitability and sustainability of smallholder cassava production in Vietnam and Indonesia by developing effective linkages between value-chain actors to increase the adoption of improved technologies.

This implies three research questions which link to the three project objectives:

1. What are the opportunities and constraints facing smallholder production and marketing of cassava within different value chains in Vietnam and Indonesia, including incentives and drivers for adoption of sustainable farming systems?
2. Can the adoption of improved cassava technologies be increased by developing agribusiness models to better link primary value-chain actors (farmers, traders, processors) and support actors (researchers, government and non-government agencies, industry bodies)?
3. How can such agribusiness models be disseminated and supported within the region?

Objective 1 – Assess opportunities and constraints for smallholder production and marketing of cassava within different value chains

1.1 Understand the macro-level drivers for the development of the cassava industry including changing market and policy arrangements for cassava (starch, feed, chips) and substitutes (e.g., maize, potato, and sugar) and the potential benefits and risks to value-chain actors

1.2 Conduct training in value-chain methodologies, economic analysis and gender analysis

1.3 Map the relationship between primary value-chain actors and supporting services in different agro-economic settings, including how information moves along the value chain and how benefits are shared

1.4 Conduct a diagnostic analysis of current cassava production systems in different agro-economic settings, including adoption of varieties, management of planting material, soil and nutrient management, pest and disease management, intercropping, labour utilisation by gender, and farm-level risk

1.5 Assess the impact of alternative agribusiness arrangements on the flow of information and materials and the distribution of benefits within and between cassava-producing communities, with particular focus on poor households, ethnic minorities, and women

Objective 2 – Increase the adoption of improved cassava production and processing technologies by strengthening linkages between primary value-chain actors (farmers, traders, processors) and with support actors (researchers, government agencies, industry bodies)

2.1 Conduct training in improved cassava practices, demonstration trials, and participatory research methods, including public sector extension services (where present)

2.2 Conduct participatory evaluation of new varieties, soil and nutrient management, pest and disease management, and intercropping with farmers and industry stakeholders, with a focus on short- and long-term economic impacts

2.3 Identify opportunities for on-farm improvement and commercial production of clean planting material

2.4 Investigate opportunities to communicate information on pest and disease management to farmers through value-chain actors

2.5 Conduct participatory evaluation of soil management practices (including intercropping)

2.6 Evaluate opportunities for value-chain actors to promote adoption of appropriate fertiliser regimes

Objective 3 – Develop policy recommendations and facilitate learning alliances for the development of a sustainable cassava industry and improvement in rural livelihoods through improved agribusiness arrangements

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

3.2 Facilitate dialogue between stakeholders (industry associations, government policy makers from key departments, farmers and researchers) to inform provincial planning and policies aimed at supporting industry development and smallholder livelihoods

3.3 Promote learning alliances between national partners and industry associations to share lessons from the project and inform national policy

3.4 Develop policy briefs based on the project that have relevance to smallholder commodity production within the Southeast Asian region

3.5 Facilitate a Southeast Asian workshop on opportunities to support smallholder livelihoods and improve cassava value chains.

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 Vietnam and Indonesia includes households of different socioeconomic, ethnic and cultural backgrounds. Cassava is grown for a range of 'market segments' within the two countries – ranging from 'sweet varieties' for direct human consumption through to 'bitter varieties' with high starch yields grown for the starch processing market. 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. Furthermore, the context in which technologies are to be tested are dynamic, with adoption in the past not an assurance of farmer or processor interest in the current situation.

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 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 Vietnam and Indonesia. These can be compared and contrasted to other cases in Laos and Cambodia (ASEM/2014/053) 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 explored 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). As indicated in the background section (Section 3), the working hypothesis was that there are incentives for value-chain actors to work together to increase productivity and sustainability through the adoption of improved practices. This required a multiple case-study approach in which mixed methods were used to understand the various processes at work and to experiment with alternative arrangements appropriate to each context.

The project established action-research sites in two regions of each country which represented various production, processing and marketing systems (Table 2). These were the provinces of Sumatra Utara and Nusa Tenggara Timur (particularly Flores) in Indonesia; and Dak Lak and Son La in Vietnam. These were also major smallholder production sites in which the issues identified above were clearly evident. Between them these sites covered different value chains including large and medium dry starch (for various end uses, including animal feed), dry chip (industry), dry chip (food), local ethanol, snack food, and fresh food markets. The sites also differed in terms of the number and types of processing factories, with likely impacts on the incentives and transaction costs involved in mobilising agribusiness support for smallholder improvement. In each site, a private-sector partner was identified during a preperatory SRA (Small research and development activity) and additional private sector actors were identified over the course of the project to assist in identifying traders and source regions where smallholder cassava production was a significant contributor to rural livelihoods.

In both countries the region with the highest concentration of processing was not chosen as case study sites. Tay Ninh Province in Vietnam has over 60 medium-large starch factories and Lampung Province in Indonesia has over 50 starch processors. With this level of competition and structure of the value chain, it was clear from the results of the proceeding SRA that collective action between processors was going to be required. These sites were recommended as scaling sites for public-private partnerships once the potential benefits were demonstrated in other Provinces with less competition.

Table 2. Characteristics of cassava value chains in study provinces

Province	Area of cassava (ha)	Average fresh yield (t/ha)	Main industries	Number of factories
Dak Lak (Vietnam)	25,720	18.4	Starch Ethanol Dry chips (industrial + animal feed)	5 starch 1 ethanol (Dak Nong)
Son La (Vietnam)	28,100	12.5	Starch Dry chips (industrial + animal feed)	1 starch
North Sumatra (Indonesia)	47,141	32.2	Starch Snack food	9 starch 8 non-starch
NTT (Indonesia)	79,164	10.2	Fresh market Dry chip (*gaplek*)	Investment in mocaf and small-scale starch

Within these case-study 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. These analyses were used to better 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, exposure to risk), and the attributes and incentive structures of the other actors in the cassava value chain(s) in each site (input suppliers, traders, processors). These analyses relied on structured and semi-structured face-to-face interviews with individual actors, small groups, and key informants along the value chain. The importance of gender and ethnicity was an important area of analysis in each of these activities with data collected to allow gender disaggregation.

In addition to these analyses, the project used an action research approach to experiment with new arrangements to choose, adapt, and promote better cassava technologies, centred on demonstration trials, field days, and participatory evaluations by primary value-chain actors. By exploring options and incentives for agribusiness involvement in demonstrating and otherwise fostering adoption of available technologies, the project developed linkages between primary actors in the value chain (e.g., farmers and processors) and support actors (e.g., researchers and processors). The participatory evaluation of demonstration trials was utilized to assess the relative advantage and trialability of the technologies under local conditions and livelihood strategies. By testing new arrangements for technology adaptation and promotion, viable (or the lack of viable) models for agribusiness involvement in improving the profitability and sustainability of smallholder farming systems were identified and described for a wider audience of end users.

5.3 Research methods

The following research methods were undertaken 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. Relevant government research, extension, and policy institutions were involved from the inception of the project. In Vietnam this has included non-project partners from VAAS, MOST, DARD, People's Committee. The focus in the early stages was at the Provincial level. In Indonesia the project was engaged with the relevant BPTP and DINAS in the project locations.
- 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.
- Private sector actors were involved in training activities and participated in value chain assessments in all sites. Local value chain training and assessments were carried out in Son La and Dak Lak in Vietnam. In Indonesia, value chain training was undertaken in Malang and value chain assessments were carried out in Sikka Regency (NTT) and in North Sumatra.
- 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 Vietnam and Indonesia. Surveys were translated into Vietnamese and Indonesian 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 Vietnamese survey teams in Hanoi (for survey in Son La) and

Dak Lak in April 2017. Pre-testing was also undertaken in both provinces at that time to build the practical experience of the survey teams and to identify any potential challenges with the electronic surveys. Household surveys commenced in June 2017 in both Dak Lak and Son La and were completed in September 2017. A total of around 256 households were surveyed in each province, based on a sample size of 32 households per village, two villages per commune, two communes per district and two districts per province.

Training on the household survey and the use of electronic tablets for surveys was undertaken for the Indonesian survey team in Malang in April 2017. Pre-testing was also undertaken close to Malang. Household surveys were completed in North Sumatra during May 2017, with a total of 140 surveys undertaken for the province. Household surveys in Sikka were undertaken between the 6th and 10th August 2017, with a total of 111 farmers completing surveys.

- 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 methods 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.

  Cassava trials were conducted annually and evaluated in the field sites in Vietnam and Indonesia. These trials included fertiliser, variety, intercrop, delayed harvest and density trials.
- 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 methods were undertaken 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 ASEM-2014-053).

6 Achievements against activities and outputs/milestones

Objective 1: Assess opportunities and constraints for smallholder production and marketing of cassava within different value chains

no.	activity	outputs/ milestones	completion date	Comments
1.1	Review cassava production, use and trade, and main substitutes in production and final markets	Annual update on cassava production, trade and utilisation in target countries and the region	Annually	A database with updated information on regional and global cassava markets have been maintained through the duration of the project using an ACIAR blog and via facebook updates. Results of the analysis have also been presented at various workshops and conferences annually while also relaying them to the AESM project and to the Agricultural Master Class series in Myanmar. An interactive webpage is under development with co-funding from RTB to continue to make data collected available https://cassavalighthouse.org
1.2	Conduct training in value-chain methodologies, economic analysis and gender analysis	Training material developed for use within the region Training report	June 2016	Practical value chain training was conducted with key stakeholders in Malang, Indonesia to map key value chains in target provinces in Indonesia. Similar training activities were conducted in Vietnam for mapping value chains in Son La and Dak Lak. Training in Malang was expanded to include representative of other government and private universities.
1.3	Assess cassava value chains in each site, including primary and supporting actors and local policy environment, and where feasible conduct initial mapping of value chains of potential intercrops.	Map cassava VC including actors, processes, flows of information Geographical representation of production and information flow is different VC and production settings Report on gender norms within the value-chain in different sites	October 2016	**Vietnam:** Value Chain assessments including key informant interviews were conducted in Son La and Dak Lak Provinces in Vietnam. **Indonesia:** Similar assessments were also conducted in Indonesia in Sikka Regency and North Sumatra The results of the value chain assessments have been presented in various workshops and international conferences.

no.	activity	outputs/ milestones	completion date	Comments
1.4	Conduct farm surveys to find current production practices, market linkages, sources of information, risks, and constraints to adoption	Establish baseline for current practices, perceptions, aspirations and opportunities. Data to be gender disaggregated.	July 2017- June 2019	**Vietnam:** Focus groups and household surveys were conducted in Son La and Dak Lak with a total of 256 household surveys completed in each province. **Indonesia:** Focus groups and household surveys were conducted in Sikka and Simalungun Regency in North Sumatra. A total of 140 surveys in North Sumatra and 114 surveys in Sikka were undertaken. **Presentations** The results of the household surveys have been presented in various workshops and international conferences.
1.5	Evaluate project impacts on knowledge, attitudes, skills, aspirations, and practices of farmers and other actors	Evaluate changes in KASA of farmers and VC actors Assess the impact of learning alliances and dialogues of raising the profile of cassava in policy development	Nov 2019 – March 2020	**Indonesia:** In East Nusa Tenggara, impact surveys were conducted with 25 farmers in Sikka and 13 farmers in Boru. Impact surveys were also conducted in North Sumatra with 70 farmers in 2 locations. **Vietnam:** Impact Assessment Surveys have been undertaken with farmers in Son La and Dak Lak during May and June 2020.

VC = Value chain, KASA = Knowledge, Attitudes, Skills and Aspirations

Objective 2: Increase the adoption of improved and sustainable cassava technologies by strengthening linkages between primary value-chain actors (farmers, traders, processors) and with support actors (researchers, government agencies).

no.	activity	outputs/ milestones	completion date	comments
2.1	Conduct training in improved cassava practices, demonstration trials, and participatory research methods	Assessment of existing capacity (human, financial) of public and private actors in cassava technologies and extension methods Increased technical capacity of both public	December 2017	**Vietnam** Training programs related to improved cassava cultivation practices were provided to 400 farmers in several districts within Dak Lak. Extension staff in multiple cassava factories were also subject to training on cassava management and relevant technologies. Additionally, field-day meetings were organized with district extension staff and farmers to discuss topics related to spacing and fertilization as well as intercropping techniques. In Son La, training programs to farmers and commune extension officials were provided on agrobiology and planting

no.	activity	outputs/ milestones	completion date	comments
		and private sector actors		techniques, weeding techniques, and pest control techniques. **Indonesia** Demonstration trials were established in Sikka and North Sumatra with the support from local cassava value-chain stakeholders. A workshop was held for developing training material for farmers on topics including cassava agronomy and nutrient management, new varieties, pest and disease management, and small-scale processing. Training sessions were also held for farmers in both Sikka and North Sumatra on silage making from cassava leaves were
2.2	Conduct participatory variety selection with farmers with varying levels of outside support from research institutions	Establishment and monitoring of different variety demonstration M&E of farmer participation in the different production and value-chain settings	Yr2, Yr3 and Yr4	Germplasm evaluation, Soil management trails and agronomic practice experiments/trials were conducted in consultation (and in some cases active participations) with stake holders and farmers in Vietnam and in Indonesia. In **Vietnam**, nine fertiliser combinations (4 in Son La and 5 in Dak Lak) were evaluated against farmers' practice and/or without fertiliser application. Market available fertiliser combinations (i.e. NPK 12:5:10 or 5-10-3 or 15:5:20) were also experimented. Single nutrient applications (i.e. 40N-10P-40K or 60N-15P-60K) came out to be profitable. Different soil management options, legume (i.e. different leguminous crops) intercropping, grass strip and cassava residues from previous year were experimented. Intercropping with legumes was the preferred options for soil management (i.e. soil nutrient status) and had been scaled up; however, concern of scarcity of farm labour has been raised by stake holders. In **Indonesia**, a total of 15 high yielding varieties (i.e. sweet and bitter) were evaluated during in project districts of East Nusa Tenggara and North Sumatra. A total of 16 different fertiliser combinations were experimented along with some manure application. Medium range fertiliser application (i.e. 45N: $45P_2O_5$ $115K_2O$ kg ha^{-1}) turned out to produce higher yield in all districts with different varieties in North Sumatra. In East Nusa Tenggara, root yield was influenced by both N and K application. As cassava roots are being removed from the field as harvest product, a balance of N and K fertiliser application is highly recommended.

no.	activity	outputs/ milestones	completion date	comments
				Options for diversifying cropping systems were experimented to make sure the availability of cassava roots for stakes holders. Intercropping with different crops were experimented. Maize intercropping came out to be popular as farm income increase in such systems in East Nusa Tenggara. However, in North Sumatra, different high value crop also experimented.
2.3	Identify opportunities for on-farm improvement and commercial production of clean planting material	Report on the demand for clean planting material in different settings Report on the costs of different 'seed systems' Develop business models for different settings reported	Jan 2017 Jan 2017 Jan 2018 July 2018-June 2019	Initial demand, incentives and potential entry points were evaluated as part of the value chain analysis. Farmers and value chain actors actively participated in harvest field days in Sikka, North Sumatra, Dak Lak and Son La and discussed relative merits of trialled improved varieties. In East Nusa Tenggara and North Sumatra workshops were held on 'Cassava development based on business models'
2.4	Investigate opportunities to communicate information on pest and disease management to farmers through value-chain actors	Agreed plan for participation of value-chain actors in communication activities Report submitted	Ongoing	Initial demand, incentives and potential entry points were evaluated as part of the value chain analysis. Farmers, value chain actors and government staff actively participated in harvest field days in Sikka, North Sumatra, Dak Lak and Son La and discussed pest and disease control methods.
2.5	Conduct participatory evaluation of soil management practices (including intercropping)	Assessment of adoptability of improved soil management practices	January 2018	Completed (detail see activity 2.2)
2.6	Evaluate opportunities for value-chain actors to promote adoption of appropriate fertiliser regimes	Agreed plan for participation of value-chain actors in communication activities	Annually	Initial demand, incentives and potential entry points have been evaluated as part of the value chain analysis. Farmers and value chain actors actively participated in harvest field days in Sikka, North Sumatra, Dak Lak and Son La and discussed relative merits of improved soil fertility management. In Son La, support has been provided to farmers expressing interest on separate application of N, P and K fertilizers. Trials have also been conducted to examine longer harvest periods and to

no.	activity	outputs/ milestones	completion date	comments
				identify optimal planting densities related to cassava. In Dak Lak a total of three farmer field-day meetings were organized where discussions involved appropriate planting methods, fertilizer application and selection of optimal intercrops.

Objective 3: Develop policy recommendation and facilitate learning alliances for the development of a sustainable cassava industry and improvement in rural livelihoods through improved agribusiness arrangements

no.	activity	outputs/ milestones	completion date	comments
3.1	Review government planning and policy procedures	Working paper on local planning and policy constraints	Not completed as there were numerous existing reviews	A review of existing secondary information in both Vietnam and Indonesia revealed that there are numerous existing reviews of agricultural and rural development policies which are directly relevant to cassava (including Vietnam Food Security Policy Review undertaken by ACIAR in 2017 and a review of maize and agriculture related policies undertaken by project SMCN/2014/049 in 2018). 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 discussion have been held with stakeholders on this topic.
3.2	Facilitate stakeholder dialogues in each case-study region to identify incentives, problems, and solutions	Dialogues conducted and reported	Throughout project	Dialogues with stakeholders were conducted at the inception meetings in Son La and Dak Lak. Stakeholder meetings with participation of the private sector and provincial government have been held since in Son La and Dak Lak. Additional private sector and local government stakeholder engagements have been conducted at field days around harvest of trials across all sites in Vietnam and Indonesia. In East Nusa Tenggara, a workshop was held on “Cassava development in East Nusa Tenggara based on business model” between the 14th and 15th of March 2019 In North Sumatra, a workshop on “Cassava development in North Sumatra based on business model” was conducted on 21-22 November 2018

no.	activity	outputs/ milestones	completion date	comments
				Provincial Stakeholder meetings and discussions in Vietnam have been held in May and July 2020.
3.3	Facilitate and evaluate a learning alliance between key stakeholders	Meetings of key stakeholders held in each country	National level policy meetings for discussion	National Policy Meeting held in Indonesia in March 2020 National stakeholder meeting held held in Vietnam in September 2020 in conjunction with AGB/2018/172.
3.4	Develop evidence-based policy briefs on agribusiness models for improving cassava-based livelihoods	Policy briefs produced and distributed	Stakeholder Briefs developed from July 2019 National level policy meetings for discussion in Indonesia in March 2020	Stakeholder briefs on fertiliser use, varieties, stakeholder linkages and pests and disease prepared for Indonesia in both English and Bahasa Indonesia and discussed with stakeholders. A stakeholder brief on project results in Son La has been developed by NOMAFSI and have been discussed with stakeholders. Stakeholder briefs on cassava pests and disease management, varieties and fertilisers in Dak Lak developed by TNU and discussed with stakeholders.
3.5	Facilitate a Southeast Asian workshop on opportunities to support smallholder livelihoods and improve cassava value chains	Workshop held and reported Workshop proceedings	Regional Symposium Jan 2018 Regional Symposium July 2019 Final Meeting and review July 2020	Two regional workshops/symposia completed, final review in July 2020.

7 Key results and discussion

The production and marketing of cassava by smallholder farmers in Indonesia and Vietnam is part of a complex global value chain influenced by many factors outside the control of farmers or actors within these countries. However, despite fluctuations in prices 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. In Indonesia cassava also provides an important source of calories and is an important cultural food with preparation of the roots and leaves included in meals, as well as main snacks made with the flour and starch. In Vietnam, cassava is still directly consumed in some regions, however on farm utilisation as an on-farm feed source continues to see farmers plant small area even in the absence of an attractive market price.

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 the technologies in question 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. These partnerships need to be developed at different scales to ensure the policy environment at the national level in conducive

7.1 Objective 1

The following section presents some of the opportunities and constraints for smallholder production and marketing of cassava within different value chains. It is presented in three sections: Market drivers and developments; value chain assessments; and Cassava production and livelihoods.

7.1.1 Market drivers and developments

The regional cassava market experienced significant fluctuations during the project period. This impacted the structure of the value chain and the flow of products within the value chain. At the same time, changes in prices changed the economic incentives for farmers to adopted new practices and other industry stakeholders to scale technologies to farmers within their supply chain. The economic profitability of the sector did impact the degree of engagement from some stakeholders in project activities.

During the period 20015-2020, both the supply and demand for cassava 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. The decline in Indonesia production was long trend largely dominated by areas in Java, however the area also declined very rapidly in the project site in North Sumatra.

Table 3: Cassava Production Area from 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 aim of collecting data on production and supply to inform Government and Industry decision making has a number of challenges. Production data was problematic to collect beyond the province level and had at least a one-to-two-year lag. This made any strategic planning or decision making impossible.

Whilst MARD reported production data by Province in Vietnam there was no centralised database of District production. This was overcome in the first year by commissioning the Information and Statistics Division of MARD to collate all the Province level data using year books. This is a common problem across all commodities and projects that could be overcome by developing the databases and interfaces. However, even if the data accessibility issues were solved there is well recognised problems regarding the accuracy and reliability of the data – with stakeholder frequently reporting issues with under reporting of cassava area.

Given the strong connection between the Cambodia and Lao market with the supply of fresh roots available for processing – information from ASEM/2014/053 was important to understand supply and trade. This allowed the program to have the most comprehensive data set for cassava production in mainland Southeast Asia.

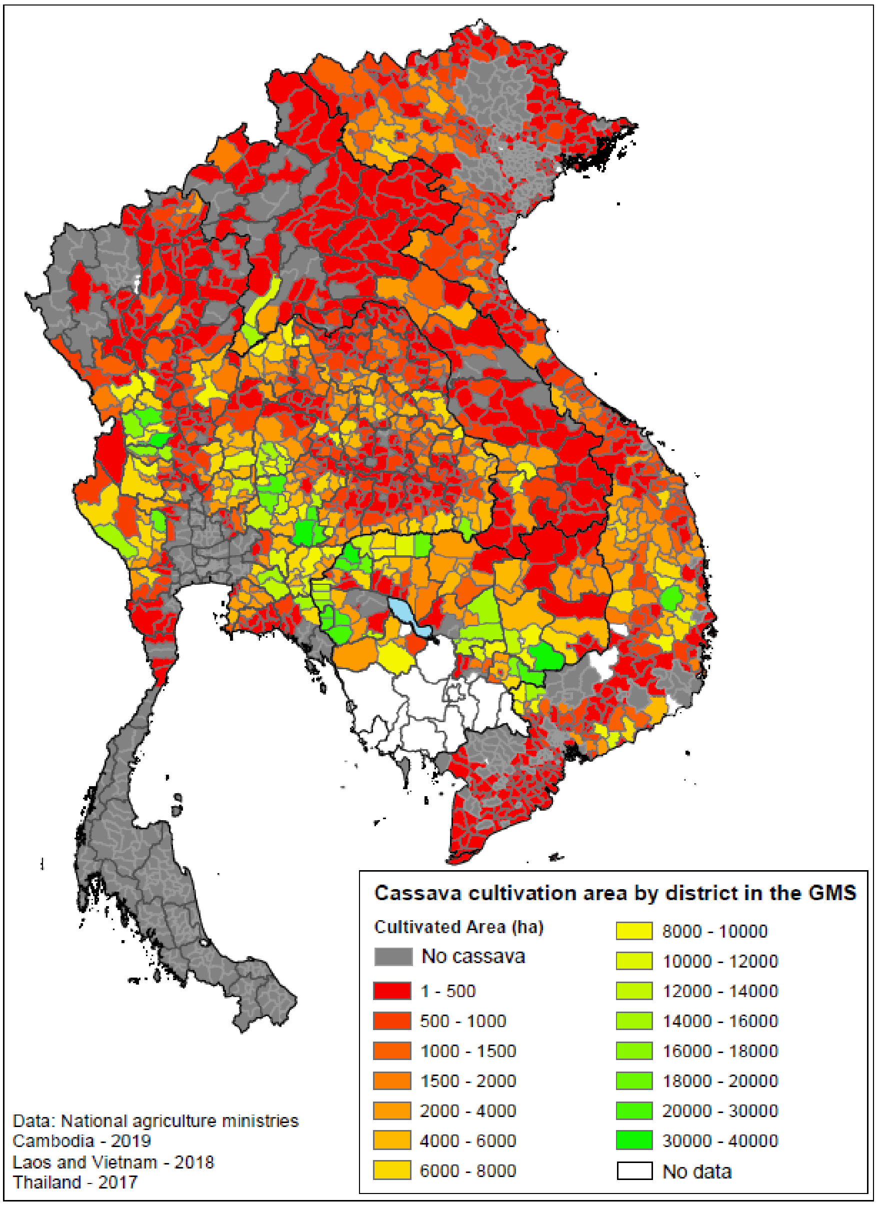

Figure 1: Cassava Cultivation area by District in the GMS

In Indonesia, the data issues were even more apparent with the Badan Pusat Statistik (BPS-Statistics Indonesia) stopping reporting most agricultural statistics in 2015 even at the Provincial level. The data available from the Ministry of Agriculture[1] was reported until 2018 at Province and 2016 at the Kabupaten (District) level.

A database has been created to monitor price and trade flows utilising published data, online national databases, and industry contacts. The data collected during the project is being transferred to an online platform managed by CIAT called "The Cassava Lighthouse". This aims to become the most comprehensive sight offering access to data, analysis, and monitoring market and policy developments. It will continue to be associated and supported by AGB/2018/172 and also link to Pest and Disease Monitoring[2]. However, to a truly useful site for stakeholders the accuracy and timelines of the data needs to improve.

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[1] *BDSP (pertanian.go.id)*

[2] *https://pestdisplace.org/diseases/cassava*

Recommendation 1 – Invest in more accurate and real-time reporting of crop production data to allow stakeholders to make strategic decisions. This would include using remote sensing data to understand cropped area of cassava and other crops.

Cassava relative prices

The project used many presentations to demonstrate to stakeholders that both the supply and demand of cassava – and thus prices – was heavily influenced by relative prices with substitutes. This included crops that could be grown in the same agroecological region – or crops that could be used in the same processing application. For examples maize and sugarcane can be grown on the same land as cassava, and are also substitutes in the main applications of the crop. Changes in other crops like coffee, rubber and palm oil may influence the supply of cassava, but over a longer trend due to their perennial nature.

Cassava had a volatile time during the project period, dropping sharply during 2015-16 before a strong recovery and returning to a long-term equilibrium. Much of these can be related to changes in Chinese maize prices and stocks which continue to have a major bearing on the outlook of the sector.

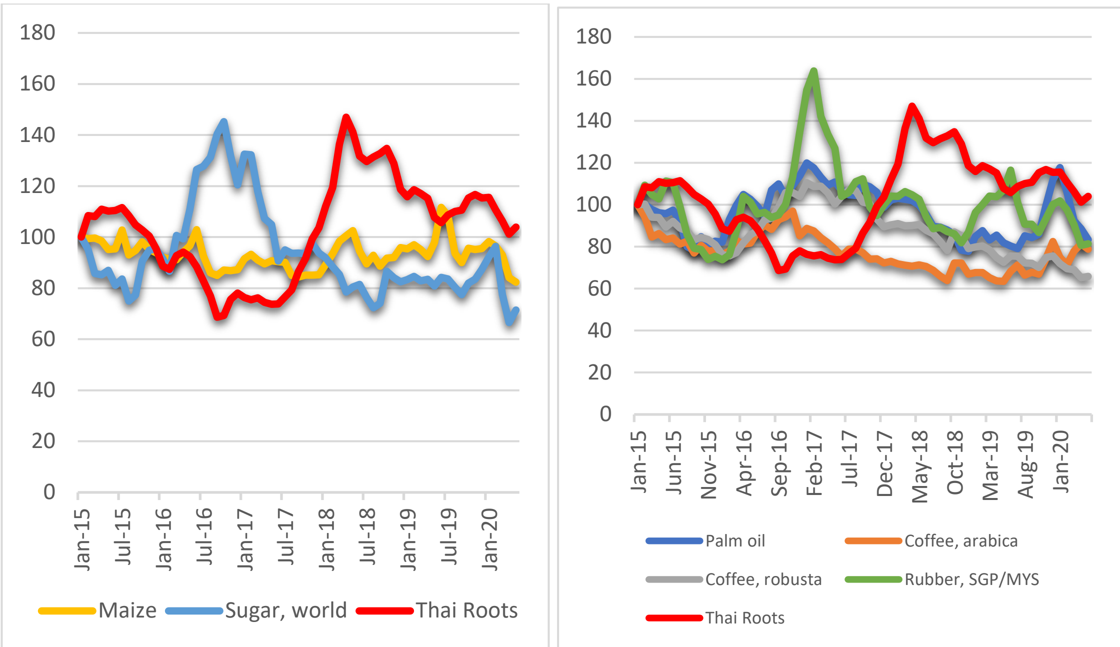


Figure 2: Relative prices of cassava roots (Thai Benchmark) and other competing crops for land and in processing applications.

The Chinese floor price announced for the October 2013 maize harvest far exceeded the US futures price for December delivery. The prospective gap in prices gave feed mills and industrial users in China strong incentive to import maize or look for alternatives. Hence the increased demand for cassava. Cassava has not been the only crop to benefit from the price distortions. Imports of barley, sorghum, and "distillers dried grains with solubles" (DDGS) for the feed and ethanol sectors all increased rapidly after 2012 as a result of high domestic maize prices. Exporters including the US and Australia benefited from these high prices.

By mid-2015 there was speculation that the "temporary reserve" price for maize would be cut as Chinese stock levels became unsustainable and pressure mounted from imports of the relatively cheap alternative – cassava. Some commentators suggested that the temporary reserve price for maize would be cut to RMB 1600/ton for the 2016 crop, down from RMB 2000 for 2015. However, on 28 March 2016 the Chinese government announced an end to the floor price for maize. The result was a significant fall in maize prices, with the nearby futures falling by around RMB 300/kg (from RMB 2000). Dalian Futures for a September delivery fell below RMB 1600/kg. The trend in imports of maize alternatives reversed, with the impact being felt throughout the cassava sector. The prices of cassava chips and cassava starch have fallen to more closely reflect the world price for the main alternative – maize – and farm-gate prices throughout mainland Southeast Asia and Indonesia fell significantly – with little understanding why by farmers who assumed traders were cheating them.

The analysis also highlighted the strong connection between the industrial sector in Indonesia and the market in mainland southeast Asia in terms of prices and trade. Deep processors such as sweetener producers, especially those in Eastern Java, enter the market to import starch from Thailand and Vietnam when domestic prices become too high. It also showed the importance of logistics costs in determining trade-flows. The transport cost from Lampung to East Java impacting the competitiveness of domestic starch within the country.

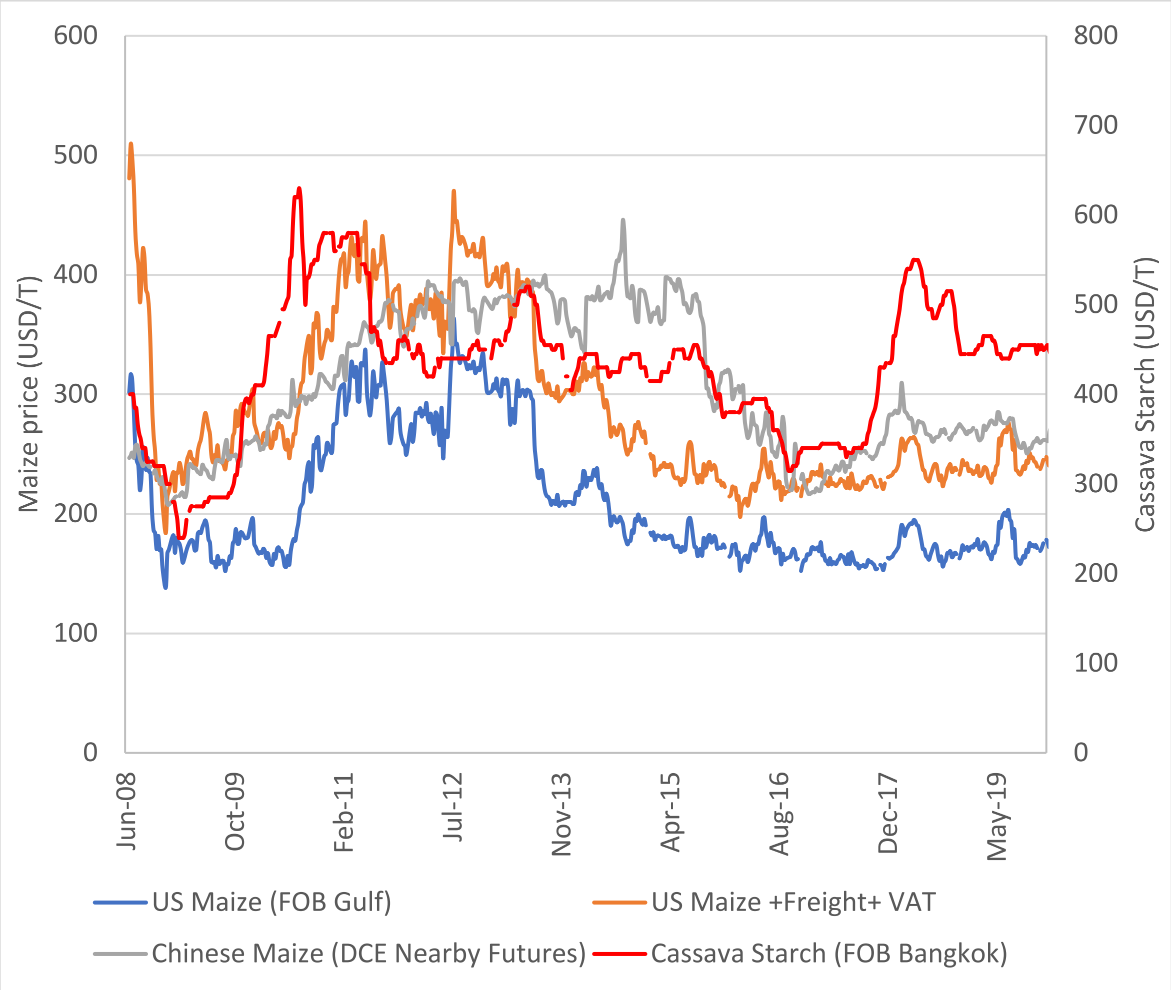


Figure 3: US and Chinese Maize prices and Thai Cassava Starch prices (2008-2019)

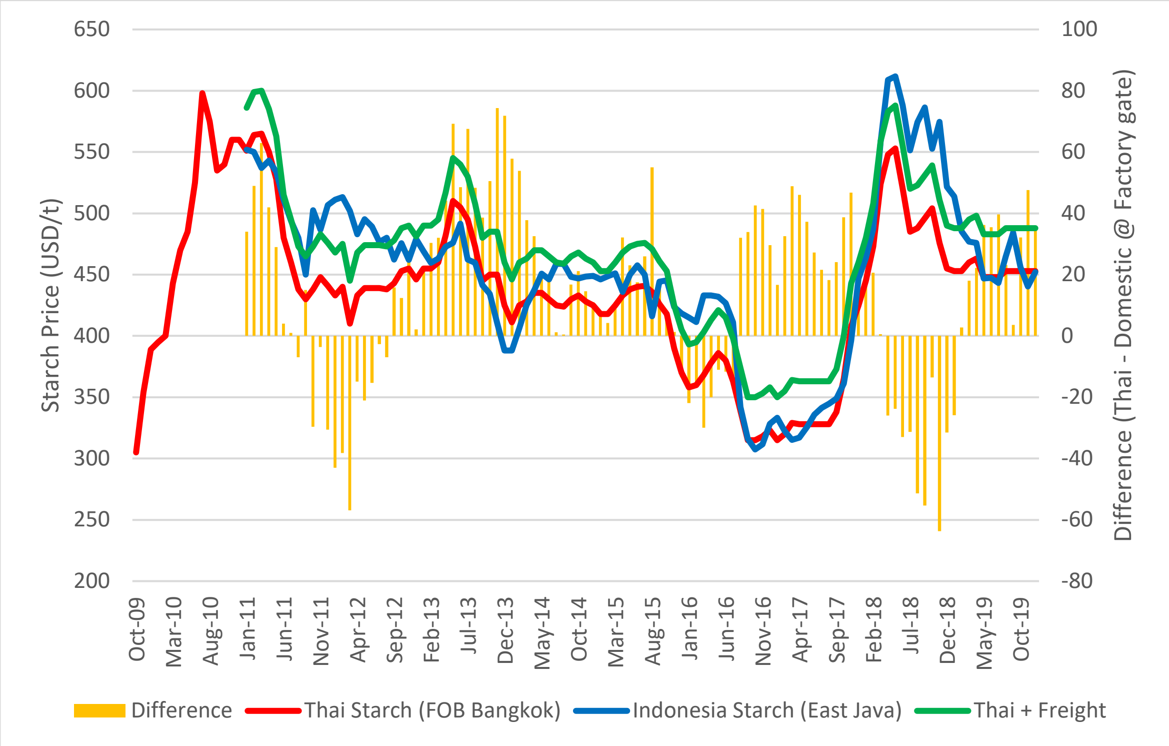


Figure 4: Thai and Indonesian Starch prices (2009-2019)

More information:
Cassava Market Update and Short-term Outlook 2018
Webinar Presentation – Policies and pandemics: understanding how global drivers and shocks influence value chain actors in the cassava sector

7.1.2 Value chain assessment in target regions

Staff from partner organizations in Indonesia conducted value chain analyses in Sikka Regency (NTT) and North Sumatra in August and October of 2016 respectively. Similar value chain analyses were conducted by NOMAFSI in Son La and Tay Nguyen University (TNU) in Dak Lak in September 2016.

In all sites, information was gathered from value chain actors through face-to-face interviews using a standardized questionnaire. Value chain actors interviewed included large and medium scale starch and dried chip processors, small-scale collectors and assemblers, medium scale traders, and larger scale traders and brokers.

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.

Son La
The cassava value chain in Son La has two main end products – cassava starch and cassava chips. Regardless of the end product, almost all of the processing occurs within

the province and almost no fresh root is transported out of Son La for processing in other provinces.

The cassava chip value chain is significantly larger than that for starch, accounting for almost 90 percent of the total annual production of fresh root. The one large scale starch factory in the province (Mai Son starch factory) consumed around 40,000t of fresh roots in 2015, with the balance of production (around 320,000t of fresh roots) being utilized to produce dried cassava chips.

There is significant cassava processing in Mai Son, including starch processing at the Son La Starch Processing Company, and dry chip processing by numerous small and medium scale enterprises at or near the airport. In addition to the concentrated processing in Mai Son, farmers in other districts also produce relatively small amounts of dried chips, usually either for livestock feed, because they were unable to sell fresh root, or because the price of cassava chips was relatively favorable at the time. This small-scale farmer processing accounts for an estimated 5000t of the 125,000 tons of chips produced annually in the province.

Starch produced by the Mai Son starch factory is predominately for export, with around 90 percent destined for China and 10 percent for Korea, Philippines, Taiwan and the domestic market. Dry chips are sold to animal feed production companies in Son La and Hoa Binh as well as for export.

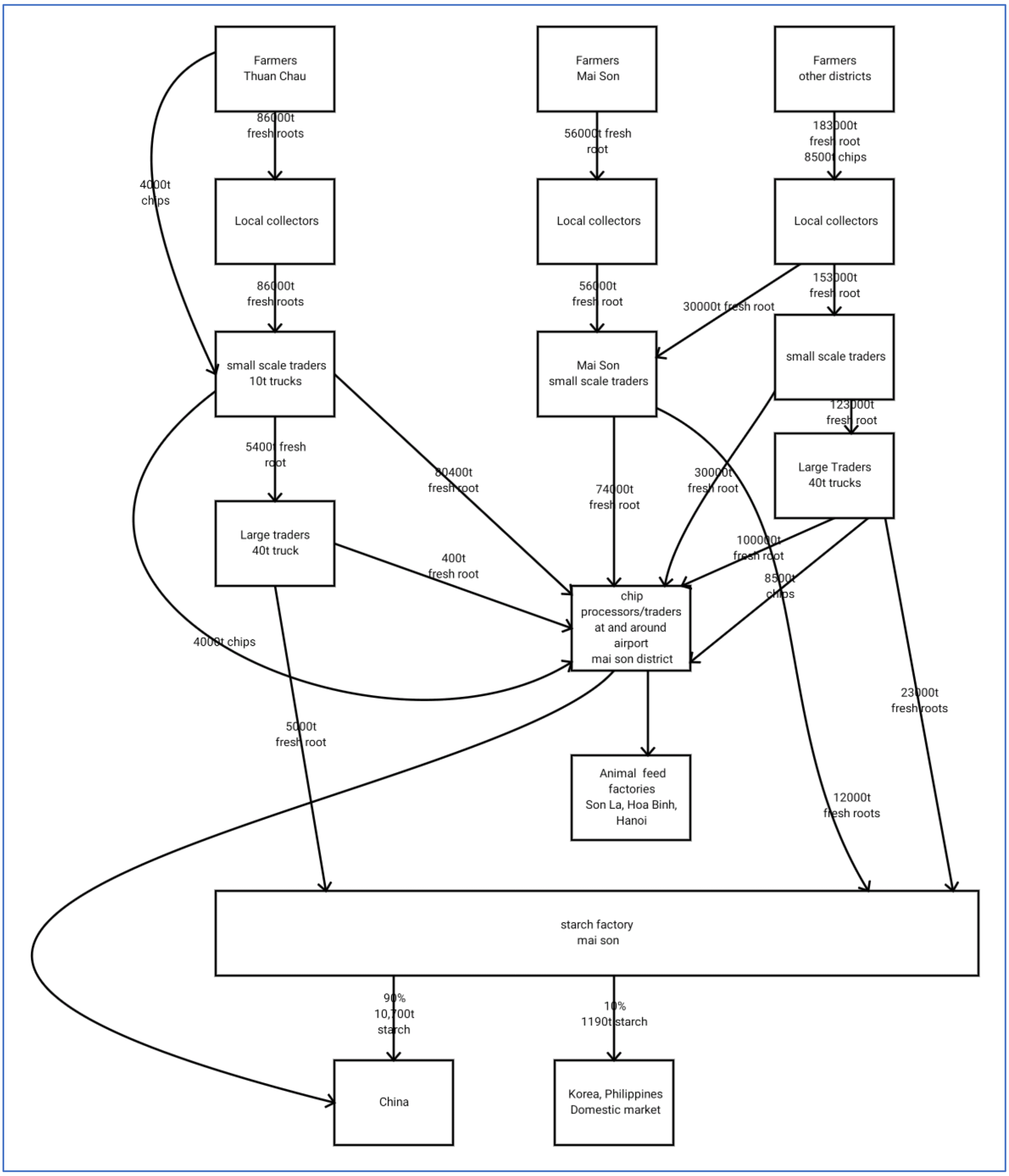


Figure 5: Stylised Cassava Value Chain Map for Son La

At the outset of the research, there was one company with a starch factory but many processors of dried chips (used for livestock feed). Hence farmers were not committed to supply the factory. Now there are two starch factories and two more planned, increasing the degree of competition for cassava roots. Although the company was interested in collaborating in the research project, its factory was operating at full capacity. Hence the company's management was mainly interested in developing technologies for farmers to extend the harvesting period beyond the current six-month window (which was as much a financial as a technical question), and in varieties with higher starch content that would improve processing efficiency. The company was interested in disseminating improved varieties with higher starch yields through its trader network, but only if someone else incurred the cost of multiplying the planting material. There was a constraint in that, while local management was interested in a research partnership, the company's head office, which controlled spending, was in Ho Chi Minh City, remote from conditions on the ground.

The company had little incentive to promote more appropriate fertiliser use because of the steep terrain (reducing the effectiveness of fertilizer outlays), its lack of capacity to process more roots if yield was increased, and the risk of side selling, given the number of alternative buyers. Likewise, there was little incentive for farmer adoption or factory promotion of conservation agriculture, given its low ranking in terms of learnability and relative advantage. However, there was evidence that the project's on-farm demonstrations had encouraged farmers to take more care in planting the cassava stems, providing a low-cost improvement to yields. There were also positive signs that local government would strengthen its cassava extension in recognition of the importance of the crop to ethnic minority households, thus compensating for the limited capacity of the processing company to take on this role.

Dak Lak

Value chains for cassava starch and dry chips in Dak Lak are predominately oriented towards the export market, and in particular towards the Chinese market. The majority of the 600,000t of fresh roots produced in Dak Lak are used by the 5 starch factories operating in the province. More than 260,000t of cassava are produced by smallholders on a total of over 11,000ha in Ea Kar and Krong Bong and much of this production is destined for the 2 factories in these districts owned by the DAKFOCAM company.

A stylized representation of the value chain map for cassava in Krong Bong is shown in Figure 6. The majority of the 150,000 tons of cassava produced in the district are used by the DAKFOCAM starch factory in Dang Kang commune, with a small proportion being utilized by household scale dry chip producers and medium scale dry chip producers.

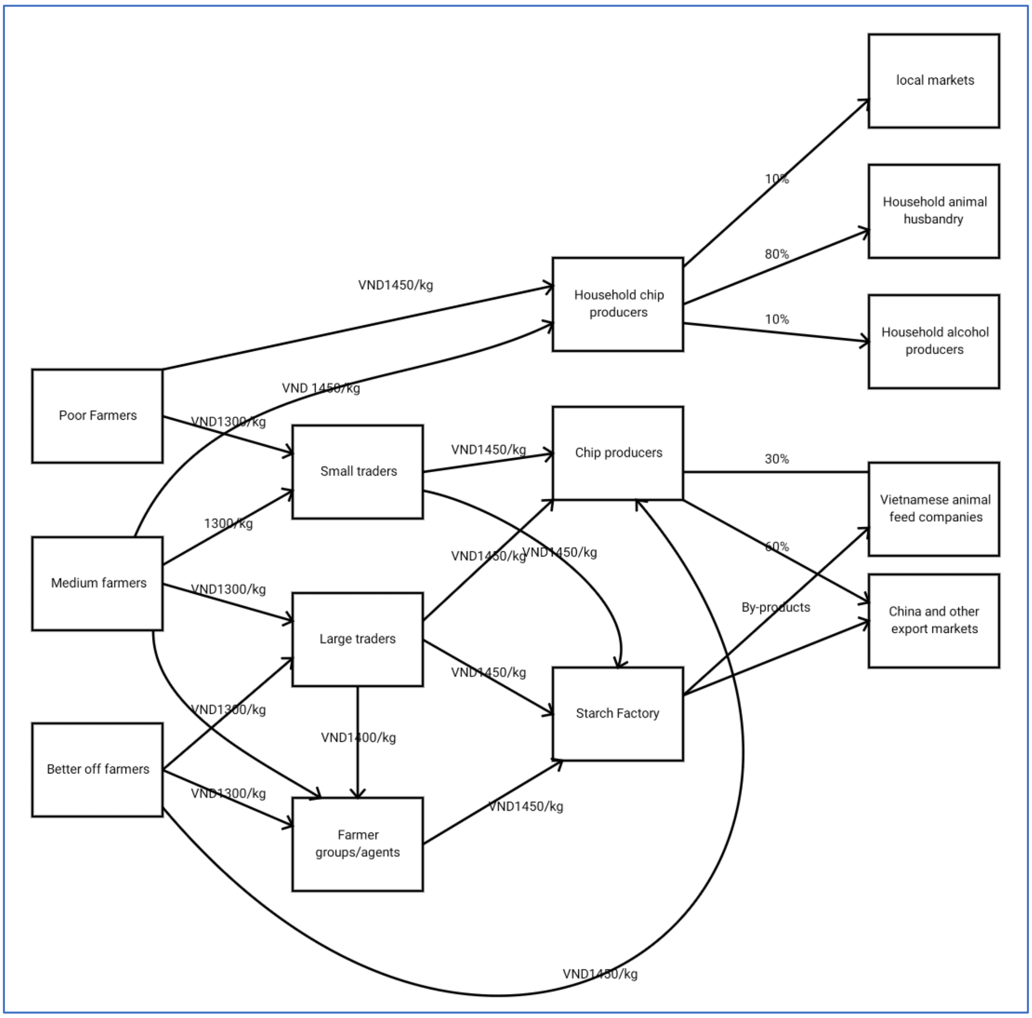


Figure 6: Stylised Value Chain Map Krong Bong

There are many starch factories in the province, processing cassava roots during most of the year. At the start of the project there was less competition, with factories able to draw on a specific catchment. Factory numbers have now increased to 11, with overlapping supply zones. All factories are short of supply and purchase roots from further afield to increase their throughput. Competition for roots is intense and margins are small. However, there is one ethanol factory that produces its own supply. In this case, company management was more interested in cooperating with researchers in knowledge development.

The starch factories clearly had limited incentive to individually invest in collaborative research and dissemination for any of the technologies due to the extreme competition, lowering the relative advantage to each actor. Investment in yield- or starch-increasing technology by one firm would potentially provide benefits to all other firms, all of whom were seeking to better utilise their capacity. There was also a perception, given that a government extension system is in place, that disseminating technologies to farmers is “not their responsibility” (as stated by a factory manager at a stakeholder consultation).

Nevertheless, in the past, networks of factories from this region were buying newly-released cassava varieties from Tay Ninh Province to the south to distribute these to farmers. There is likely a good business case for the formation of a processors’ association that could levy its members for such research and dissemination activities. This becomes even more urgent now that diseases such as Cassava Mosaic Virus (CMV) are contaminating the value chain, causing potential economic hardship to both farmers and processors.

East Nusa Tenggara

In Sikka (East Nusa Tenggara) cassava is grown as a major staple food for home-consumption and trade in local food markets. Hence traditional "sweet" eating varieties are utilised, with few or no inputs. Farmers practise piecemeal harvesting when they need food or cash. The price of these eating varieties in the market is higher than that of industrial ("bitter") varieties. There is a small-scale cottage processing industry producing cassava-based food products for local purchase but no processing for animal feed or starch. The project experimented with introduced varieties and alternative multi-cropping systems on farmers' land. The research conducted with farmers demonstrated that increasing the density of cassava within the traditional maize-cassava system could improve the yield and income generated from cassava, without a decline in maize production as feared by farmers.

In partnership with the project, an entrepreneur established a pilot processing plant for animal feed and invested in distributing a new, high-yielding industrial variety (Malang 4) to farmers in both upland and lowland locales in Sikka and a neighbouring district. The transaction costs associated with the dissemination of technology to a relatively small number of farmers resulted in the price he was offering being substantially lower than the price farmers could get from the piecemeal selling of their cassava to food traders. Though Malang 4 is considered an industrial variety, it can also be consumed as a food crop with some additional processing (i.e., soaking in water). The extensive opportunistic side-selling was thus threatening to undermine the viability of the pilot project and ongoing expansion of the processing capacity.

In this case, stakeholder consultations indicated a strong argument for a public-private partnership to lower the cost of knowledge transfer, with the local agricultural office providing initial support in introducing suitable varieties and multiplying them while the processor distributes them to farmers. An NGO or development project could catalyse and support the process.

North Sumatra

A starch factory established in 1974 in Pematang Siantar that is the sole buyer of fresh roots for most cassava smallholders in the district. The factory produces starch for the domestic market and is not well connected to R&D agencies, concentrated in Java. The company works through seven or eight agents who coordinate supply through a network of local traders, each of whom has their own network of farmer-suppliers. Credit for production inputs is channelled through these networks but there is no formal contracting. Side-selling is minimised by the monopsonistic nature of the local processing market, the high transport costs, and the high degree of personal trust among traders. If the factory has excess supply, it will allow its traders to sell elsewhere but, during the research, the factory was operating at only 40% of capacity.

Given these attributes, the company's management was very interested to cooperate with the research team, particularly in varietal trials to increase farm yields and hence the supply of cassava roots to the factory. The company provided land for the first set of varietal trials, which were managed by a lead-agent who was also a cassava farmer. Traders and farmers inspected these trials during field days and evaluated varieties for subsequent testing. The company paid for additional planting material to be shipped from Java, and some agents and traders took stakes of the new varieties for testing and multiplication on their own land, with subsequent dispersal to farmers.

The company was also supportive of fertilizer trials conducted in combination with the varietal testing, again expecting increased yields. However, problems with sourcing an appropriately formulated commercial brand and a bias in government policy towards subsiding fertilizers for rice made it difficult to translate the fertilizer trials into farmer adoption. The company also supported the intercropping trials proposed by researchers, not for reasons of improved soil management but in the expectation that, with a productive intercropping system, farmers might continue to grow cassava in times of low prices.

The factory's agents played a critical role in transmitting knowledge from the central node to farmers via their trading networks. However, the agents differed in their commitment to this process, based not on differences in their ability to capture profits but on individual attributes. More generally, late in the project, when financial pressure on the company was resulting in delayed payments along the value chain, the loyalty of some agents to the factory was tested, inducing them to seek out a more distant starch factory to supply. In sum, the company was willing to invest in a research partnership to generate and disseminate highly adoptable technologies (varieties, fertilizer-use) that would increase farmers' productivity and hence factory supply, knowing that it could both disseminate the technologies and capture their benefits through its informal but stable supply network and its position of effective monopsony. However, even in this case, financial pressures could disrupt the process of knowledge transfer.

The results of the value chain analyses have been presented in the International Conference on Root and Tuber Crops for Food Security in Malang (2017), the North-West Vietnam Research Symposium (2017), the MTR/Research Symposium in Vientiane (2018), the NAFRI 20th Anniversary Symposium, Laos, (2019), the mid-term review/ research symposium (Vientiane; January 2018) and have also been included in Country Profile papers and in a series of Project Discussion Papers.

1. **Value Chain Analysis, Household Survey and Agronomic Trial Results in Son La, Vietnam;** Pham Thi Sen, Dominic Smith, Lava Yadav, Cu Thi Le Thuy, Le Viet Dung, Phan Huy Chuong and Jonathan Newby **,** Discussion Paper Number 1**,** May 2018
2. **Value Chain Analysis, Household Survey and Agronomic Trial Results in Dak Lak, Vietnam;** Nguyen Van Nam, Dominic Smith, Lava Yadav, Cu Thi Le Thuy, Le Duc Niem, Nguyen Van Minh, Nguyen Van Dat and Jonathan Newby, Discussion Paper Number 2, May 2018
3. **Value Chain Analysis, Household Survey and Agronomic Trial Results – North Sumatra;** Wani Hati Utomo, Yudi Widodo, Kartika Noerwijati, Ruly Krisdiana, Suhartini, Erwin Wisnubroto, Dominic Smith, Rob Cramb, Jonathan Newby and Lava Yadav, Discussion Paper Number 4**,** July 2018
4. **Value Chain Analysis, Household Survey and Agronomic Trial Results – Sikka;** Wani Hati Utomo, Yudi Widodo, Kartika Noerwijati, Ruly Krisdiana, Suhartini, Erwin Wisnubroto, Dominic Smith, Jonathan Newby, Rob Cramb and Lava Yadav; Discussion Paper Number 7, July 2018.

7.1.3 Cassava Production and Livelihoods

Incomes

It is important to recognize that farmers who grow cassava in the project sites in both Vietnam and Indonesia 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.

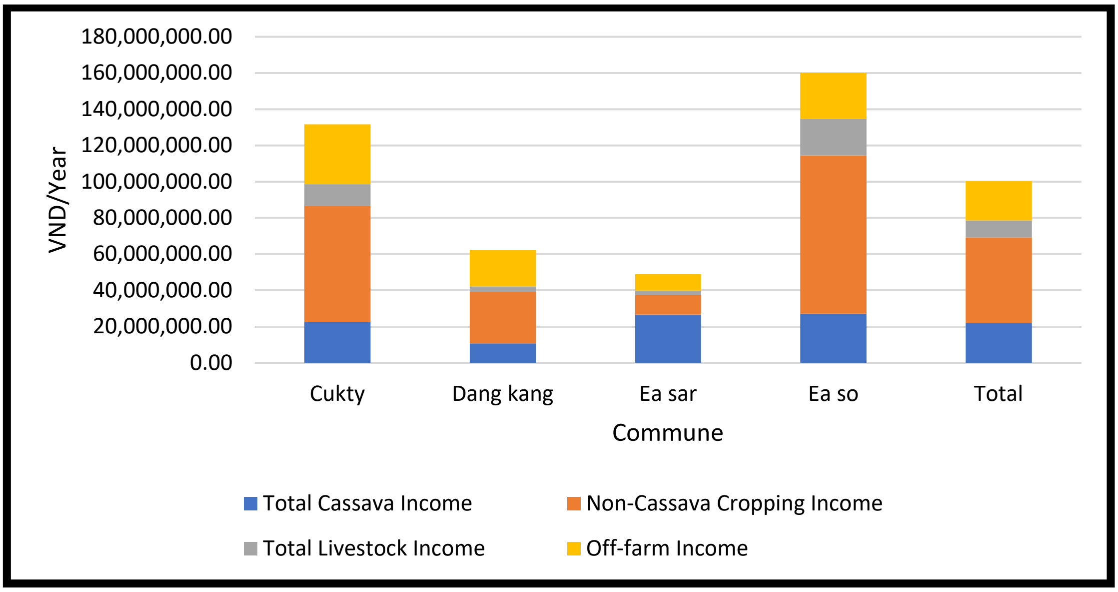


Figure 7: Source of Income, by Commune, Dak Lak

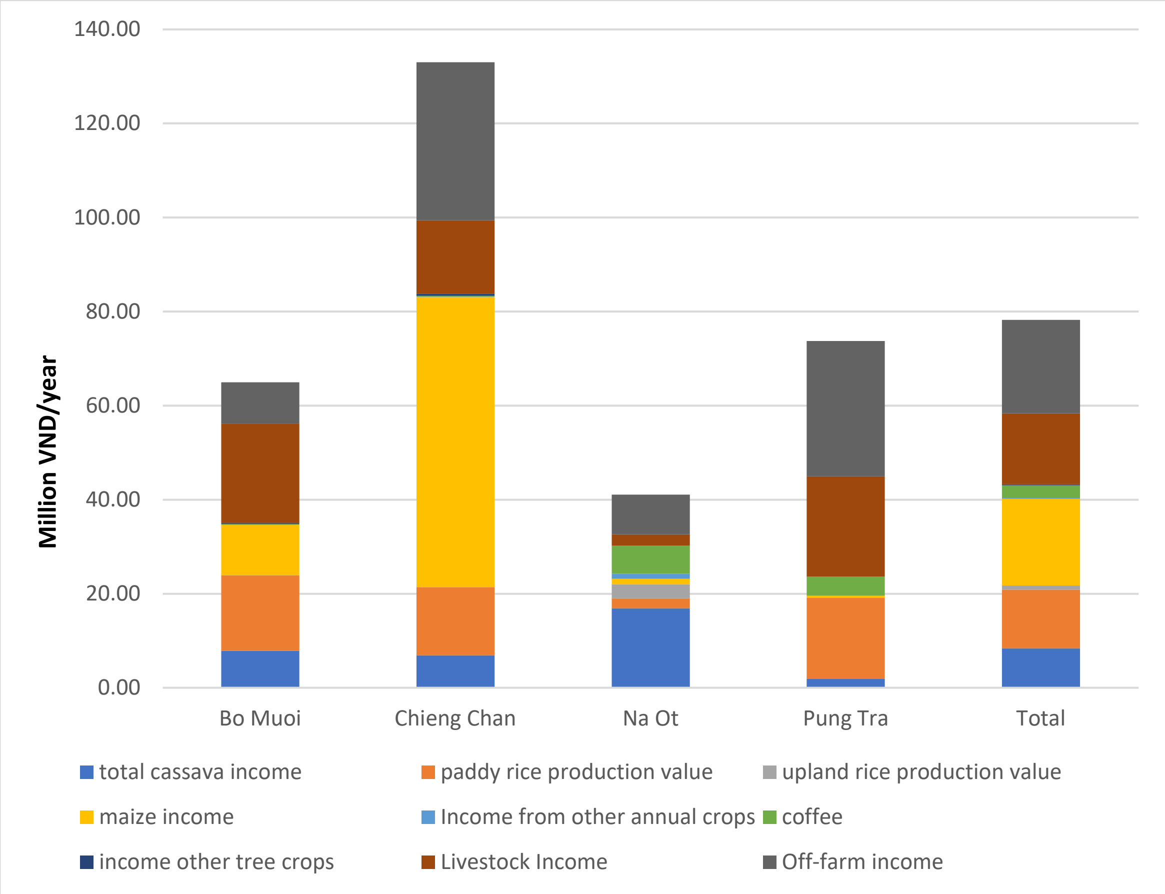


Figure 8: Source of Income, by Commune, Son La

On average, income from cassava production in **Dak Lak** constituted around 20% of the overall household income. Households in Ea Sar commune were most dependent upon cassava with income generated from cassava production contributing to around 50% of their household incomes. On the other hand, cassava production only constitutes less than 20% of income for households in Ea So and Cukty. In **Son La**, income from cassava production accounts for an average of around 15% of total household income. Households in Na Ot commune were most dependent upon cassava with income generated from cassava production contributing to around 40% of their household incomes. On the other hand, cassava production only constitutes less than 5% of income for households in Pung Tra and Chieng Chan.

In **Indonesia**, cassava provided about 25 percent of household income in both East Nusa Tenggara and in North Sumatra. In both sites, off farm income is a significant source of livelihoods for farmers.

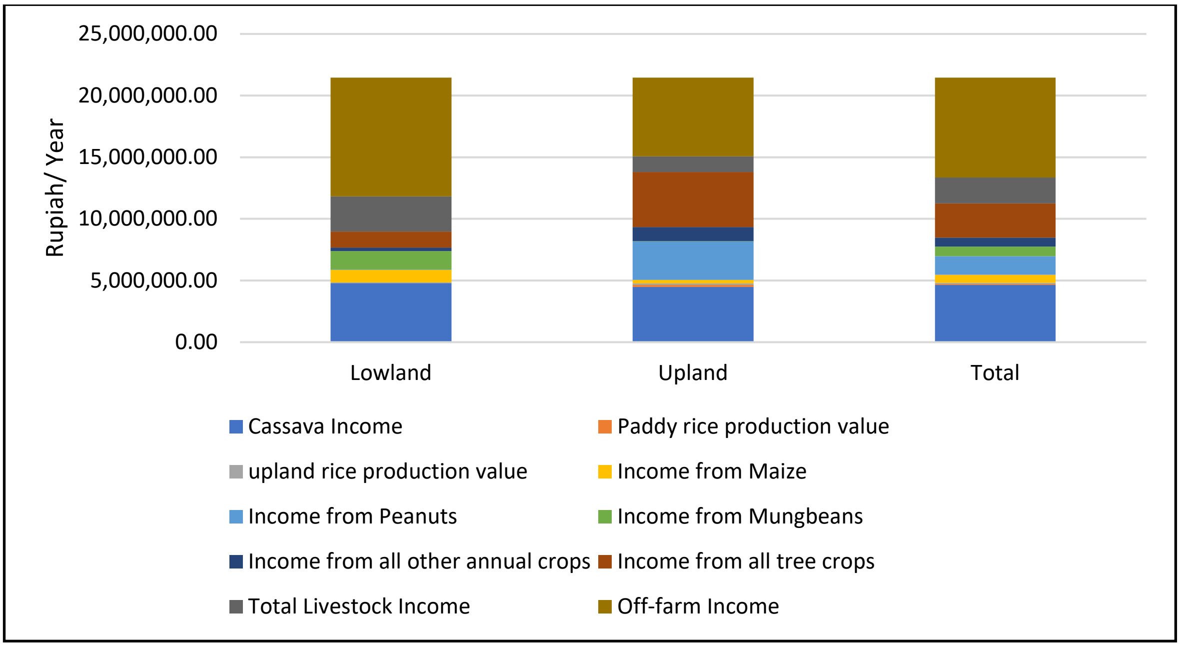


Figure 9: Source of Income, by Location, East Nusa Tenggara

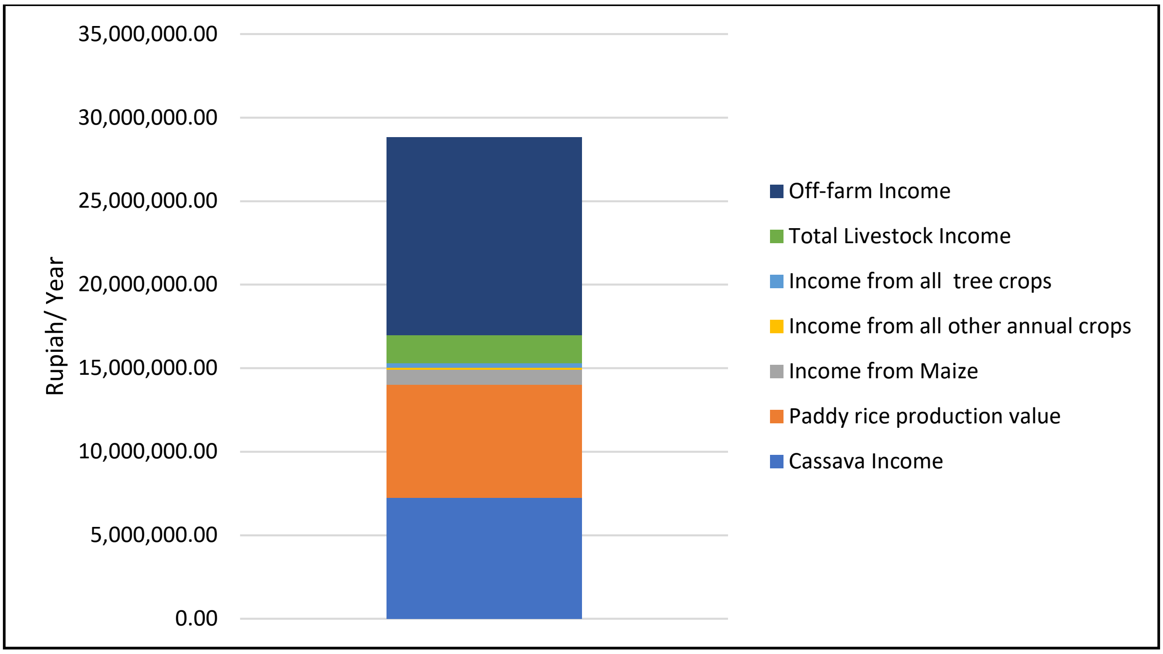


Figure 10: Source of Income, North Sumatra

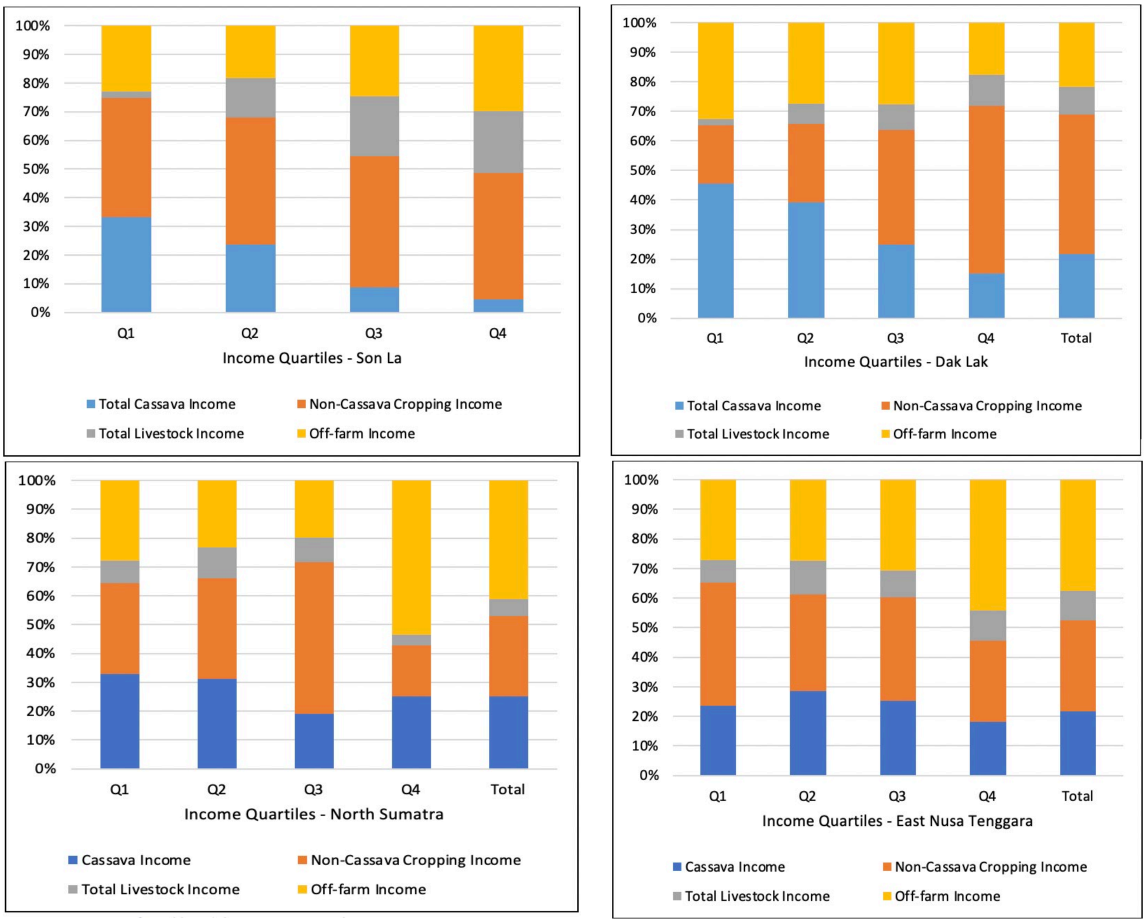


Figure 11: a) Son La - Sources of Livelihood, by Income Quartile; Panel b) Dak Lak - Sources of Livelihood, by Income Quartile; Panel c) North Sumatra - Sources of Livelihood, by Income Quartile; Panel b) East Nusa Tenggara - Sources of Livelihood, by Income Quartile

The sources of livelihood by income quartile are shown in Figure 11 (panels a and b for Vietnam and in panels c and d for Indonesia). The figure highlights the importance of cassava as a source of livelihood to the lowest income households. Income from cassava constitutes between 25 and 45 percent of the total source of livelihood for the lowest and second lowest income quartiles. Cassava declines in importance as an income source for higher incomes quartiles in all sites except for East Nusa Tenggara. The figure also shows the increasing importance of income from off farm sources in all sites as households become wealthier.

Production and Yields

In 2016, the average cassava yield per hectare in the surveyed communes in Dak Lak varied between 16.8 tons per hectare in Ea H'Leo and 24.5 tons per hectare in Ea Sar and Ea Pal. In Son La, production area per household varied between 0.31 hectares in Pung Tra and 0.96 hectares in Na Ot. Average production ranged from 4 tons per household per year in Pung Tra to 13 tons per household per year in Na Ot. Yields per hectare were similar across all sites in Son La, ranging from 14.8 tons per hectare in Pung Tra to 16.6 tons per hectare in Bo Muoi. Yields at all sites in Son La were lower than in Dak Lak.

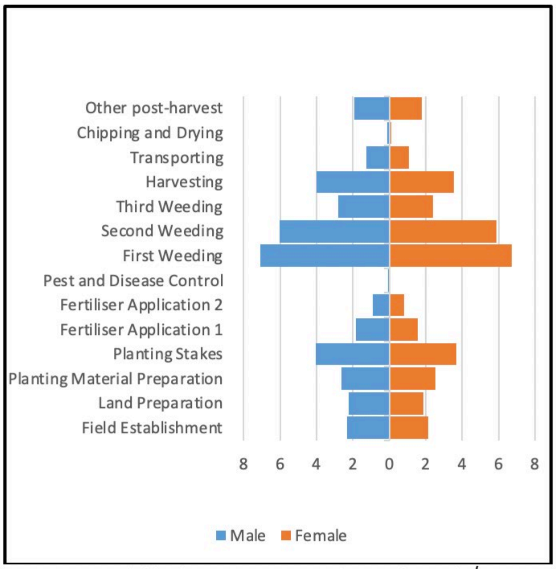
Cassava production in North Sumatra was around 14.81 tons per household with an average harvest area of 0.54 hectares at a yield of 28.74 tons per hectare. In Sikka (East Nusa Tenggara), production area per household varied between 0.48 hectares for lowland farmers and 0.44 hectares for upland farmers. Yields were relatively low at 7.82 tons per hectare for lowland farmers and 9.23 tons per hectare for upland farmers.

Across both countries there was a recognition by farmers that their cassava production was unsustainable. In North Sumatra, around 46 percent of farmers thought that their yields were declining moderately or rapidly. In Sikka, this proportion was around 24 percent, while about 70 percent of farmers in Sikka perceived that yields were relatively constant or fluctuating a small amount with no clear trend.

In Son La, more than 73 percent of farmers though that yields were declining moderately or rapidly, which could be correlated with soil erosion, which more than 90 percent of farmers reported at a problem. In Dak Lak, more than 46 percent of farmers thought that yields were declining rapidly or moderately.

Labour and gender roles

In both Dak Lak and Son La, there seems to be no specific gender roles in cassava production, with male and female person-days per year for each cassava production related task being relatively even. This is different to the case of paddy rice, where there is significant gender disparity between different production tasks[3].



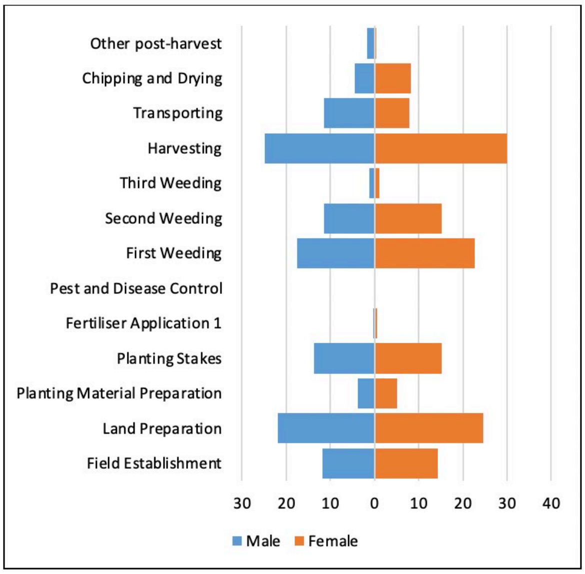


Figure 12: Panel a) Dak Lak – Household labour days per hectare for different production tasks, by gender; Panel b) Son La– Household labour days per hectare for different production tasks, by gender

In Sikka, specific gender roles do not seem to exist for most activities related to the production of cassava. The various tasks involved in cassava production generally shows an even distribution of person-days per hectare across male and female agricultural workers. However, this does not mean all tasks are gender neutral. Activities such as harvesting, transportation, fertiliser application and pest and disease control are dominated by men while chipping and drying along with other post harvest work are generally managed more by women.

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[3] *See for example, Truong Thi Ngoc Chi, Nguyen Thi Khoa, Bui Thi Thanh Tam, and T.R. Paris (2004), Gender roles in rice farming systems in the Mekong River Delta: an exploratory study, in G.L. Denning and Vo Tong Xuan (eds). Vietnam and IRRI: A Partnership in Rice Research. Proceedings of a conference held in Hanoi, Vietnam, 4-7 May 1994.*

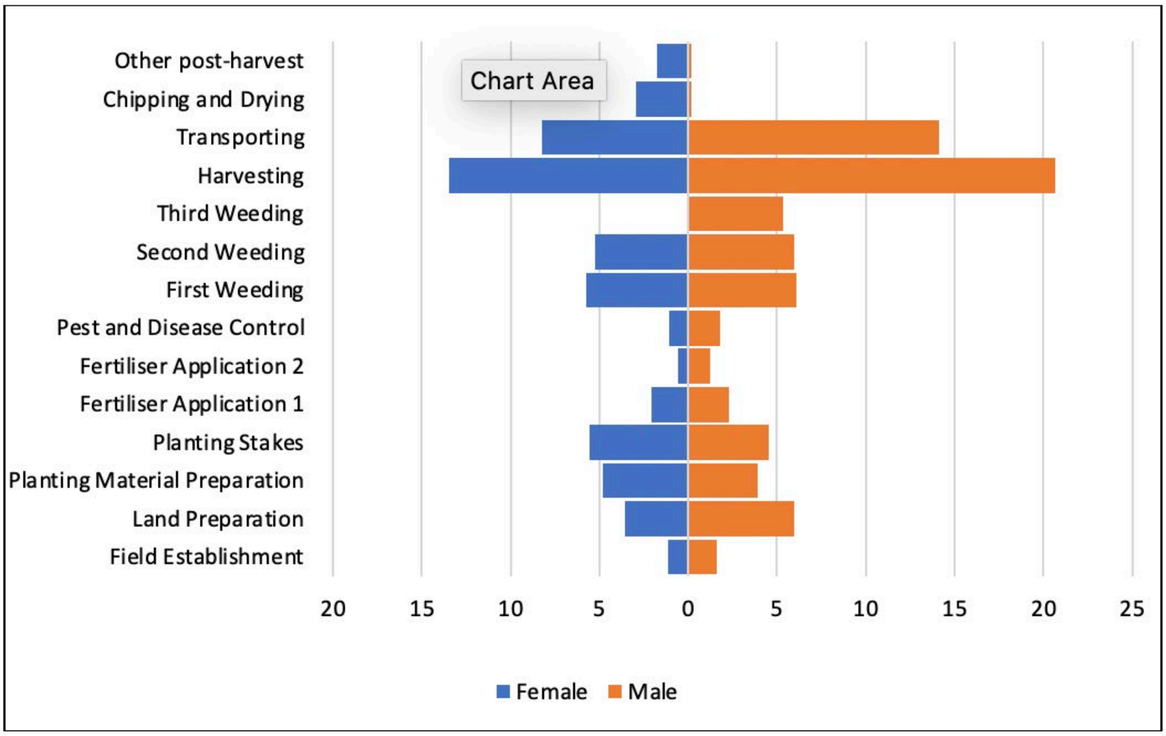

Figure 13: Sikka – Household labour days per hectare for different production tasks, by gender

In North Sumatra, while specific gender roles do not seem to exist for most activities related to the production of cassava, there is overall greater involvement of men in most of the tasks. In general men supply more person-days per hectare across all tasks involved in cassava production. For certain tasks such as chipping and drying, harvesting, second weeding, pest and disease control, fertilizer applications, planting material preparation and land preparation, men contribute over twice as many person-days per hectare.

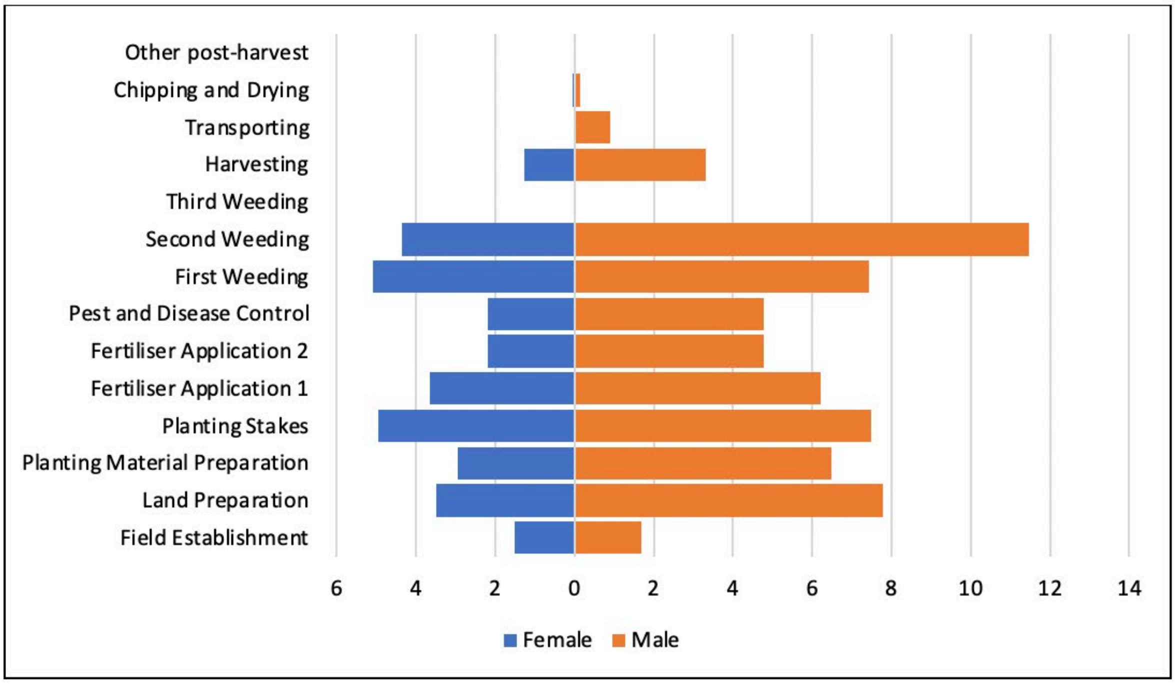

Figure 14: North Sumatra – Household labour days per hectare for different production tasks, by gender

Plans for growing cassava in the future

In Son La, more than 76 percent of farmers indicated that they intended to plant cassava into the future, with only 8.2 percent not intending to grow cassava after the current season. The remainder were unsure about their future plans for cassava production (Table 4). The proportion of farmers not intending to grow cassava in the future was highest in Na Ot and lowest in Chieng Chan.

Table 4: Future Production Intention, by Commune

Will you grow Cassava in the Future?	**Bo Muoi**	**Chieng Chan**	**Na Ot**	**Pung Tra**	**Total**
Yes	80.0%	71.9%	70.3%	82.8%	76.3%
No	7.7%	3.1%	17.2%	4.7%	8.2%
Unsure	12.3%	25.0%	12.5%	12.5%	15.6%

In Dak Lak, more than 54 percent of farmers indicated that they intended to plant cassava into the future, with only 9.5 percent not intending to grow cassava after the current season. The remaining 36 percent were unsure about their future plans for cassava production (Table 5) The proportion of farmers not intending to grow cassava in the future was highest Cu Kty and lowest in Ea So.

Table 5: Future Production Intention, by Commune

Will you grow Cassava in the Future?	**Cu Kty**	**Dang Kang**	**Ea Sar**	**Ea So**	**Total**
Yes	41.3%	77.4%	78.5%	20.6%	54.5%
No	14.3%	9.7%	9.2%	4.8%	9.5%
Unsure	44.4%	12.9%	12.3%	74.6%	36.0%

When asked if they believed they would be growing cassava in five year's time, over 56% of surveyed farmers in North Sumatra provided a positive response while about 43% said they were not sure. Only one respondent said they plan to discontinue cassava production. The respondents in the second income quartile were the most optimistic about their cassava production with over 71% predicting that their cassava production will be retained in the years to come.

Table 6: Future production intention, by income quartile

Will you grow cassava in the future?	**Q1**	**Q2**	**Q3**	**Q4**	**Total**
Yes	50.00%	71.43%	52.94%	50.00%	56.30%
No	3.13%	0.00%	0.00%	0.00%	0.74%
Unsure	46.88%	28.57%	47.06%	50.00%	42.96%

In Sikka, all of the surveyed farmers indicated that they would intend to grow cassava in the future.

7.2 Objective 2:

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 Vietnam and Indonesia 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 & Aye, 2014).

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 fertilizers 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 & Aye, 2014)

Soil Management including intercropping and conservation agriculture techniques.

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. 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 7, 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 7 - 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 – fertilizer application depends on type of fertilizer, 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 results and discussions are presented for each of the four sites under the following headings for each main technology type trialled at that site:

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

5. Policies

7.2.1 Daklak

A. Testing of different cassava varieties with stakeholders

Agronomic results

Season 2017-18

In Dak Lak, HLS10, HLS11, KM 419, KM140, KM505, KM94 and Rayong 9 were evaluated in two different types of soils (i.e. Acrisol and Ferrasol) and with two types of practices (i.e. Framers' practice and MARD recommended practice). For the Farmers' practice, 100kg phosphorous fertilizer and 250kg NPK (15-5-20) ha^{-1} and for MARD recommended 90 kg N - 60 Kg P_2O_5 - 90 kg K_2O + 1 t ha^{-1} bio fertilizer was applied in three replicates.

Fresh root yield was significantly affected by treatment X variety interaction ($P < 0.001$) and also soil type significantly affected fresh root yield ($P < 0.001$). The MARD practice yielded higher compared to farmers' practice in all locations. Furthermore, on an average across all location, fresh root yield was 1.4-fold higher in Ferrasol compared to Acrisol. Variety KM419 (45.0 t ha^{-1}) and HLS11 (45.1 t ha^{-1}) demonstrated highest yield which was 1.8- and 2-fold higher compared to farmers' practice (Table 12.1). Starch content in the varieties were significantly different ($P < 0.001$) and ranges from 27.5% (variety KM505) to 30.8% (variety HLS11).

Season 2019-20

At Eatu commune, Buon Ma Thuot City, an experiment was carried out to evaluate 21 new CIAT clones (i.e. elite lines) compared with popular varieties KM419 and KM94. Wide range of variation was observed among the elite lines when considered the fresh root yield (Fig 1A). Line GM579-13 produced highest yield (96.8 t ha^{-1}) and the lowest (14.2 t ha-1) was by line SM1669-5. Popular varieties, KM419 and KM94, yielded 40.2 and 41.0 t ha^{-1}, respectively; which is almost 40% of the highest yielded elite line. Highest yielding line GM579-13 also had highest (30.1%) starch content. Starch content varied between 25 to 30% (Fig 1B). Popular varieties, KM419 and KM94, had 26.9 and 28.7% starch content, respectively.

Economic results

The evaluation of new varieties illustrated the potential for the introduction and adoption of new varieties to significantly increase household incomes. The actual economic impact depended on both the initial soil productivity of the land (soil type) and other management practices (such as fertiliser). Secondly, the price of fresh roots varied through the project period from factory gate low of around $62 USD/t to short-term maximum in excess of $200 USD/t. Assuming a 5t/ha increase from moving from KU50 to either KM419 or HLS11, at average prices ($134/t) the benefit per hectare of changed variety would be around $672. At the lowest prices the benefit was still $311/ha. The 10t/ha increase and above average price saw very significant increases in benefits to farmers and traders.

These results need to be considered as arising under very low disease pressure. Indeed, trials being conducted in Cambodia and Southern Vietnam have indicated the susceptibility of both KM419 and HLS11 to CMD. What the results do show is that significant benefits can arise at the farm level if farmers have an opportunity to test, evaluate and adopt different varieties that match their context.

Partnerships developed

The field level economic results illustrate the high potential for testing of new varieties to increase productivity and household incomes. The evaluation of new varieties conducted by TNU was done in consultation with factories and extension services. The incentives for these factories to engage in the evaluation process varied between the different factories based on the location and competition for roots. Factories indicated a willingness to collaborate with research partners to evaluate new varieties. This also included some investment in TNU staff to provide training to farmers and introducing new varieties.

Having said that, the incentive decreased as the distance from the factory increased and the exclusivity over the extra roots generated through changed practices became less assured. One processor with their own land for production collaborated to identify the most suitable variety for their farm by allocating land and labor for the evaluation of 17 CIAT elite varieties and trials of CMD responses between current elite varieties of Vietnam.

The competition for feedstock and value chain structure meant that the incentive for an individual starch factory taking a leading role in widespread dissemination of new varieties was constrained. However, a strong interest in new varieties was very apparent. This included factories seeking to purchase stems of newly released varieties from southern Vietnam. This inadvertently introduced CMD to the central highlands. Establishing a central source of clean planting material from the central highlands will become of critical importance. The will required a public-private partnership approach to overcome some of the incentive constraints.

The central Highlands is a key area of evaluating the new CMD resistant varieties being developed in a new project. Some of the exiting partnerships developed during this project will assist in the evaluation, multiplication, and dissemination of new varieties in the future.

Changed practices

The results of the trials generated significant interest in getting access to new varieties. This became complicated as new evidence of susceptibility to CMD became apparent. The new varieties that were initially introduced were distributed to other households within the commune (97) by the initial household that participated in the trial.

The potential for maintaining clean planting material in disease free zones towards the end of the project saw the area of production increase from 3 to 5ha, plus some distribution to relatives.

B. Fertiliser

Agronomic results

Application of fertilizer increased yield by 1.4-fold to 2.7-fold (i.e. averaged with all treatment) in demonstrations in Dak Lak (Table 12.2). Five different fertiliser treatments were tested in two different soil types, fertiliser treatment X planting density interaction was not significant for fresh root yield (Table 12.2). Fresh root yield ranges from 19.2 to 45.4 t ha^{-1} across all treatment and locations. Furthermore, fresh root yield on an average 1.3-fold higher in Ferrasol compared to Acrisol.

Fertilizer treatment X planting density interaction was not significant for starch content (P=0.935). Starch content ranges from 28.5 to 31.2% across all treatment and locations. Medium rate fertilizer application, 108N-72P_2O_5-108K_2O, resulted in highest starch content (31.4 %) when planted at 12,500 Plants ha^{-1}. Similar result was observed during following year (Fig 2). Highest yield (37 t ha^{-1}) was achieved at medium density (12,500 plant ha^{-1}) and medium fertilizer application (90N-60P_2O_5-90K_2O + 1 t bio-fertilizer per ha^{-1}). Lowest yield (12 t ha^{-1}) was from treatment lowest density with no fertiliser.

To evaluate different cultivation practice to reduce disease severity, project recommended treatment showed less disease symptoms, higher fresh root yield and starch content over farmer's practice (Table 12.3) during 2019-20 season. In general, presence of symptomatic plants was very low (i.e. ranges between 0.09 to 0.5%) for CMD. There was no presence of CWBD in the experiment. Among the varieties, HLS14 resulted in the best considering all the parameters in the experiment (Table 12.3).

One farmer and an ethanol factory engaged in multiplication of planting material of three cassava varieties during 2019 season (Table 12.4). HLS11 had 95% CMD symptomatic plants in factory operated field; and HLS12 and HLS14 had 4 and 3% CMD symptomatic plants. HLS11 had reputation to be highly susceptible to CMD, however, in the multiplication block symptoms were mild. There was no CWBD symptomatic plants observed in any of these fields. PCR results from asymptomatic plants from diseased field did not show presence of virus that cause CMD.

Economic results

The economic analysis showed the potential for significant economic benefits from farmers changing their fertiliser management practices. The results varied based on soil type and were only subject to a small number of locations. Nevertheless, they indicate very attractive returns on investment (marginal rate of return) even at low prices.

On the acrisol, combination of 108N+72P2O5+108K2O and density of 15,625 plants per hectare generated the highest net returns. Moving from farmers practice to the higher fertiliser application rate produced an attractive rate of return. On the other hand, given that the increasing the density did not result in a statistically significant increase and a marginal rate of return of around 100%, the cheaper option of maintaining the traditional density would be more be the current recommendation. On the ferrasol the highest net benefits were achieved at the higher fertilizer rate, but plant at 10,000 plants/hectare. Once again, the marginal rate of return was significantly large even at the lowest prices experienced during the project period.

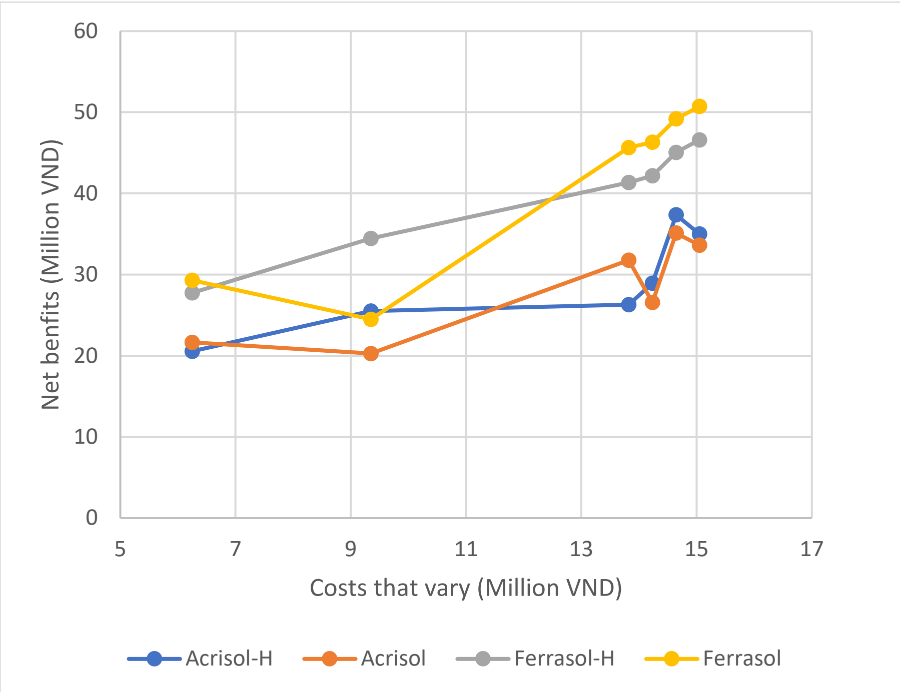

Figure 15 – Marginal return analysis of fertiliser x density trial in Daklak

Fertilizer has significant effect on cassava starch content. To maximize return on starch processing, it is recommended that cassava price at farm gate should be paid against starch content instead of paying in bulk to encourage farmers to apply more optimal fertilizer on cassava.

Partnerships developed

As indicated above, demonstrations and field days were help in collaboration with starch processors. The team from TNU provided training to farmers in specific supply chains supported by the starch processor. There is opportunity for ongoing collaboration for training farmers and establishing demonstrations within specific supply chains – typically close to factories with more assurance of delivery. This involves the engagement of key traders.

Changed practices

Farmers that participated in the demonstration field days reported a change in knowledge, but widespread changed practices need ongoing support. The demonstrations did not include a comparison of farmers current application method – broadcasting. During feedback sessions farmers reported they the additional labour required for the placing fertiliser under the soil is a constraint. The inefficiency of broadcasting (particularly on sloping land) needs further demonstration.

In terms of density, farmers have other reasons to maintain higher density that were not captured. At a higher density the labour demand for weeding is less and the effort required for harvesting is reduced. This again related to labour productivity highlighting the importance of considering the returns to labour in technology design

C. Managing soils through intercropping and grass strips

In two trials, intercropping of legumes with cassava and response of different fertilizer and density to cassava yield was evaluated. All trials were planted between in 19th May 2018 harvesting was completed in 21st January 2019. Legumes were harvested in September 2018.

Cassava root yield was not significantly affected by interaction of intercropping treatment X variety (Table 12.5). However, sole cropped cassava produced lower yield compared to cassava when grown with intercropped legumes. On an average yield increase for variety KM419 was 1.3-fold and for variety HLS11 it was 1.2-fold while legumes were intercropped. Highest fresh root increase was recorded for KM419 with red beans 8 t ha-1 compared to sole cropping. Considering both cassava varieties and all legumes that were intercropped, average root yield increase for cassava with intercropping was 16% higher compared to sole cropped cassava (Table 12.5). Starch content of cassava variety was not significantly affected by interaction of intercropping treatment X variety (Table 12.6). Starch content of both cassava varieties across all intercropping treatment ranged between 28.7 to 30.4 %. Furthermore, intercropped legume yield was not significantly affected by interaction of legume X cassava variety (Table 12.7).

During 2019 season, cassava was intercropped with peanuts and enhanced cassava yield was obtained compared to sole crop (Table 12.8). Sole cropped cassava yielded 31.8 t ha-1. Intercropping increased cassava yield ranged between 2.1 to 6.7 t ha-1. Highest yield increased (6.7 t ha-1) when cassava was grown at 10,000 plant ha-1 and peanut was fertilized. However, unfertilized peanuts also enhanced cassava yield by 3.6 t ha-1 suggest that an extra 3.3 t ha-1 of cassava was achieved by the extra fertilizer that was added to pea nuts that, presumably, was also abetted to cassava. Fertilization to peanuts also boosted yield by 1.3-fold for peanuts. Sole cassava was planted at higher density compared to other treatment may have some influence on the yield.

Higher density of plants in the sole cropped cassava showed greater removal of nutrients. At the end of the experiment, soil analysis demonstrated marginal decline of all nutrients when cassava was grown as sole crop at 15,625 plant ha-1 density by contrast all other treatments add and/or remain the same for all nutrients (Table 12.9). Similar results were also observed in other demonstrations when cassava was grown in higher density during the project.

Lower density of plants showed marginally higher fresh root yield. HLS12 produced 0.6 t ha-1 and HLS14 produced 0.5 t ha-1 higher yield when compared between planting density of 15,625 and 17,857 plants ha-1 (Table 12.10). There was no effect on starch content. In general, HLS12 produced higher fresh root yield and starch content compared to HLS14. There was no CMD and CWBD symptomatic plants in this experiment.

At the end of the experiment, soil analysis demonstrated marginal decline or remain the same for all nutrients when cassava was grown (Table 12.11). Higher density of planting decline soil nutrient marginally higher.

Economic results

The economic analysis of the intercropping appears to make a compelling case for intercropping. However, it is difficult to separate the additional cassava yield from changed management (fertiliser, weeding) rather than the impact of the intercrop itself.

The additional income generated by legumes still provided a significant return on investment based on the marginal cost of including the intercrop - ranging from 129-255%. However, the additional labour requirement is challenging to value in small plots. Feedback from farmers still see the additional labour required as the main constraint to adoption of intercropping on a larger scale. That is, the opportunity cost of labour is considerably high and households not wanting to hire the additional labour (added cash costs) required to cultivate intercrops.

Table 8: Intercropping incomes and returns on investment

Treatment	Net Cassava Income	Net Legume Income	Net total Income	Additional Cost (legumes)	Return on Investment in legumes
Monoculture cassava	25.98		25.98		
Cassava intercrop with red beans	36.32	11.62	47.94	4.56	255%
Cassava intercrop with cow peas	36.15	10.91	47.06	4.63	236%
Cassava intercrop with mungbeans	30.32	6.01	36.33	4.65	129%
Cassava intercrop with peanuts	34.48	10.39	44.87	5.48	190%

Partnerships developed

There was limited interest by local stakeholders promoting intercrops of legume with cassava. However, rubber production company was interested in intercropping cassava into rubber plantation when rubber is still little to save weed management efforts and maximize income at initial phase of rubber plantation.

Changed practices

Farmers who participated in the trials of legume intercrop acknowledged of soil moisture improvement and additional income gained from intercrops but they also informed the challenges in adoption of the technic because of time consuming in weed management, planting legumes and negative impact into cassava fresh root yield that were not covered by the additional income gained from intercrops. In reality, there were no changes in the practices observed during the project implementation period.

7.2.2 Son La

A. Variety

A total of six varieties, Red Lá tre (local variety), KM94, KM21-12, Rayong 9, BK and 13sa05 were evaluated in two different communes in two districts with fertiliser 80N+20P+80K during 2017 and during 2018 season and in one commune during 2019 season.

During 2017 season and during 2018 season the yield was very low for all varieties in both locations which ranges between 12 to 24 t ha^{-1}. During 2019 season, higher yield was recorded for all varieties compared to previous two seasons (Table 12.12). There was variation in starch content among the varieties ranges from 27.7 to 30%

New variety 13Sa05 yielded highest (23.8 t ha^{-1}) followed by Rayong9 20.6 t ha^{-1} BK900 20.2 t ha^{-1} in Pung Tra commune. However, all these three varieties performed poorly in Chieng Chan commune where yield were ranged between 15.5 to 12 t ha^{-1}. Popular variety KM94 and La Tre produced similarly in both locations (Table 12.12). As there was very different result was observed for different variety, during 2019 season six varieties were evaluated again in big plots. New variety 13Sa05 yielded 31.1 t ha^{-1} followed by Rayong9 29.0 t ha^{-1}, however, variety BK produced marginally higher (32.4 t ha^{-1}). Popular variety KM94 produced lower yield (27.5 t ha^{-1}); however, starch content was highest (29.2%). In this experiment higher yielding varieties produced lower starch content ranging between 25.4 to 27.5 % (Table 12.13).

Repeating evaluation of varieties in three years of 2017, 2018 and 2019 show that two new improved varieties of 13Sa05 and BK can give good growth and higher yield in comparison to two existing popular varieties of KM94 and Red La Tre. The two new improved varieties can give high starch contents from 29% to 30%. In terms of plant architecture, they have short plant type which can be more resilient in steep land and strong wind. They have many roots but short that make easier for harvesting.

These two new varieties also respond better to fertilizers than locally popular varieties of KM94 and Red La Tre. Under the same conditions of soil (flat and fertile or steep and infertile) and without infection of pest and disease, same dose of fertilizer which is either 40N/10P/60K equivalent to 87kg Urea + 142kg triple superphosphate + 80 kg KCL or 60N/15P/60K equivalent to 130kg Urea + 213 kg triple superphosphate and 120kg KCL, BK and Sa1305 can give from 18 tons/ha to 32 tons/ha which significantly higher from 14%-17% than that of KM94 and Red La Tre.

In regards of density, these two varieties of BK and 13Sa05 performed good growth and higher yield compared to other varieties at both densities of 10,000 plants/ha and 12,500 plants/ha.

However, these two varieties are more susceptible to pest and disease than KM94 and Red La Tre. It is observed that many plants of BK and 13Sa05 were infected with Witches Broom Disease and Pink Mealybug in 2018 that make significantly yield loss while KM94 and Red La Tre were found healthy. In addition, it is harder to reserve BK and 13Sa05 stems for planting material in following season (can be reserved less than 2.5 months). These two new varieties also have low germination rate under drought conditions than KM94 and Red La Tre.

Economic results

BK and 13Sa05 could provide higher income than local varieties of BK and KM94 just thanks only higher yield performance of from 14% to 76% depends on field conditions (steep and flat).

Partnership developed

New introduced varieties showed significant incentives to both farmers and factories thanks to its well performance in fresh root yields and starch contents. One of starch processing factories have involved in distribution of new varieties to farmers (20 ha) in two years of 2018 and 2019. In addition, local extension agency have already involved in promotion of new varieties in collaboration with NOMAFSI.

Discussion between local authority, NOMAFSI and the factory in Son La has been started in order to widely distribute advanced varieties based on the project results.

Changed practices

Farmers have started to source the new varieties to grow since 2019. The cassava processing factories in Son La started to source the new varieties to distribute to farmers through its trader network since 2018, at least 10ha of planting materials of new varieties each year.

B. Fertiliser

Fertiliser application increased yield in all treatment and in all locations (Table 12.14, 12.15). Fertiliser treatment X location interaction was significant (P<0.001) (Table 12.14) as fertilizer responded differently in different locations. Across all locations, without fertiliser treatment produced lowest yield (17.8 t ha^{-1}) and 600 kg ha^{-1} NPK (5:10:3) produced the highest (19.8 t ha^{-1}). However, in following season, fresh root yield was not significantly (P=0.008) affected by interaction of location X fertiliser as cassava responded similarly to fertilizer treatment in all locations (Table 24). Considering all three locations on an average root yield increased by 1.7-fold to 2.0-fold compared to without fertiliser treatment (Table 12.14, 12.15).

Fresh root yield was not significantly (P=0.019) affected by of interaction Location X treatment. Average yield was higher (i.e. 1.3-fold) in Chiềng Chăn compared to Púng Tra commune across all treatment. In Chiềng Chăn, highest yield (i.e. 25 t ha-1) was achieved with highest density (20,000 plant ha-1) and in Púng Tra highest yield was obtained with 12,500 plant ha-1. Starch content was similar (28.3 to 30%) for all treatment and locations

In Púng Tra of Son La province highest yield was also obtained with 12,500 plant ha^{-1}. However, Chiềng Chăn, highest yield (i.e. 25 t ha^{-1}) was achieved with highest density (20,000 plant ha^{-1}) (Fig 3). Large plot demonstrations during 2019 season also confirm previous results- highest yield (i.e. 16.9 t ha^{-1}) was achieved with M3 (12,500 plant ha^{-1}). Marginal yield penalty (~1.0 t ha^{-1}) was observed at density M4 (10,000 plant ha^{-1}). Highest density [M1 (20,800 plant ha^{-1})] produced 2 t ha^{-1} lower yield compared to M3 (12,500 plant ha^{-1}).

The impacts of fertilizer levels depend also on the land conditions (slopes, fertility) and fertilizers type and application method (only basal application, or with 1 or 2 top dressing times). In Bo Muoi, for example, the fertilizer trial was established in a flat land blocks where in the previous year maize and cowpea were planted with high fertilizers rate (600 kg/ha of NPK for the basal and 150 kg/ha urea for top dressing), the impact of fertilizers on cassava yield was not clearly observed. That might be because the soil was still rich in nutrient elements left over from previous legume/maize crops and also from these crops ‘residues).

Economic results

Economic analysis including gross margins analysis, returns to labour, and marginal returns analysis (return on investment) were conducted. Applying single N, P, K fertilizers at right rates gave higher economic return than using composed NPK fertilizers. For sloping lands in Sơn La, the level of 40N-10P-40K (equal to *87 kg urea + 142 kg superphosphate + 80 kg potassium chloride*) gave highest net return per working day, while the level of 60N-15P-60K (equal to *130 urea, 213 kg superphosphate + 120 kg potassium chloride*) gave highest fresh root yield and total net return. Applying fertilizers at 3 times (1 basal dressing and 2 top dressing times) brought higher impacts.

The marginal rate of return (MRR) of moving from the pre-blended NPKs to the straight NPK was extremely large. That is, the additional costs and labour produced a very large return on investment given the additional cost were low and response significant. Only in one location was their benefits from increasing the rate to 60N-15P-60K. The analysis was also conducted at 1,400 VND/kg. While farmgate prices varied based on location, the factory door price has varied widely from 1,100 VND/kg to over 3,000 VND/kg. The average price over the past 5 seasons has been 2528 VND/kg.

Table 9: Economic analysis of Fertiliser treatments

Location	T0	T1	T2	T3	T4
Púng Tra Commune					
Total material cost (000vnd)	1000	2350	2950	3021	4028.1
Total labour	175	175	198	186	209
Net return	19622.0	17642.0	28074.0	32258.6	29963.9
Net return per workingday (000vnd)	112.1	100.8	141.8	173.4	143.4
Net return per 1000vnd spent (000 vnd	19.6	7.5	9.5	10.7	7.4
Marginal rate of return (%)	-	Dominated	433	2177.0	Dominated
Bó Mười Commune					
Total material cost (000vnd)	1000	2350	2950	3021.4	4028.1
Total labour	170	185	192	184	210
Net return	18138.0	22584.0	25246.0	32944.6	35409.9
Net return per workingday (000vnd)	106.7	122.1	131.5	179.0	168.6
Net return per 1000vnd spent (000 vnd	18.1	9.6	8.6	10.9	8.8
Marginal rate of return (%)	-	329.3	443.7	10782.4	244.9
Nà Ớt Commune					
Total material cost (000vnd)	1000.0	2350.0	2950.0	3021.4	4028.1
Total labour	159	167	183	184	185
Net return	18333.3	21800.0	29850.0	30128.6	29805.2
Net return per workingday (000vnd)	115.3	130.5	163.1	163.7	161.1
Net return per 1000vnd spent (000 vnd	18.3	9.3	10.1	10.0	7.4
Marginal rate of return (%)		256.8	1341.7	390.2	Dominated

Partnership developed

Technical extension on fertilizer application and training materials have been taken over by local extension agency for continue to distribute and organize training of farmers in other location of Son La. In one of the project sites (Pung Tra), traders and village extension workers and farmers have started to coordinate with each other in order to source right NPK fertilizer and make it available at the village for farmers.

The private sector partners from the starch factory joined field days, however given the competition for feedstock showed little interest in promoting fertiliser. As mentioned earlier, increasing yields per hectare was not a major incentive of the factory other than by increasing starch content.

Changed practices

Farmers in the project sites have started to applied fertilizer on cassava instead of without application of fertilizer at all. Few farmers have already tried to apply top dressing potassium on cassava to improve yields and starch content.

C. Managing soils through intercropping and grass strips

A total of 11 demonstrations of intercropping of cassava were conducted in 4 locations in Son La province. Fresh root yield was not affected by intercropping as there was no significant interaction between intercrop X locations (Table 12.16). However, in all trials 10 to 16% higher fresh root yield was obtained when intercropped with legumes (i.e. mung bean or cow peas) compared to sole crop cassava. On average of all trials sole crop produced 16.2 t ha^{-1} and legumes intercropped cassava produced 18 t ha^{-1}. Legume crops received 80 kg ha^{-1} [NPK (5-10-3)], presumably, have contributed to the increased yield in cassava. Residues of cassava also demonstrated similar yield increase as shown for legume intercropped (i.e. yielded 17.6 t ha^{-1} average of all trials), can be attributed to the leaching of nutrients from the residues. No effect of Grass-contours on the yield of cassava was found.

Economic results

Intercropping with **cowpea or peanut** produced additional income source and also gave the highest total net return and net return per working day. Intercrops also help improve soil quality (biomass and N-fixation). However, this practice required more financial & labour inputs, and also brought additional difficulties for crop management, especially in term of pest control.

Grass-contours reduced total net income, net return per working day and also net income per 1000VND spent, because of increased material costs required for grass planting and management while grass did not bring any additional income; The use of grass as feeds was not efficient in our trial case, due to high labour consumption for harvesting and carrying grass long way from the field to home for cattle or fishes.

Cassava-plant-residue-contours had no impacts on the cassava growth and yield, but could also prevent a significant amount of soil from being washed off away. This practice is easy for farmers to apply and does not require additional financial input.

Changed practices

Contour lines made by cassava plant residue are the practice adopted and maintained by farmers, especially on the field that is very steep. Intercrop with legumes and making contour lines with grass are not adopted as farmers don’t see it worthwhile doing so. Challenges identified by farmers in maintaining sustainable cultivation practices in slopping land include requirements of extra labour and input cost, difficulties in management of crops and pest and diseases (especially with intercrops); difficulties in management of grass strips, harvesting and transporting grass from the field to home to feed cattle. In addition, soil reservation impacts made from these practices on steep field are not obviously observed. Farmers who were interested in forages to feed their animals were interested to plant the grasses either closer to their house or where the livestock were kept.

D. Extending Cassava Harvest Season window

Starch factories can naturally only operate during the harvest season, resulting in under utilization of capacity and shutdown during much of the year. To extend the harvest window to supply cassava fresh root to factories most of the year, cassava crop was grown for extended period. As the duration of the crop increased, fresh root yield of

cassava also increased (Fig 4A). Highest yield was achieved at 20 months of growth for both varieties, KM94 and La Tre, 35.5 and 27.6 t ha^{-1} respectively. KM94 produced on an average 1.18-fold higher compared to variety La Tre.
Yield penalty (2 to 4 t ha^{-1}) was observed during harvest in rainy season (i.e. April to June) compared to harvest at optimum crop duration (i.e. 10 to 12 months growth). During normal growing season (i.e. 10 to 12 month growth), KM94 produced highest yield (24.6 t ha^{-1}) in January harvest after 10 month growth whereas La Tre produced highest (19.6 t ha^{-1}) in March after 12 month growth.

Starch content decline as the crop growth period increased (Fig 4B). Highest starch content (i.e. 30%) was observed for both varieties after 9 and 10 months of growth. During rainy season, the starch content was lowest for both varieties. At the end of the experiment after 20 months, the starch content was 27.6% and 28.6% for KM94 and La Tre, respectively. Starch content of KM94 marginally higher compared to La Tre when considered the whole experiment duration of 20 months.

Economic results

Harvest of cassava at 20 months after planting (in November of the following year) could generate higher net income than harvest at 10 months age thanks to an increase in yield from 10%-15%, depending on the variety, higher price of fresh root because of limited supply and lower input costs of establishment. In the case of La Tre variety, harvesting 20 months after planting gave 2 fold-higher net income compared to that harvested at 1 year after planting (Fig.6).
However, harvesting in the middle of the year produced lower economic returns due to a lower starch yield impacting the farm gate price. Currently, there are also not the other actors operating to collect roots and take to the factory. Therefore, if the economics of extending the season were viable other changes would have to occur.
The figure below used an opportunity cost of capital of 2% per month (reflecting local short-term borrowing rates) to look at the potential returns to a farmer of extending the season. However, extending to harvest to 20 months also means that a whole season has been forgone.
The additional yield generated for the extended season does not cover the lost income from two crops even when accounting for the reduction in costs associated with growing the second crop.

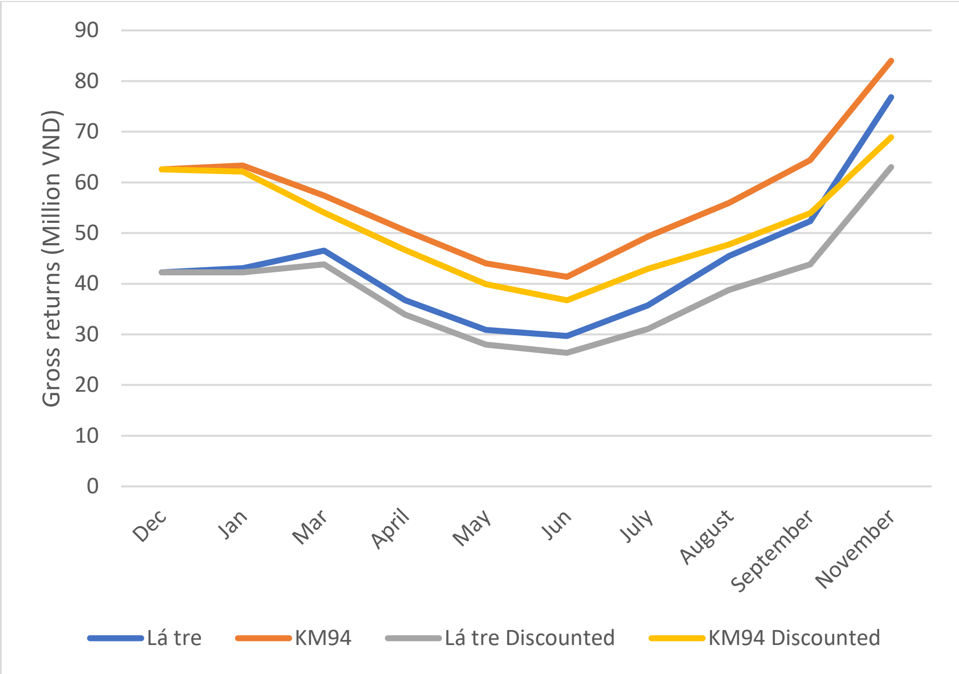

Figure 16: Gross returns to extended season harvesting

Partnerships developed

Initial meeting between cassava processing factories, traders and local extension agency have been occurred to discuss on how to organize production that meet with minimum demands of fresh roots for the factory to operate year-round or at least in off season. The factories have agreed to offer higher price in off-season and acceptance of cassava roots at 22% of starch content in the first month of processing operation. Challenges facing stakeholders are raining season and scale of production of cassava roots in off-season which is still very limited and not sufficient for factory to operate currently.

With a high price to offset the starch yield penalties there may be some potential to push the season for a few months in a few specific location, however this would need to be done without losing the opportunity to establish the subsequent crop or an alternative crop with similar returns.

7.2.3 North Sumatra

A. Variety

Agronomic results

A total of 11 high yielding varieties were evaluated. Introduced varieties, Malang4 (49.8 t ha^{-1}), UB1/2 (38.7 t ha-1), UB4472 (35.8 t ha-1), Adira1 (36.3 t ha-1), Faroka (41.7 t ha^{-1}) also performed well compared to local varities (Table 12.17). Farmers' responded positively to introduced varieties and prefer the following varieties Gajah, Tambak Udang, UB ½, Malang6, Faroka. During 2018 season, varietal demonstrations were conducted with farmer's participations (Table 12.18). In 2017, the adoption of Malang4 variety were in 4 sub-districts of North Sumatra and average yield was 40.0 t ha^{-1} (Table 12.18). During 2018 season, there was demonstrations in different areas (Table 12.19) and the yield was consistently higher for project introduced technology compared to local technologies (Table 12.19).

Economic analysis

Similar to other case study sites, the introduction of new varieties results is significant economic benefits at the farm level and is highly adoptable in the starch processing market segment. The price of cassava fluctuated throughout the project period impacting the economic benefits each year.

Through the life of the project the price fluctuated from 500 IDR/kg to over 1,000 IDR/kg. Analysis was conducted at 700 IDR/kg indicating the potential for Malang 4 to increase income by 6,160,000 IDR/ha ($4,400 USD/ha). The actual distribution of the increase in income between farmers and traders will depend on the distance to the factory and the associated transport costs. Given that Bumi Sari is the main purchases of roots, they have a high probability of capturing the benefits of increased productivity, but need to continue to work through the agents and traders to manage the supply throughout the processing season.

Partnerships and business models

The project developed a strong relationship with the starch processing company Bumi Sari Prima for the introduction of new varieties. The initial evaluation of varieties was conducted on Bumi Sari land and managed by one of their main agents. At the harvest field day for the first year of variety evaluation factory staff, agents and key traders attended as well as some local farmers.

Malang 4 was subsequently provided to farmers to plant in their own fields. Cultivation (land preparation, plant spacing, fertilising, weeding) was done according to the farmers' practices. After harvesting, farmers handed over 50% of their cassava stems to the project to be distributed to other farmers.

The project paid 500 Indonesian rupiah per stem (which can be used for up to five cuttings). The project helped with cuttings, fertilisers and herbicides, and supervised the farmers to ensure that the work was done correctly. In 2016–17, Malang 4 was planted by 26 farmers who were located in four subdistricts of Simalungun Regency and one subdistrict of Toba Samosir Regency. Each farmer planted Malang 4 on an area of 0.2–0.3 ha. In 2017–18, the number of participating farmers increased to 51, in Simalungun Regency (three subdistricts), Toba Samosir Regency (one subdistrict) and Deli Serdang Regency (two subdistricts). More farmers were willing to participate but there were not enough cuttings. To measure the yield, the project team sampled 16 farmers' fields randomly. These 16 farmers were also asked about their problems and opinions regarding planting Malang 4 and to compare the yield with that from the previous year.

The main constraint to the model was the speed of multiplication of the new variety. Introduction of rapid multiplication technologies would be a high priority for future investment in North Sumatra to speed up access to new varieties. Given the value chain structure, rapid multiplication could once again be developed with Bumi Sari and scaled through different agents to supply farmers in their supply zone.

Changed practices

After project farmers introduced Malang 4, 51 farmers planted it by 2017–18 across a total of 8.22 ha. The main factor limiting more rapid uptake was the lack of availability of stakes. The yield of Malang 4 obtained by the 16 selected farmers varied widely, from 30 t/ha to 50 t/ha, due to the diversity of cultivation techniques, fertiliser and weather. However, in almost all cases Malang 4 gave a higher yield than the local varieties planted in the previous year; in no case was a lower yield reported.

Policy implications

The partnership between project partners in Malang (ILETRI and UB) was an effective means of introducing new varieties into North Sumatra. While the private sector partner invested in paying for additional shipment of Malang4 and inkind investment in area and time, the project subsidised the costs involved in in bringing capacity to the province and the facilitation of activities. Ongoing activities beyond the life of the project would need to engage with different partners. Cassava is not a high priority for the DINAS, so strengthening partnerships with the University of North Sumatra would be important for ongoing partnerships between Bumi Sari and research organisations. This could involve capacity building in tissue culture and rapid multiplication of cassava germplasm.

B. Fertiliser

Agronomic results

Seven different fertilizer treatments- F1, 200 kg Phonska/ha; F2, Phonska 200 kg + 125 kg Urea + 125 kg KCl/ha; F3, Phonska 200 kg + 5 t manure/ha; F4, Manure 10 t/ha; F5, Phonska 200 kg +25 kg Urea + 50 kg KCl/ha; F6, 100 kg Urea + 100 kg SP-36/ha and F7, 200 kg Urea + 100 kg SP-36/ha^{-1} were tested. During 2017 season fertiliser experiment result was not conclusive. However, fresh root yield on an average 1.3-fold higher for Malang 4 compared to Malaysia (Table 12.20).

The following year (i.e. 2018 season), with a little modification, 5 different fertiliser treatment was experimented on farmers' field in five locations (Table 12.21). Across all site, fertiliser with higher K application (45N: 45 P_2O_5 115 K_2O kg ha^{-1}) yielded highest (ranging 26.3 to 47.1 t ha^{-1}). In another experiment, where maize was intercropped with cassava also same fertilizer combination yielded highest.

Economic analysis

The economic analysis once again showed the high potential for improved use of fertiliser to increase incomes and provide a high return on investment, even at low prices. Consistent with lessons from other sites, the importance of access to single fertiliser and in particular KCL to increase the amount of potassium (K) applied.

The table below shows the high MRR for increasing fertiliser application rates from the current farmer practices. At low prices, additional urea application (N) does not provide a MRR that is likely to see widespread adoption (MRR<100%). However, increasing fertiliser and especially increasing K has a very significant benefit on returns. These results were consistent when the a maize intercrop was introduced with the added cassava yield from the additional K providing strong economic incentive for the application of additional KCL.

Finally, similar to other case study location, the high cost of organic fertiliser (in this case manure) does not provide any short-term economic justification for application.

Table 10: Net benefit analysis and Marginal rate of return of fertiliser trial in North Sumatra

Treatment N-P2O5-K2O	Fertiliser cost (IDR/ha)	Yield (t/ha)	Net Benefits (IDR/ha)	MRR	Net Benefits (IDR/ha)	MRR
			High price (1500 IDR/kg)		*Low price 575 IDR/kg)*	
45-45-45	1,080,000	29.6	35,897,500	-	15,929,650	-
90-45-45	1,332,000	30.2	36,410,500	204%	16,029,550	40%
60-60-60	1,440,000	30.8	37,057,500	599%	16,268,850	222%
45-45-115	1,730,000	37.9	45,637,500	2959%	20,059,050	1307%
10t Manure	4,285,714	30.3	33,566,786	Dominated	13,126,436	Dominated

Partnerships and business models
The partnership model was similar to the one developed for variety dissemination. However, given the additional costs involved and the limited access to suitable fertiliser the project developed a relationship with PT Wilmer who produce different fertiliser blends that are more appropriate for cassava, as well as straight fertilisers.

Changed practices and policy

During the field day at Tiga Dolok, all participating farmers showed interest in the intercropping system. They now understand that planting cassava in between their maize did not influence maize yield. They expressed willingness to practise this system in their farms and to try other crops to intercrop with cassava

However, the current fertiliser subsidy arrangements make KCL relatively expensive when compared to 15-15-15 and Urea. Until these distorting policies are changed it will be difficult to convince farmers to increase the amount of potassium applied.

C. Managing soils through intercropping

Agronomic results
Cassava was intercropped with following crops during the 2018 season (1) cassava monoculture, (2) Cassava intercropped with maize, (3) mungbean, (4) soybean, (5) peanut, (6) upland rice, (7) mellon, (8) red bean, (9) cowpea and (10) ginger. The treatments were arranged in a Randomized Block with 4 replications.

Economic analysis
Intercropping with ginger resulted the highest gross income due to the price of ginger is good. From this intercropping experiment indicated that maize intercropping is worst among the ten treatments due to the poor yield of cassava only 22.3 t ha^{-1} (Table 12.22). However, most of these markets are not well developed an would need further investigation before widespread adoption would be recommended. The analysis has also not included the changes in labour demand, which is difficult to calculate from small scale plots.

7.2.4 East Nusa Tenggara

A. Variety evaluation

Agronomic results

A total of 7 high yielding cassava varieties (i.e. sweet variety-Tambak Udang, and bitter varieties- Faroka, UB ½, UB 14772, Gajah, Malang 6 and Aldira) were evaluated and compared with two local sweet varieties (i.e. Sika Putih and Sika Kuning) during 2017 season. Due to exceptionally dry season, cassava could not grow well (~30% of each plot was affected) and there was heavy presence of mealy bugs. However, the fresh root yield was calculated from individual plant measurements (means of 6 to 9 plants/plots). Fresh root yield of high yielding varieties ranged from 31.2 to 45.7 t ha^{-1} which was 1.2 to 1.7-fold higher compared to local varieties (Table 12.17). All varieties yielded higher in the experimental field compared to farmers' field (Table 12.17). Farmers responded positively to introduced varieties and prefer the following varieties Gajah, Tambak Udang, UB ½, Malang6, Faroka.

HCN content in Malang4: An experiment was conducted for reducing HCN content of Malang4 cassava variety. In the previous experiment Malang4 variety yielded more than 50 t ha^{-1}. This is significantly higher than other introduced or local varieties grown by East Nusa Tenggara farmers. However, with its high HCN content, this variety is not suitable for direct human consumption. Lab tests were conducted by 20 students from East Nusa Tenggara to reduce HCN content in this variety using NaCl and $NaHCO_3$.

Experiments demonstrated that HCN content in Cassava (Malang4 variety) can be lowered by submerging the tuber in Sodium chloride or in sodium bicarbonate solution (Table 12.23). HCN in un-treated tuber was 114.23 mg kg^{-1}. and with different treatment combination it reduced to 44.6 mg kg^{-1}. The HCN content is considered as safe for consumption is about 50 mg kg^{-1} or less; for example, HCN content of sweet variety Tambak Udang is much lower (i.e. 26.7 mg kg^{-1}) (Table 12.23).

Mealybug Survey and yield of different cassava: Observation in 2018 showed that a lot of cassava field infested by mealybug, with the intensity could be 100% of the field area. However, the yield of healthy and infested cassava was not much different. Presumably, due to the late infestation during growth phase in which cassava tuber already developed. To test this hypothesis, a conduct survey study was designed with the expectation that some cassava plant in a field would be infested in the early growth phase. The data collected was the date of the beginning of mealybug infestation, yield of the infested cassava and as a comparison the yield of healthy cassava at the same field. Ten cassava plants were used as the sample.
Mealybug infestation did not significantly influenced cassava (calc t= 2.02; t-Table 5%= 2.14) yield. The same phenomenon was observed in 2018.The reason for this phenomenon because infestation of mealybug occurred at 7-8 months after planting, at which cassava has form their tuber. The effect of mealybug infestation probably would significant if the infestation occurs at earlier stage of cassava growth (Table 12.24).

Economic results

The economic analysis of variety change in NTT needs to take a more nuanced evaluation than in the commercial sites in Indonesia and Vietnam. The local varieties are grown for a different market segment than the introduced commercial varieties. The sweet varieties sold in the local market command a much higher price per kilogram (7,500-10,000 IDR/kg at market), whereas the price paid in the processing sector is only 700 IDR/kg paid at the farm gate. The farmgate price for sweet varieties varied based on distance to market from 2,200-7,000IDR/kg[4], still a significant order of magnitude greater than the industrial market[5].

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[4] *Based on household survey data*
[5] *Prices in the local markets fell significantly due to COVID impacting demand. Estimates were 4000IDR during 2021*

However, beyond the price x yield comparison, economic analysis needs to consider the ability to market additional production which is sold by the bundle or sack in local markets from piecemeal harvesting. On a straight comparison variety adoption for the industrial market segment – the adoption of the introduced varieties would result in the equivalent of a $875/ha increase in farm level income if grown as a monoculture. That is, the introduction of improved varieties for the industrial sector is a necessary, but not sufficient condition to developing the sector.

However, farmers are unlikely to replace their current production area for home consumption and the small amount dedicated for commercial production and marketed throughout the year to local markets with industrial varieties as the increase in yield did not offset the significant reduction in price. Therefore, the role of industrial varieties may play is for intensification of current systems or bring fallow land into production. Even then, the significant difference in price between the market segments is very challenging to incentivise farmers to increase production with the price – even if the results provide return to their resources.

Partnerships and business models developed

The project developed a strong partnership between the team from University of Brawijaya, and partners at Universitas Nusa Nipa, DINAS, and an enthusiastic cassava entrepreneur (small-scale processor). This enabled the initial testing of varieties introduced under the management of DINAS, with the local processor later working through his traders and agents to distribute stems of the best performing varieties to other regions in the supply zone. This included moving the reach of the project into new beyond the administration boundaries the project originally intended to work from Maumere to also include East Flores, highlighting the ability of private sector partners to scale beyond political boundaries.

The partnership was well recognised by the Maumere Regency Government with the Bupati (head of the Regency) hosting variety trials and field days inside the grounds of the official government residence.

Introducing a new variety was the most tangible entry point of private sector engagement in the Flores context. Learning from cross-site visits to other project sites, the local processor partners attempted to replicate the agent model, paying a commission for roots collected. He introduced the preferred new varieties to several traders, agents and directly to farmers. Within two years the new varieties had been distributed to over 80 farming families across two regencies, who he was buying fresh roots directly from and processing dried meal for the animal feed sector.

Whilst this small-scale this model featured some aspects of a successful approach during the period of the project, it highlighted the challenges of developing sustainable partnerships when the scale of processing of an individual actor is low. The additional costs of supporting smallholders and promoting cassava production were only distributed across a relatively small volume. Therefore, attempts to cover these costs impacting profit and ability to pay higher prices. The second challenge was the ability to buy farmer product when they wanted to sell – leading to side selling.

These issues highlighted the need for ongoing facilitation and support by a government or NGO stakeholder to bare some of the overhead costs, which would be justified given the potential income and social benefits. At the same time, the model would need to be expanded to other traders and processors to justify the development of an intervention, help share the cost over a large volume, and bring impact at scale.

The case study also highlighted the need to introducing rapid multiplication methodologies so more farmers could be reached quickly. Access to planting material became a constraint to reaching more farmers given the difficulty and high costs of transporting stems from Java to Maumere. Again, given the scale of production this is something that would likely need to be subsidised and centralised at a government agency or in partnership with the local university.

Finally, further development of market connection further down the value chain is needed before interventions could be scaled. This was not possible during the life of the project as the scale of production was not yet met. The current focus was on replacing imported livestock feed, particular for pig production. There was strong demand for feed during the project period, however the incursion of African Swine Fever into Flores was impacting demand after the project completion. This highlights the risk of engaging in commercial markets with limited other viable markets when developing the value chain on the island in NTT.

Changed KASA practices

Within the life of the project there was an expanding adoption of industrial varieties and an interest in testing new varieties. Malang4 became a popular variety amongst farmers who participated in field days. By the end of the project about 20% of farmers had begun to share the new varieties with family and friends, but most was kept to expand their own production. African Swine Fever and COVID-19 was beginning to impact both the demand and connectivity between the actors in 2020. In 2021 the processor managed to purchase from 40 farmers who the new varieties had been distributed to.

Policy changes

The potential for impact at scale from the introduction and distribution of new cassava varieties (either for direction consumption or industrial purposes) has the potential to improve incomes and food security in eastern provinces of Indonesia. The case study highlighted the challenges for bringing impact at scale when working with even the most enthusiastic of small-scale processors. Longer term support and links to development projects is required to introduce new technologies and build capacity locally. While local government support was strong for the activities, resources were not allocated to expanding activities as the COVID pandemic began to impact funding decisions.

B. Fertiliser and alternative cropping systems

Agronomic results

To investigate the effect of fertilizer application on the growth and yield of maize and cassava+ maize intercropping was carried out during 2018. The following treatments were established. Maize Monoculture No Fertiliser (**MF0**), Maize Monoculture with N- 200 kg Urea (1st at planting; 2nd at 45 days after planting, DAP) (**MN**), Maize Monoculture with NPK- 200 kg Urea/ha (1st at planting; 2nd at 45 dap); 100 kg Superphosphate 36 (SP36) and 100 kg Potassium chloride (KCl) at planting (**MNNPK**), Intercropping cassava-maize (2m x 1m) No fertilizer (**MC_1F0**), Intercropping cassava-maize (2m x 1m) with N 300 kg Urea/ha (1st at planting; 2nd at 45 dap; 3rd after maize harvested) (**MC_1N**), Intercropping cassava-maize (2m x 1m) with NPK -300 kg Urea/ha (1st at planting; 2nd at 45 dap; 3rd after maize harvested). 100 kg SP 36 and 100 kg Potassium KCl at planting (**MC_1NPK**), Intercropping cassava-maize (1m x 1m) No fertilizer (MC_2F0), Intercropping cassava-maize (1m x 1m) with N 300 kg Urea/ha (1st at planting; 2nd at 45 DAP; 3rd after maize harvested) (MC_2N) and Intercropping cassava-maize (1m x 1m) with NPK-300 kg Urea/ha

(1st at planting; 2nd at 45 dap; 3rd after maize harvested). 100 kg SP36 36 and 100 kg KCl at planting (MC_2NPK). Fertliser treatment increase both crop yield (Table 12.25), cassava yield was highest at 1m X 1m planting density (with NPK) (47.5 t ha^{-1})

In another experiment in 2019, Cassava and maize yield was significantly increased by fertiliser application in East Nusa Tenggara (Table 35). Cassava yield increase was between 3- to 5-fold depending on the fertiliser combination. Maize yield was influenced by nitrogen application only. However, cassava yield, was influenced by N and K application (Table 12.26).

Diversifying cropping systems: Cassava yield was highest in monoculture practice (Table 12.27). In all intercropping practice cassava yield was lower (between 10 to 27.1 t ha^{-1}) as the planting density was adjusted (low). However, when calculated Land Equivalent Ratio (LER) the yield of intercrop system was higher in all treatment and the highest (LER 1.78) was for cassava with maize intercropping with higher density (Table 33). Following season, demonstration of the effect of fertilizer application on yield of maize and cassava-maize intercropping was carried out in (Table 36). Farm productivity was increased significantly due to intercropping and fertiliser application as yield for both crops increased (i.e. for maize up to 2.6- and for cassava 5-fold compared to sole cropping (Table 36).

Furthermore, in 2019, there were 86 farmers from Sikka and East Flores District participated the project demonstration by adopting the improved technology (new varieties, improved cropping system, and fertilizer application). In general, the yield of cassava (i.e. with improved technology) was far higher than the yield of farmers cassava (Table 12.28). This yield increases certainly by increasing cassava population and proper fertiliser application. In the past farmers in East Nusa Tenggara planted cassava about 2.500 to 4000 plant/ha, and if they used fertilizer it applied for maize only.

Economic results

Maize is the main staple crop for many households in NTT with cassava sometime intercropped at very low density. It was important to demonstrate that any economic benefits generated by increased cassava production did not compromise food security or income from the maize crop. There agronomic results illustrate the potential to intensify the production system either by introducing cassava or increasing the density of cassava within the maize intercrop.

The farmer’s current practice only applied fertiliser at the planting of maize with cost varying between IDR 700,000 (monoculture cassava) and IDR 1,100,000 (intercropping with maize) per hectare. The net return of fresh tuber yield from the current practices were around IDR 14,000,000 per hectare (monoculture wide planting space 2 x 1) to 21,000,000 (intercrop with maize). If farmers adopt the fertiliser recommendation from the trial (300kg Urea + 100kg Superphosphate + 100kg Potassium Chloride kg per hectare), it is expected that farmers will get an increase in income of around IDR 17,000,000 (monoculture wide planting space 2 x 1) to 30,000,000 (intercrop with maize) per hectare, while costs will increase by IDR 1,000,000

A marginal analysis of both the fertiliser application and density of cassava was conducted. The results show the great potential to increase incomes by modifying the production system. However, the results also indicated the importance of addressing fertility management if intensification were to occur. The marginal rate of return from increased fertiliser management were very significant for adding nitrogen to the maize crop, and again highlighted the importance of access to NPK fertiliser when cassava was added to the system to maximise the economic potential of the cropping system.

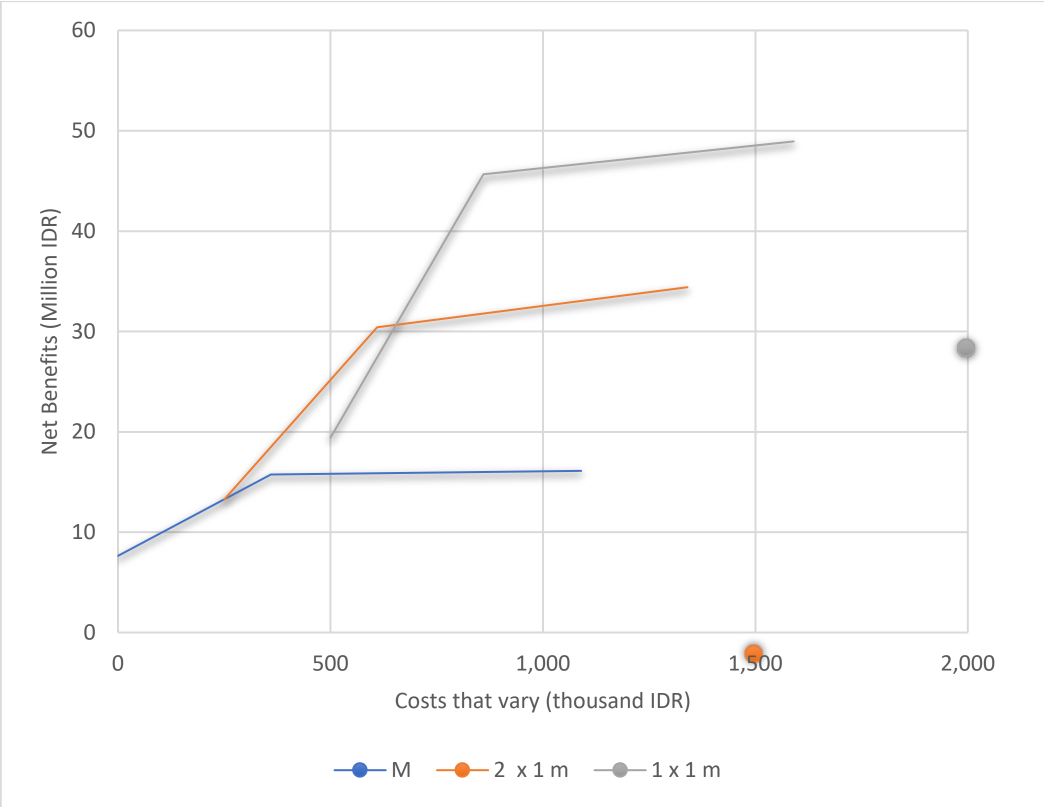

Figure 17 – Marginal analysis of fertiliser and increased density of cassava in maize-based systems in NTT.

Participatory budgeting was conducted in Hokeng District with farmers who had trialled the intercropping system. The results showed that farmers yields were far lower than those in the trial – however the fertiliser and other management was not conducted optimally in farmers fields. Also, in this case the comparison was between monoculture cassava and a cassava-maize system. These results do illustrate that it often easier to introduce a cassava-maize system into a maize monoculture, as opposed to introducing maize into a cassava monoculture.

Table 11: Net benefit analysis and Marginal rate of intercropping in NTT

	Cassava Monoculture	Cassava Mono (USD)	Cassava-Maize	Cassava-Maize (USD)
Material costs (A)	1,110,000	$78	1,630,000	$115
Labour costs (B)	2,360,000	$166	2,560,000	$180
Total costs (A+B = C)	3,470,000	$244	4,190,000	$295
Focus group yields (0.8 maize + 25t cassava)				
Revenue (D)	17,500,000	$1,232	21,500,000	$1,514
Net returns (D-C)	14,030,000	$988	17,310,000	$1,219
Net returns to household resource (D-A = E)	16,390,000	$1,154	19,870,000	$1,399
Labour days (F)	59	59	64	64
Net returns per labour day (E/F)	277,797	$20	310,469	$22
Experimental yields (4t maize + 35t cassava)				
Revenue			40,500,000	$2,852
Net returns			36,310,000	$2,557
Net returns to household resource			38,870,000	$2,737
Labour days			64	64
Net returns per labour day			607,344	$43

Partnerships

The same partnership model was used as with the variety activities. The private sector partner was very interested to demonstrate to maize farmers the potential incorporate cassava into their production system. As indicated above, there was little interest in the private sector partner introducing maize into a cassava mono-culture.

Changed practices

Together with the distribution of Malang 4 records were kept for 85 households in Sikka District (Maumere) and Hokeng District (East Flores). After the completion of the project 70% of farmers surveyed during the adoption survey in Sikka indicated a willing to continue buying fertilizer (subsidized fertilizer with the help from the extension officer in arrange the fertilizer plan for farmers/RDKK[6]) for their intercropping maize and cassava, while 30% of farmers are reluctant since there will be an extra cost.

Policy

The potential for a combination of introduced new industrial varieties, appropriate fertiliser, and changed cropping configuration has great potential to increase farmer incomes, provided farmers are well linked to market. One of the main challenges to this occurring is the current availability and access to appropriate NPK fertiliser, the history of subsidized fertiliser, and the need to access fertiliser through groups and formal processes. Without changes in policy there is a strong needs for collaboration between farmers-trader/industry field extension officer to plan the fertilizer requirement for the following planting season.

[6] *Rencana Definitif Kebutuhan Kelompok*

Those farmers using fertiliser in East Nusa Tenggara are using subsidized fertilizer, thus it will need cooperation between farmers group and extension officer to formulate the fertilizer plan for farmers/RDKK.

The results of the experiments and fields days have generated support from both the Sikka and East Flores Bupati (Chief regent of the district). At the final meetings there was support for upscaling of cassava farming in the region with the provision of inputs and extension. However, in the absence of a broker between government, industry, farmers and researchers this may not occur. The case study highlighted the need for strong public sector or development partners support to scale new cassava technologies in this context.

7.3 Objective 3

7.3.1 Review of national policies

A review of existing secondary information in both Vietnam and Indonesia revealed that there are numerous existing reviews of agricultural and rural development policies which are directly relevant to cassava (including Vietnam Food Security Policy Review undertaken by ACIAR in 2017 and a review of maize and agriculture related policies undertaken by project SMCN/2014/049 in 2018). 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.

Vietnam
Preliminary discussion on local government policies and priorities were conducted during the inception meetings in each site. DARD and the People's committee outlined the views and perception on cassava and priorities for the project. There are limited direct policies at the national level, besides some unenforceable targets – including the national level of cassava and minimum prices.

Indonesia
Similar to Vietnam there are few national level policies around cassava and the crop is largely impacted by policies in the substitute commodities. In Sikka there are some local policies around diet diversification. In North Sumatra there is limited government support and regulation of the cassava sector. Various policies impact the processing and logistics in both countries.

7.3.2 Facilitate stakeholder dialogues in each case-study region

Vietnam
First stakeholder dialogs were conducted at the inception meetings in Son La and Dak Lak. These meetings included participation by researchers (including those outside the project), DARD officials, MOST, Provincial Peoples Council, and cassava processing industry. By involving government and private sector actors in the value-chain training and assessments, these actors also had the opportunity to interact with groups of men and women farmers in the target districts. Farmers, government and private sector value chain actors participated in the harvest and assessment of the 2017 trials in both Son La and Dak Lak. The project also presented papers and posters at the North-West Vietnam Research Symposium in Hanoi in November 2017.

A stakeholder meeting was held in Dak Lak on 30th March 2018, with the participation of private sector and provincial government. A stakeholder meeting was held in Son La on 5th July 2018, with the participation of private sector and provincial government.

At the national scale, the arrival of CMD in Vietnam and the importance of industry and government coordination in response has brought forward the need for national level meetings in association with other projects. The project results will provide useful inputs into these discussions highlighting the importance of cassava for the poorest households in the uplands of Vietnam and how different approaches for extension utilizing the value chain need to be developed based on the location.

The results have already been used in communicating the urgent need for action at several international forums. Project team members participated in the workshop "Solutions for CMD prevention and control in Daklak" organized by the National Extension Centre in October 2018 and provided experiment results from 2017/2018.

During 2018-2019, three farmer's field-day meetings were organized with participation from crops and pest and disease sub-department of Daklak (10 staff), district extension station and 50 farmers in Dak Lak. Discussion topics included: Spacing and fertilization practices applicable for HLS11, HLS11 intercropped with four types of beans, and KM419 intercropped with four type of beans.

Further provincial meetings and discussions with stakeholders in Vietnam have been held in Son La (May 2020) and Dak Lak (July 2020).

Indonesia

Strong stakeholder relations have been formed in North Sumatra during repeated field visits. The project team travelled with the Director of Bumi Sari and one of the key cassava trading-agents. Meetings were held at Bumi Sari with the largest agents who coordinate with traders to supply the factory. The group (research +private sector) also met with BPTP to discuss the project and their priorities and capacity. Stakeholders were also invited to the harvest of multiplication trials in North Sumatra and the harvest of variety, intercrop and fertilizer trials in North Sumatra in September 2017.

Team members continued to liaise with both public and private sector actors with higher frequency as more results became available. In Sikka, there has been strong engagement with the local DINAS who managed the trials with the support from an enthusiastic private sector actor. There has also been engagement with the Nusa Tenggara Association (NTA), an NGO that may have interest in scaling innovations into the areas in works. There have also been cross-site visits of private sector actors from Sikka to North Sumatra. The project supported and presented papers at an International Workshop of root and Tuber crops in October 2017 in Malang. The project team also met with representatives of ICFORD in Bogor on June 5th, 2018 to update about project progress and to explore government priorities around cassava research.

In North Sumatra, a workshop on "Cassava development in North Sumatra based on business model" was conducted on 21-22 November 2018 at "Horison" hotel, Pematang Siantar, North Sumatra. The workshop was attended by 40 participants from government officials (District Agricultural Service), Researchers form University and Research Institute, Extension Services, Cassava trader and industries, and farmers. The workshop was aimed at collecting information from various cassava stakeholder industries for the development of cassava in North Sumatra.

The workshop was inaugurated by Prof. Wani Hadi Utomo, as the team coordinator. Presentations were made by two key speakers, namely: 1) Director of Legumes and Tuber Crops from the Ministry of Agriculture who presented a paper entitled "Cassava Development Policy in Indonesia", delivered by Dr. Yuliantoro Baliadi (Head of ILETRI), and 2) Head of the North Sumatra Province Food Crops and Horticulture Office, who presented a paper entitled "Policies on the development of Cassava in North Sumatra", delivered by Dr. Unedo Koko Nababan. This was followed by a presentation on the topic of “Farming system, processing, marketing, farmers respons, and opportunities for developing cassava in North Sumatera” by Mrs. Rully Krisdiana. Mr. YudiWidodo presented “The results of agronomic research as a basis for the initial policy of developing North Sumatra” and finally Dr. Kartika Noerwijati presented “The results of adoption of Malang 4 variety in North Sumatra”

In East Nusa Tenggara, a workshop was held on “Cassava development in East Nusa Tenggara based on business model” between the 14th and 15th of March 2019 at “Sylvia” hotel, Maumere, East Nusa Tenggara. The workshop was attended by 40 participants including government officials (District Agricultural Service), Researchers form University and Research Institutes, Extension Services, Cassava traders and industries, and farmers. The workshop was aimed at collecting information from various cassava stake holder industries for developing cassava in East Nusa Tenggara.

The workshop was inaugurated by the Bupati of Sikka District, East Nusa Tenggara Province. The head of East Nusa Tenggara BPTP (Balai Pengkajian Technology Pertanian) provided an overview of the policy and strategy of tuber crops in East Nusa Tenggara, Mr. Tomy Jare (Trader/Industry) discussed cassava trading measures in East Nusa Tenggara, Mr. Erwin (University Tribhuwana Tunggadewi, Malang) provided details on the results of agronomic trials in East Nusa Tenggara, and Dr. Suhartini (University of Brawijaya, Malang) provided some insights on the socio-economic conditions of cassava farmers in East Nusa Tenggara. The second day of the workshop a visit was made by the participants to a fertilizer experiment site and also to some farmer fields where the methods had been adopted.

The mid-term review/research symposium held in Vientiane enabled dialogues between private sector, government and research stakeholders to take place. Stakeholder dialogues with the participation of government, private sector and research actors from Indonesia, Vietnam, Laos, Cambodia and Myanmar continued during the regional research symposium held in North Sumatra in July 2019.

7.3.3 Facilitate and evaluate a learning alliance between key stakeholders

Indonesia

A National level policy dialogue was held in March 2020. This event was supported by the project in association with the Indonesia Cassava Society (ICS) and the Directorate General of Food Crop. The meeting included representatives from (1) Ministry of Agriculture (Ditjen TP, BB Biogen, Balitkabi, BKP); (2) the Ministry of Cooperatives and SMEs; (3) LIPI; (4) Regional Agricultural Service; (5) Academics (UNEJ, ITB, UB); (6) Communities; (7) Industries; and (8) Small and Medium Enterprises[7].

The outcomes include submission to the Minister of Agriculture and the President of the Republic of Indonesia to have cassava considered one of the strategic crops for Indonesia; prioritising research; development of national cassava seed system; establish demonstration; enhanced coordination between farmers and processors; addressing price fluctuations; developing standards for cassava starch and MOCAF; support domestic utilisation and promote exports; promote consumption as food; preparing for new diseases and strengthening cooperation between all relevant stakeholders.

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[7] *Agenda, participants and presentations are online at: https://research.aciar.gov.au/cassavavaluechains/indonesia-2/index.html*

The general conclusion is that the timing is very good for lifting the profile of cassava within the Indonesian Government and efforts should be made to maintain coordination in the future.

Vietnam

There have been several national level meetings and discussion during the project life supported by different organisation – largely in response to cassava disease. The project has contributed to these discussion highlighting the economic and livelihood importance of cassava based on the results of the household survey and market assessments.

A final National Policy Dialogue was planned for early 2020 subsequent to the Province level meetings. However was postponed due to COVID travel restrictions impacting the former meetings. Given the focus on cassava disease and seed systems in ongoing cassava ACIAR activities in Vietnam, it was decided to postpone and combine with the meeting planned for AGB/2018/172 later in 2020. This provided an opportunity for results of the first year of disease resistance screening to be presented.

7.3.4 Develop evidence-based policy briefs on agribusiness models for improving cassava-based livelihoods

As much of the discussion and many of the recommendations in the briefs relate to the private sector the briefs have been produced as Stakeholder Briefs, rather than Policy Briefs. The stakeholder briefs summarise issues, findings and key policy recommendations related to major topics under the project. The intended audience for the briefs is national level policymakers, Local Government and extension centres and private sector stakeholders.

Four Stakeholder briefs have been prepared for Indonesia and discussed with stakeholders. The briefs are available in both Bahasa Indonesia and in English and can be downloaded from the project website. The briefs for Indonesia are:

1. Fertilizer use in the Cassava Sector in Indonesia
2. Varieties in the Cassava Sector in Indonesia
3. Pests and Diseases in the Cassava Sector in Indonesia
4. Developing Stakeholder Linkages in the Cassava Sector in Indonesia

Four Stakeholder briefs have been prepared for Vietnam and are available in Vietnamese and English and formed the basis of stakeholder discussions in the key stakeholder workshop held in Son La in May 2020 and the subsequent Project stakeholder meeting in Dak Lak. The briefs for Vietnam are:

1. Cassava Pests and Disease Management in Dak Lak
2. Cassava Varieties in Dak Lak
3. Cassava Fertiliser in Dak Lak
4. Sustainable Cassava Development in Son La

7.3.5 Facilitate a Southeast Asian workshop on opportunities to support smallholder livelihoods and improve cassava value chains

A regional research meeting was held in Vientiane in January 2018 in conjunction with the mid-term review of AGB/2012/078 including the research team, government staff and private sector partners from each of the project sites to share project results and discuss key topics related to cassava production and value chains in South East Asia.

In July 2019 a regional research symposium was held in North Sumatra bring together research team, government staff and private sector partners from each of the project sites. The topics covered included the agronomic and economic analysis of trials and demonstrations as well as presentations on the value chain and stakeholder engagement. Several panels discussion were facilitated.

The Proceedings from the Symposium have been published by ACIAR.

The final project meeting was planned for Dak Lak in the Central Highlands of Vietnam. It was proposed to follow a similar process with industry and government partners from project sites coming together. Unfortunately this was cancelled due to COVID.

It is clearly evident from following Facebook posts that the research symposium in North Sumatra and the mid-term review and research symposium in Vientiane created strong networks and friendships between different actors in the value chain and between the 5 countries in the overall Cassava Value Chains and Livelihood Research Program(Vietnam, Indonesia, Lao PDR, Cambodia and Myanmar). It is hoped that these networks can be maintained and research and development results and ideas shared throughout southeast Asia.

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 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 has 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 AGB/2012/078) 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.

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 Vietnam and Indonesia. This was followed by training on the household survey instrument and the use of electronic tablets for the Vietnam and Indonesia 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.

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.

Table 12: Training and capacity building activities.

Date	Capacity Building Type	Location	Participants*
Aug-17	Training on Value Chain Analysis	Malang	UB Staff, ILETRI staff, private sector, Universitas Islam Malang, Universitas Pembangunan Nasional, Universitas Tribhuwana Tunggadewi: Unitri, Universitas Wisnuwardhana Malang (Unidha), Universitas Muhammadiyah Malang, UNIPA- Maumere
Sep-16	Training on Value Chain Analysis	Son La	NOMAFSI staff, staff from Mai Son and Thuan Chau Districts, private sector
Sep-16	Training on Value Chain Analysis	Dak Lak	TNU Staff, Staff from Ea Kar and Krong Bong Districts, private sector
Apr-17	Capacity Building on Household surveys and use of tablets	Son La	NOMAFSI Staff
Apr-17	Capacity Building on Household surveys and use of tablets	Dak Lak	TNU Staff
Apr-17	Capacity Building on Household surveys and use of tablets	Malang	UB Staff, ILETRI staff
June-19	Capacity Building on Plant physiology and mineral nutrition in cassava and legume intercropping systems	Hanoi	FCRI Staff, AGI staff

In 2018/2019 three Master's students and 11 Bachelor students graduated from Tay Nguyen University in Dak Lak with topics related to the cassava project. A further four Masters students and 35 bachelor students are expected to complete topics based on the cassava project by the middle of 2021.

TNU students graduating with Master of Crop Science:

1. Trần Thị Phương Lan: Reseach on density and fertilizer on KM419 on acrosol in KrongBong district, Daklak province
2. Nguyễn Thị Mai: Evaluation of potential cassava varietiesin KrongBong Daklak
3. Nguyễn Thành Đạt: Reseach on density and fertilizer on KM419 on acrisol in Easar, Eakar, Daklak

TNU students graduating with Bachelor of Crop Science:

1. Trình Công Trình: Evaluation of some potential cassava varieties in Easar, Eakar
2. Hồ Văn Thắng: Identify inorganic fertilizer for KM419 on acrisol in Easar, Eakar
3. Nguyễn Hữu Hiếu: Evaluation of some potential cassava in DangKang, KrongBong
4. Phan Thị Thanh Nhàn: Research on fertilizer and density on KM419 on acrosol in Hoa Phong commune
5. Trần Quốc Thảo: Research on fertilizer and density on KM419 on ferrasol in Hoa Phong commune
6. Phan Thị Minh Thư: Identify suitable fertilizer dose for HLS11 in Chukty commune
7. Nguyễn Bá Cường: Identify suitable fertilizer dose for HLS11 in Chukty commune
8. Đinh Thị Ngoãn: Identify suitable fertilizer dose for HLS11 in Chukty commune
9. Nguyễn Thành Đạt: Evaluation of 6 new varieties on ferrasol in Hoa Phong commune
10. Lưu Thị Hương: Research on legume intercrop with KM419 on acrisol in Chukty commune, KrongBong district
11. Lê Thị Hằng: Research on legume intercropped with KM419 on acrisol in Chukty commune, KrongBong district

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 students who will be able to contribute to cassava development across the region well into the future.

8.3 Community impacts – now and in 5 years

Trials of new technologies, combined with field days and the involvement and support of value chain actors in dissemination of technologies and information, are starting to achieve significant outcomes for the project, including increasing levels of adoption of new varieties, fertiliser types and soil conservation techniques. The expansion of this adoption, through the projects long-term private sector partners and with the support of local government, is expected to lead to positive impacts for smallholder farmers.

Vietnam:
Son La
Activity: Cowpea and peanut seeds and grass seedlings were provided to five farmers who expressed their interest in trying to intercrop in their own cassava field at the harvest field day in beginning of 2018. Seeds to cover 5,200 m2 and technical were provided to these 5 farmers.

Results: 3 farmers adopted the project intercrop technology into their own farm as follows: (i) One farmer intercropped cowpea in 500m2 and harvested 22kg seeds (equivalent to 440kg/ha) (ii) One farmer intercropped peanut in 1000m2 and harvested 50kg fresh pods (equivalent to 500kg/ha) (iii) One farmer intercropped grass strip in contour line (1000m2) and got 320kg grass (equivalent to 3.2tons/ha). Two other farmers planted grass in their home garden.

Feedback from farmers are (i) additional income generated from intercrops. Soil erosion is improved. (ii) cowpea and grass should be intercropped in the field where it is easily accessible and not far from home to save harvesting time as these intercrops is required multiple harvest.

Dak Lak
10 staff from planting department, extension center and district staff and 50 farmers attended each farmer field day to observe and evaluate the results of variety, density and fertilizer trials. A total of 150 farmers (including 87 males and 63 females) participated in the three field days. A total of 21 farmers with around 9 hectares of production in Hoa Le Commune (Krong Bong) have adopted improved variety HLS11 and 30 farmers bought HLS11 from HARC to plant around 20ha in CuMga district.

Indonesia:

East Nusa Tenggara:
In 2019, there were 86 farmers from Sikka and East Flores District who participated the project by adopting the improved technology demonstrated by the project (new varieties, improved cropping system, and fertilizer application). Project help with the seeds (cassava and maize), fertilizers, and supervision (in cooperation with the Field Extension officer). Because maize is the main food for East Nusa Tenggara people, all farmers planted cassava in between their maize crops.

North Sumatra:
In 2019, about 40 farmers (30 farmers already planted their plant, and the rest will plant in June 2019) adopted the improved technology demonstrated by the project (new varieties and improved cropping system). Project help with the seeds (cassava and maize), fertilizers, and supervision (in cooperation with the Field Extension officer). Because maize is the main food for East Nusa Tenggara people, all farmers planted cassava in between their maize crops.

8.3.1 Economic impacts

The economic impact of the project is contingent on ongoing adoption of the recommended practices and scaling by different partners. The research has clearly shown the degree of autonomous scaling without ongoing facilitation will vary considerably between the different technologies and regions.

In the following section the potential economic impacts are examined under some plausible scenarios.

Son La

There is significant potential for economic impact at the farm level from the introduction of new varieties. While the yield increased between communes a 5t/ha increase from new varieties over the existing local varieties is assumed. At average prices this would amount to around $550 USD/ha per year. The current area of cassava production in Sonla is around 34,800 ha. Assuming a 10% adoption rate this would increase farm incomes by over $1.9 million USD per annum. It would take at least 5 years to reach this level of adoption given the slow multiplication rate. Furthermore, this would assume that CMD is not introduced to the region prior to this occurring. By year 10 we assume it would be possible for 25% adoption.

The economic impacts of fertiliser also varied between trial locations based on a range of factors. An increase of $480 per ha is assumed, however the level of adoption is expected to vary between location. The household survey showed that around 74% of households were already using chemical NPK fertiliser but blends not ideal for cassava. Changing farmers practices when they are already purchasing and applying fertiliser should be easier than the case in Laos and Cambodia where farmers first had to be convinced of the change. Therefore, we assume that 25% of household may adopt the recommended practices within the first 5 years and 50% by year 10. Based on these assumptions the potential economic benefit would be around $4.18m in year 5 (25%).

The current starch factories are running at close to full capacity, therefore it is difficult to quantify the benefits to industry from increased production. Without additional starch processing capacity additional roots would most likely enter the dried chip value chain.

DakLak

Similar to the case study in Sonla there is significant potential for farm level benefits in Daklak, but due to the large excess processing capacity that operates throughout the year, the potential for industry benefits is also significant.

A $672/ha benefit was calculated the economic benefits as a result of the adoption improved varieties. The aggregate impact is complicated by the outbreaks of CMD in Daklak and the central highlands. It assumed that CMD can be contained in the regions, 10% adoption by year 5 is assumed of new varieties would amount to $2.6m USD or $6.5 at 25% per annum by year 10. These are conservative estimates given the rate of adoption of new varieties found when using DNA fingerprinting. A more formalised system of evaluation and clean seed system is going be need now that CMD has arrived to the region.

A combination of varieties and fertiliser would see farm income rise even further. In Daklak around 85% of households reported using chemical NPK fertiliser. Changing farmers current practices to those recommended after agronomic and economic analysis resulted in an increase in farm level net benefits by $674/ha. Therefore, we assume that 25% of household may adopt the recommended practices within the first 5 years and 50%

by year 10. Based on these assumptions the potential economic benefit would be around $6.5 m USD in year 5 (25%) and $13 m USD by year 10.

The additional production of roots would result in additional starch processing. Using an average processing margin of 25USD/t the adoption of new varieties and changed fertiliser management my result in 15t/ha production increase. Again, assuming a 10% adoption, this would result in an additional $382,000USD in starch processing revenue. On top of this there would be added sales of processing revenue with a value of $560,000 per annum.

Given the low likelihood of adoption of intercropping without further changes in production and marketing, no economic impact has been calculated.

North Sumatra

Consistent with the two case studies in Vietnam, the commercial case study in Indonesia demonstrated the large potential economic benefits that can accumulate when new varieties and improved management are introduced. The results varied between different location that technologies were trialled, however we again assume a 10% conservative adoption of Malang4 and improved fertiliser in the main areas servicing Bumi Sari (Simalungun and Toba Samosir) this aggregates to $1.4million USD per annum and additional starch processing revenue of $415,000 USD. Once again the relativity of the benefits between farmer and the processor highlight the justification for government intervention.

East Nusa Tenggara

The aggregate potential economic benefits in the site in Flores are limited based on the current scale of the intervention. There are significant economic benefits at the farm level, but without further support and policy reform these are unlikely to translate into large aggregate benefits.

The current private sector partner may be able to scale activities to around 200ha. However, given the large benefits per hectare this would still aggregates to over $580,000 USD per year. Therefore, changes in policy to make inputs more available, linking local processors to farmers, and processors to next product markets could have significant impact on the economic development of rural communities.

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

There were no significant positive or negative environment impacts of the project by the end of the project. Addressing the issues around soil erosion and land degradation remains an important challenge for the sector. The project results highlight to important issues in relation to this:

1. The existing technologies promoted to address the environmental impacts of cassava production (erosion and soil degradation) are not likely to be adopted by farmers, even if they are made aware of them through direct involvement in training whether provided by public or private sector actors.

2. Despite the impact of declining yields on value chain actors, it is unlikely given the nature of the technologies and the value chain composition that these actors will invest considerable time and resources into promoting practices to address sustainability.

Farmers involved in the project are aware that contour grass strips have positive impacts on soil conservation, but adoption remain extremely limited due to the additional labour requirements. Guinea grass is highly appreciated by farmers with livestock, however they prefer to establish forage plots nearby the house for easier cut-and-carry to feed animals. Similarly, intercropping with legume was of little interest to farmers as the system consumed additional labour and made other tasks such as weeding more difficult.

The above was a working hypothesis at the beginning of the project. Yet there remain new initiatives throughout the region to promote such systems despite the challenges for both farmer adoption and incentive for scaling. Therefore, it is hoped that these finding contribute to the call for urgent research to address land degradation in different contexts through the development of new production systems and support models for sustainable and equitable transitions toward these new systems.

8.4 Communication and dissemination activities

The project website www.cassavavaluechains.net contained key project information and serves as a clearing house for project publications, including discussion papers, conference presentations, working papers and other publications as they become available. This site has been successfully archived on the ACIAR webpage at: https://research.aciar.gov.au/cassavavaluechains/

The Facebook group “ACIAR Cassava Value Chain and Livelihoods Program” now has more than 1,173 members. The group remains active with around 760 members being active in 2021. Members include key national policy makers, national level researchers, Provincial and District staff, private sector actors (processors and traders), and farmers. At the moment, much of 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/

The CRP RTB continues to give visibility to the project activities. In CRP II the project is mapped to Flagship 5 – “Improved Livelihoods at Scale” – but some results are reported into other flagships.

The project has generated 1 book, 1 Symposium proceedings monograph, 3 journal articles, 11 discussion papers, 46 conference presentations, 5 posters and numerous training materials. These are able to be accessed at https://research.aciar.gov.au/cassavavaluechains/ and are listed in Section 10 of this report.

Key project findings have been discussed with stakeholders at national forums, the regional workshop held in January 2018, the Regional Symposium in July 2019 and in conjunction with the final review of the project in July 2020. Project findings have also been developed into a series of stakeholder briefs which have been used as the basis for dialog with government and private sector partners.

9 Conclusions and recommendations

9.1 Conclusions

The global market demand for cassava-based products continues to expand as new applications and starch-based products are developed and cassava chips continue to be an important raw material in animal feed and ethanol production. Given the wide variety of applications of cassava-based products and the range in export destinations, the market outlook for cassava produced by smallholder farmers in Southeast Asia needs to be considered in the context of market and policy development in a range of commodities that can be substituted in different applications in which cassava is used; and geographies that both produce and consume these products. During the life of the project the strong connection between the markets of cassava starch market of Indonesia and mainland southeast Asia was demonstrated. More importantly, the strong influence of shocks in Chinese demand on farm gate prices throughout both Vietnam and Indonesia became extremely apparent.

Despite the long-term growing demand, cassava in both Vietnam and Indonesia continues to be a relative neglected crop relative to the contribution to rural livelihoods – either via food security or household income. Both government and private sector investment in research and development remain at low levels relative to crops such as rice and maize. As a result, there are several challenges facing sustainability of both the production systems and the industry with differential adoption of existing technologies. The current pest and disease situation adds to the concern regarding the limitations in the scaling of technologies.

The aim of this project was to increase the profitability and sustainability of smallholder cassava production in Vietnam and Indonesia by developing effective linkages between value-chain actors to increase the adoption of improved technologies. The degree of private-sector interest and involvement in the project's research agenda in each of the project locations varied with the characteristics of the technology, of the farming population, and of the value chain.

The research found that particular contexts, private-sector value-chain actors had incentives to invest in the extension of research outputs to smallholder farmers, even without formal financing and contracting, but generally not without initiation and support from public-sector actors or other knowledge brokers. In other contexts, however, there is little incentive for private-sector involvement, and public-sector or non-government actors will need to take more responsibility for supporting smallholders with their technology needs. Thus, the private sector cannot be seen as a panacea for generating research impacts at scale.

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 financial incentive to get involved.

In all sites, the project was able to identify 'champion' within the value chain that had an interest in experimenting with technologies to improve cassava production. This was nearly always related to testing new varieties within their own or company land. The research did not find a case where the private sector had spontaneously become involved in widespread or systematic research-based technology dissemination, particularly through participatory methods and field days. Furthermore, the ongoing engagements of ‘champions’ was often based on personal interest and individual personality characteristics rather than based on institutional requirement or priority. This meant that they were often not in a position to institutionalise or scale the partnerships without some form of ongoing external facilitation.

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, 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. There was evidence that traders and factory staff understood that different approaches and models were need to engage with different farmers based on ethnicity to secure feedstock, this understanding hadn’t translated into active measures to lift productivity and had the potential to be exploitative.

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. Furthermore, there are parts of the pipeline for disease-free planting material is likely to be uneconomic to be conducted by private sector partners (eg. Tissue culture and production of mother plants). Having said that, industry is likely to benefit greatly from farmers adoption (or minimise losses) and could contribute to the sustainability of upstream activities.

These requirements for partnering with the private sector are summarised in Box 2. 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.

Box 2: 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 fertilizer 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

1. **Strengthen public-private partnerships in support of R&D**

The results showed that the incentive for individual companies to engage in the extension of technologies to smallholders was highly variable depending on several factors related to the characteristics of the technology, the value chain structure, and the production systems (and livelihoods) of target farmers.. Nevertheless, individual value chain actors continue to benefit from the limited public and non-government investments in the sector. Funding models to formalise public and private contributions to R&D need continuing facilitation and support. This is critical in areas with high levels of externalities and non-exclusivity over benefits generated. Communicating the potential benefits (or avoid losses) across the value chain of increasing investment in the sector is essential.

The current disease situation in Vietnam may provide a unique opportunity for the industry to see the potential losses that no action will cause. Developing public-private partnerships is a key feature of the new project AGB2018/172. A system of R&D levies could support both the extension of technologies within specific supply zones and contribute to national level research. It is important that such as system does not distort the flow of roots to the highest value market segment (eg. Domestic v export; starch vs dry chips).

The situation in Indonesia is much more complicated with several market segments and large on-farm consumption and utilisation. For the large-scale commercial starch market segment there is potential for similar engagement however would create some issues with small-scale processors who compete for roots within the same supply zone.

2. **Promote Engagement with Ministry of Agriculture and Ministry of Commerce and other line agencies**

The project initiated and facilitated stakeholder consultation and dialogues at the Regency scale in Indonesia and Province scale in Vietnam. Large national consultation meetings planned for 2020 were interrupted by COVID-19 but were held in Indonesia.

The importance of the cassava sector for livelihoods and economic development remains hidden from policy makers. In Vietnam, the high export value does give the sector some prominence, however the contribution to income generation and poverty reduction remains less visible at the national scale. Cassava does still carry some stigma of being a ‘poor-mans’ crop grown on sloping hills resulting in land degradation

Cassava still remains a secondary crop in terms of national priorities in both countries, often due to poor access information about its contribution to food security, rural livelihoods, economic development and national trade balance. Lifting the profile of cassava is essential for supporting the industry development and sustainability.

3. **Engage in policy dialogues on fertiliser subsidies and availability**

The awareness, knowledge and current use of fertiliser in cassava production system in both Indonesia and Vietnam is resulting in sub-optimal outcomes and inefficiencies. The availability of fertiliser most suitable for cassava production (either as Urea, TSP and KCL or suitable blends) varies between sites. In Indonesia the existing fertiliser subsidy system are distorting what fertiliser farmers apply to their crop. Engagement around policies impacting the availability and use of fertiliser should continue at the same time as engagement with the fertiliser value chain; cassava value chain and extension providers.

For further information:
Fertiliser Stakeholder Brief - Indonesia
Fertiliser stakeholder brief – Dak Lak
General stakeholder brief - Son La

4. Invest in data gathering and reporting

Invest in more accurate and real-time reporting of crop production data to allow stakeholders to make strategic decisions. Understanding the short-term supply within specific supply chain would help value chain actors make decision. The current area of production would also assist governments in planning and approving new investments in processing. This would include using remote sensing data to understand cropped area of cassava and other crops. A regional investment would also enable actors to evaluate overall supply and how it may impact prices.

At the same time, ongoing efforts to understand changes in demand should be develop at the national scale. The interpretation of supply and demand with some forecast of impact on prices should be communicated to value chain actors and farmers.

Within the harvest seasons, collation and reporting of spot prices at different locations would also aid farmers in making decisions around harvest and marketing. The same platform could incorporated into information regarding the geographic availability and price of new varieties or disease-free cassava stems.

5. Strengthen and Modernise Cassava Breeding Programs

During the project life new diseases (CMD) became a serious issue within Vietnam. ACIAR has already responded to this problem through the investment in the project “Sustainable Solutions to Cassava Disease in Mainland Southeast Asia”. This project includes capacity building in cassava breeding in Vietnam.

The project in Vietnam and Indonesia highlighted the strong connection between the industrial sectors of mainland southeast Asia and Indonesia. It also highlighted how quickly pest and disease can spread from the industrial sector into the food sector in the outer islands (eg. Cassava mealybug in Flores). This highlights the urgent need to introduce sources of resistance to CMD into Indonesia for introgression into breeding pipelines for both the starch sector (bitter high starch content varieties) and direct food sector (sweet varieties).

6. Develop national cassava seed systems

During the project access to adequate volumes of planting material was a constraint to the speed at which activities could be scaled. This was particularly the case in Indonesia with high costs associated with transferring stems to different parts of the archipelago.

The challenges of multiplication and dispersal of new varieties to farmers also now need to confront the arising disease situation in the region.

- Investment in in-vitro facilitates and capacity to receive germplasm
- Training in in-vitro at regional universities
- Introduction of rapid multiplication centers in key provinces in partnership with private sector

7. Invest in research on sustainable cassava systems meeting farmer needs

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.

Technologies for soil conservation were also characterised by low learnability and (individual) relative advantage; hence there was little or no interest in these technologies, even for the steeply sloping land of Northwest Vietnam where they are most relevant. This is a major concern for the sustainability of the production system and contributes to the poor image and underfunding of research and development.

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11 Appendix 1: Key Agronomic Activities and Results

11.1 Conduct training in improved cassava practices, demonstration trials, and participatory research methods

Vietnam:

TNU, Ea Kar and Krong Bong agriculture and Rural Development Offices and district extension stations provided training on improved cassava cultivation practices to 200 farmers in 4 communes in Ea Kar and Krong Bong districts in March, 2017. The training was carried out in conjunction with the Ea Kar cassava starch processing factory and Dang Kang (Krong Bong) starch processing factory. At the request of M'Drak district, the same training course was provided to 200 farmers in M'Drak district with the training cost covered by the district's budget in April, 2017. The training was carried out in conjunction with the Khanh Duong starch factory in M'Drak district.

In Dak Lak, TNU provided advice and training on cassava management practices and technology for extension staff of five factories in Ea kar, Krong Bong, Cu M’gar districts in 2019. Additionally three farmer field-day meetings were organized with participation from crops, pest and disease sub-department of Dak Lak (10 staff), district extension station, and a total of 50 farmers. Discussion topics included: Spacing and fertilization practices applicable for HLS11, HLS11 intercropped with 4 types of beans, and KM419 intercropped with 4 type of beans. A total of 30 farmers in Cu’Mgar district have bought HLS11 from HLRC for the season 2018/2019 occupying a total of 20 hectares in Cu’Mgar district (non-project site).

A program for training farmers and local extension officers was also developed in Son La with collaboration from Son La DARD. The first training session in cassava agrobiology and planting techniques were attended by 73 farmers and commune extension officials. In April 2019 NOMAFSI and Son La Dard were also involved in hosting training sessions on weeding and pest control techniques for farmers and commune extension officials in April and June of 2019 respectively (Further details on the training programs including power point slides from the first training session can be found in http://cassavavaluechains.net/vietnamese/).

Indonesia:

In Indonesia, UB and ILETRI staff provided practical training to government and private sector partners including DINAS staff, local university staff, cassava trading agents and traders responsible for managing trials. Demonstration trials were established in Sikka (Flores) and Siantar (North Sumatra) with support from local cassava value-chain stakeholders. In June 2017, a two-day workshop was held to develop training material for farmers. Topics covered cassava varieties, planting materials preparation, agronomic aspect of cassava growing (include cropping system), soil management (tillage requirement, fertilization and soil conservation), pest and diseases management and simple technology for cassava processing.

Additional training by ILETRI-UB was provided during the harvest field days in Maumere and North Sumatra in late 2017. This covered topics on cassava agronomy and nutrient management, new varieties, pest and disease management, and small-scale processing. The training participants included farmers, traders, agents and factory staff. The partner institutions also drew on additional staff not directly involved in the project. The training was also attended by local government officials and attracted coverage in local media.

A training on 'making silage from cassava leaves' was conducted on 15 March 2019. The motivation for the training was the scarcity of animal feed faced by farmers during the dry seasion (kemarau) in East Nusa Tenggara. On the other hand during the wet season there is excessive amounts of animal feed available (including cassava leaves). Hence preserving the excess feed material for the dry season would help alleviate the problem related to limited feed supply for East Nusa Tenggara farmers. A total of 20 farmers from Tebuk village, Maumere and about 15 students from the Faculty of Agriculture, University of Nusa Nipa (UNIPA) Maumere participated in the training session which was delivered by Dr. Marjuki. In North Sumatra a similar training on silage making from cassava leaves was also conducted on the 15th of March 2019 where a total of twenty five participated in the training session which was delivered by Prof. Titiek Islami.

11.2 Activity: Conduct participatory variety selection with farmers with varying levels of outside support from research institutions.

Improved technology (i.e. sowing method, timely weeding and fertiliser application) and high yielding varieties were disseminated among farmers in different provinces of Vietnam and Indonesia. The aim was to expand the use of new technologies among growers with varying levels of support from private institutions. An overview of the experimental trials carried out during the length of the project listed below. Details of trial protocols and results can be found in each of the separate annual reports.

Vietnam

The focused project districts were Thuan Chau (communes Bó Muoi and Pung Tra) and Mai Son (communes Chieng Chan and Na Ot) of Son La and KrongBong and Eakar of Dak Lak province. Experiments, trials and demonstrations were carried out in these communes unless stated otherwise. First batch of experiments and/or trials were established during 2017-18 cropping season and followed till end of the project (i.e. 2019-20 season). In most cases, replicated plot trials were carried out at the start of the project then followed on to big plot demonstrations. Throughout the project different stakeholders were consulted and/or involved in establishing the trails and disseminating results.

Germplasm evaluation: A total of 13 varieties were evaluated in Vietnam in two provinces. Variety Rayong9 and KM94 was common in all evaluation trails. During 2017-2018 season, Sa21-12, BK, 13sa05 and La Tre (Local variety) were

evaluated in Son La. The trial was conducted in 5 replicates with NPK at 60N-15P-60K kg ha^{-1}.
In Dak Lak, HLS10, HLS11, KM 419, KM140, KM505 were evaluated in two different types of soils (i.e. Acrisol and Ferrasol) and with two types of practices (i.e. Framers' practice and MARD recommended practice). For Farmers' practice, 100kg phosphorous fertilizer and 250kg NPK (15-5-20) ha^{-1} and for MARD recommended 90 kg N - 60 Kg P_2O_5 - 90 kg K_2O + 1 t ha^{-1} bio fertilizer was applied in three replicates.
Following up on the result of 2017-2018 season, same varsities were evaluated in big blocks (150 m^2) on Farmers' field in same communes in Son La in 2018-19 and in 2019-20 season.
As cassava mosaic disease (CMD) spreading in the region since 2017, during 2019-20 season, at Eatu commune, Buon Ma Thuot City of Dak Lak province, an experiment was carried out to evaluate 21 new CIAT clones (i.e. elite lines) compared with popular varieties KM419 and KM94. The experiment was harvested after 10 months at the end of 2019. The experiment was established, managed and monitored by TNU and in collaboration with Centre for Crops Seeds and Animal Breeds.

During 2019-20 season three varieties, HLS11, HlS12 and HLS14, were evaluated to find out tolerance to CMD and Cassava Witches Broom disease (CWBD) at IaRve commune, Easup District, Daklak; where ~10% of planting area was CMD infected by 1st week of February 2020. There were two treatments, farmers' practices (planting density 0.6 m x 0.6 m and fertilizer 250 kg NPK 15:5:20 ha^{-1}) and recommended practice (planting density 0.8 m x 0.8 m and fertilizer 90 kg N ha^{-1} 60 kg P_2O_5 ha^{-1}, 90 kg K_2O ha^{-1} and 1 t bio fertilizer ha^{-1}). Experiment was conducted in big plots 2000 m^2.

Effect of fertiliser application: In Son La, four treatments were evaluated compared with no fertilizer application during 2017-18 and in 2018-19 season. P_0-No fertilizer; P_1-300 kg ha^{-1} NPK (5:10:3); P_2, 600 kg ha^{-1} NPK (5:10:3); P_3, 40N -10P-40K + 80 kg K_2O; P_4, fertilizer deep placement, 40N-10P-40K + 80 kg K_2O. After evaluating the results, during 2019-20 season following fertiliser rates were compared- T_0 no fertilizer, T_1 NPK (5-10-3) 300 kg ha^{-1} basal application, T_2 NPK (12:5:10) 300 kg ha^{-1} basal application, T_3: 40N-10P-40K (i.e. 87 kg Urea, 142 kg Superphosphate, 80 kg KCl), T_4: 60N-15P-60K (i.e. 130 kg Urea 213 kg Superphosphate, 120 kg KCl, Lam Thao factory, Phu Tho province, Vietnam). T_1 and T_2 was applied at planting and for T_3 and T_4 all Phosphorous was applied at planting with 1/3rd of N and K, rest of N and K was top dressed in two application 45 and 75 days after planting.

Soil management: In Son La different intercrops and soil management techniques were evaluated and compared with sole cassava cropping. In the experiment cassava variety KM94 was intercropped with peanut (*Arachis hypogaea*), cowpeas (*Vigna unguiculata*), mung bean (*Vigna ratiata*), grass Ghinea (*Panicum.maximum*) strips and contour lines of cassava stake residue compared with sole cassava during 2017-18 and 2018-19 season.
In Dak Lak soil management experiment was first established during 2018-19 season. HLS11 and KM419 were evaluated to find benefit of intercropping with four different legumes, mung bean (*Vigna ratiata*), red bean (*Vigna angularis*), cow pea (*Vigna unguiculata*) and pea nuts (*Arachis hypogaea*) and compared with sole cropping. Evaluating previous season results, peanuts was intercropped with

cassava variety HLS11 and compared with sole cropped cassava on big plots ($2000\ m^2$) without any replicates. Cassava was fertilised with 90 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, 90 kg K_2O ha^{-1} and 1 t bio fertilizer ha^{-1} and applied at each plant. Cassava was planted in two different densities 1.0 m x 1.0 m (10,000 plant ha^{-1}) and 1.0 m x 0.8 m (12,500 plant ha^{-1}). However, sole crop cassava was planted at density 0.8m x 0.8m (15,625 plants ha^{-1}). For peanuts there were two treatments, fertilized (400 kg lime powder ($CaCO_3$) ha^{-1}, 75kg Urea ha^{-1}, 150kg Super phosphorous ha^{-1}, 100kg KCL ha^{-1} and 1 t bio fertilizer ha^{-1}) and unfertilized to quantify yield benefit of the intercropping and fertilizer.

Density and fertilizer: During 2017-18 season variety KM94 and during 2018-19 season Variety HLS11 was evaluated in experiments in different combinations of fertilizers (N, P and K) and planting densities. Five fertilizer treatments (P_0, No fertilizer; P_1, 90N-60P_2O_5-90K_2O; P_2, 99N-66P_2O_5-99K_2O; P_3, 108N-72P_2O_5-108K_2O; P_4, 117N-78P_2O_5-117K_2O) were compared with Farmers' practice (P_5,100kg Phosphorous fertilizer + 250kg NPK (15-5-20) kg ha^{-1}). The trails were conducted in two different soil types (i.e. Ferrasol and Acrisol), with three different planting densities, 15,625, 12,500 and 10,000 Plants ha^{-1} in two different soil types in Dak Lak.

During 2018-19 season, four planting densities were evaluated with variety KM94 order to find the most appropriate (i.e. fertile soils and low-investment-capacity farmers). The treatments were as follows: M_1 (0.8m X 0.6m, 20,800 plant ha^{-1}), M_2 (0.8m X 0.8m, 15,600 plant ha^{-1}), M_3 (0.8m X 1.0m, 12,500 plant ha^{-1}), M_4 (1.0m X 1.0m, 10,000 plant ha^{-1}) in Son La. Following year same experiment was conducted in large plots (i.e.160 m^2).

Extending the cassava harvest window: Two popular varieties, KM94 and La Tre, were evaluated for fresh root yield and starch content during harvests in off season (i.e. from May to September) to ensure availability of cassava roots during off season. 60N-15P-60K fertilizer was used as describes above for fertilizer trial. A total of 10 harvest were done over a period of 20 months. First harvest was after 10 months of growth (i.e. normal practiced harvest) was in December 2018, following that 9 more harvests was carried out during 2019, January, March, April, May, June, July, August, September and December. This trial was designed based on the feedbacks from Son La starch factory to operate until September instead of April as currently.

Indonesia

The focused project districts were Sikka Regency of East Nusa Tenggara province and Siantar and Simalungun districts of North Sumatra. Experiments, trials and demonstrations were carried out in these provinces unless stated otherwise. First batch of experiments and/or trials were established during end of 2016 cropping season. Monitoring of different variety demonstration and evaluation of farmer participation in the different production and value-chain settings were completed during 2018-2019 and the final set of on-farm trials was carried out during 2019-2020.

Germplasm evaluation: At the start of the project during 2016 season, in Sikka regency, 8 varieties (four sweet varieties- local Sika Putih and Sika Kuning; and

introduced Mentefa and Tambah, four bitter introduced varieties- Faroka, UB ½, UB4772, Gajah) were evaluated. During 2017 season, two more bitter introduced varieties, Malang6 and Aldira were also included. The varieties imported to the region was also evaluated in farmers' fields. In the experiment, 300 kg Urea (46% N); 150 kg SP_{36} (36% P_2O_5); 100 kg KCl (50% K_2O) ha^{-1} fertiliser was used. Considering the performance of the imported varieties, in other locations-e.g. Hokeng, Larantuka district, demonstration was organized in 2018 season.
In North Sumatra, during 2016 season 12 varieties, UB½, UB4472, Adira1, Malang4, Cecek Ijo, Faroka, Gajab, Ketan, Kaspro, Malaysia, Adira4, Cikaret were evaluated.

Effect of fertiliser application: During 2018 season, in East Nusa Tenggara fertilizer trial were conducted to determine the optimum rate of Nitrogen and Potassium. The experimental treatments were-Nitrogen rate (N0: 0 kg N; N1: 45 kg N ha^{-1}; N2: 90 kg N ha^{-1}; N3: 180 kg N ha^{-1}) and -Potassium rate (K0: 0 kg K_2O; K1: 25 kg ha^{-1} K_2O; K1: 50 kg K_20 ha^{-1}; N3: 100 kg K_20 ha^{-1}). The treatment combinations were: N0K0, N1K0, N2K0, N3K0, N1K0, N1K1, N1K2, N1K3, N2K0, N2K1, N2K2, N2K3, N3K0, N3K1, N3K2, N3K3. The experiment was arranged in randomized block design with three replications. All treatments were applied with 100 kg ha^{-1} Super Phosphate 36 (36% P_2O_5).

In North Sumatra fertilizer trials were carried out in Siantar at an experimental field belonging to PT. Bumi Sari Prima. Strip plot design with three replications was used. The treatment structure of this fertilizer application trial was 7 different fertiliser treatments (Farmers' practice-200 kg Phonska ha^{-1}, Phonska 200 kg + 125 kg Urea + 125 kg KCl ha^{-1}, Phonska 200 kg + 5 t manure ha^{-1}, Manure 10 t ha^{-1}, Phonska 200 kg + 25 kg Urea + 50 kg KCl ha^{-1}, Applied 100 kg Urea + 100 kg SP-36 ha^{-1}, 200 kg Urea + 100 kg SP-36 ha^{-1}) with two cassava varieties (Malang4 and Malaysia) during 2017 season (Annual report 2017). After reviewing the results, following season (i.e. 2018) five different fertiliser combinations, 300 kg Phonska ha^{-1}, Phonska 300 kg + 100 kg Urea ha^{-1}, Phonska 300 kg + 100 kg KCl ha^{-1}, Phonska 400 kg ha^{-1}, Animaldunk 10 t ha^{-1}. In this on-farm experiments evaluating the results of germplasm evaluation, following varieties (Malang4, Dacon (i.e. sister line of Rayong72) Huaybong60 and Faroka were evaluated at 5 sites [i.e. Sinasak, Tapian Dolok (Mr. Muchlis's land), Tanjung Tonga, Siantar (Turisno's land), and Siantar (Factory land)-2 experiments, Sipasung (Factory Land)].

Diversifying cropping systems: The intercropping other crops with cassava was experimented as cassava price was dropping. There was an interest in these experiments from the starch industry as to ensure farmers continue to grow cassava rather than shifting into other crops due to movement of cassava price. Intercrop trials in Sikka was carried out during 2017, 2018 and 2019 seasons. First season there was six intercrop treatments (cassava plus maize (local system), cassava plus maize (introduced system), cassava plus peanut, cassava plus mungbean, cassava plus soybean) in 4 replicates (Annual Report 2018). Following seasons, the technology was demonstrated among the farmers.
In North Sumatra, intercropping experiment was with two types of cassava, grafted (i.e. root of Faroka and stem from *Manihot glasiovii*) and normal, with peanuts and peanuts followed by mungbeans during 2017. Following year (i.e. 2018), cassava monocrop was compared with intercropping with maize, with upland rice, with

legumes (i.e. soybean, peanuts and cow pea). After reviewing the results of 2017 experiments in Sikka regency and North Sumatra, 2019 season intercropping cassava with maize and upland rice was demonstrated.

Reducing HCN content of Malang4: Experiment was conducted for reducing HCN content of Malang6 cassava variety. In the previous experiment Malang4 variety yielded more than 50 t ha^{-1}. This is significantly higher than other introduced or local varieties grown by East Nusa Tenggara farmers. However, with its high HCN content, this variety is not suitable for human consumption. Lab tests were conducted by 20 students from East Nusa Tenggara to reduce HCN content in this variety using NaCl and $NaHCO_3$.

11.3 Identify opportunities for on-farm improvement and commercial production of clean planting material

Initial demand, incentives and potential entry points were evaluated as part of value chain analysis. Farmers and value chain actors actively participated in harvest field days in Sikka, North Sumatra, Dak Lak and Son La and discussed relative merits of trialled improved varieties.

In Dak Lak in 2018-2019, efforts were made towards the establishment of a clean planting production and distribution model with a farmer-businessman, but this did not succeed as the farmer was too busy with other activities and could not see immediate benefits from clean planting material production and distribution.

In North Sumatra considerable achievements have been made in the dispersal of the variety Malang4 through the value chain. Malang4 is an open pollinated variety formally released by ILETRI in 2001. It is one of the varieties grown in East Java, but new to North Sumatra. In 2015-16 the variety was selected by farmers and traders at the first participatory evaluation conducted by the project with Bumi Sari. In 2016-17 25 farmer/traders received planting material and trialling the variety in other areas in the supply zone. In 2018-19 more farmers (around 60) will have received Malang4 from the trader/farmers with the main agents providing a key player in moving material through the value chain. The project purchased stems for 500IDR/stem (5-8 stakes/stem) that were provided free of charge to the next round of farmers. Shipment of stems from Java to North Sumatra is relatively expensive. It is recommended that the rapid multiplication technology being developed in AGB/2018/172 be transferred to North Sumatra for primary multiplication with Bumi Sari and the main agents.

In the absence of disease pressure, and low frequency of new varieties being released the industry led seed system may prove to be a one-off mechanism to achieve rapid dispersal. However, if the production area continues to contract and expand based on relative prices there may be some opportunities for the system to be maintained. With Bumi Sari continuing to support the primary evaluation of new technologies there should be opportunities for CIAT to work with ILETRI-UB to evaluate new clones and begin planning for emergency responses if/when disease presents itself. The reported presence of ‘Huay Bong’ varieties in North Sumatra indicates that the private sector has recently transferred material from Thailand to Sumatra. This is a very high risk activity, and every effort should be develop a domestic seed system from in-vitro movement between countries and rapid multiplication in core cassava regions.

In NTT, the project has tested both sweet and bitter varieties in some core locations. After the field day in 2017 the 25 farmers received 'new' varieties for evaluation on their own land. Due to the limited quantity of planting material produced by the initial trial, additional stems were sent from East Java to facilitate high numbers of farmer involvement (6000 stems including Gajah, Malang 4, Faroka, and Tambak Udang). The project team has also developed a relationship with the Agricultural High School at Hogeng, Larantuka District. The project is conducting a variety trial at Hogeng with students and staff from the school involved. Small-scale industry managers have also been involved in this activity.

The importance of clean planting material and rapid multiplication and dispersal is likely to become an increasingly high priority in Dak Lak. CMD has not formally been announced in the central Highlands, but seed system studies have shown that planting material has been purchased from Tay Ninh, the main hotspot of the disease in Vietnam. Furthermore, the Central Highland borders the areas of infection in Cambodia. New clones from CIAT have been sent to two locations in the Central Highlands. The first is managed by TNU and the second has been funded and managed by one of the ethanol producers. The importance of industry coordination around surveillance and clean seed systems appears to be an important entry point for activities under objective 3.

11.4 Investigate opportunities to communicate information on pest and disease management to farmers through value-chain actors

Initial demand, incentives and potential entry points evaluated as part of value chain analysis. Farmers, value chain actors and government staff actively participated in harvest field days in Sikka, North Sumatra, Dak Lak and Son La and discussed pest and disease control methods.

Addressing pests is likely to become an important part of activities in Sikka given that cassava mealybug was observed during the value-chain assessments and focus groups. Researchers working on a national mealybug monitoring effort visited the site and the project team communicated their findings with them. Extension information exists on this topic in Bahasa Indonesia which was previously developed by CIAT.

Cassava witches broom disease (CWBD) is currently present in Dak Lak with cassava mosaic disease (CMD) having a high likelihood of arriving in the near future. Extension material for witches broom is currently available in Vietnamese with some previous efforts made to show videos at the processing factory under the CIAT IFAD Emerging Pests and Diseases of Cassava Project. Given that the household survey showed around 50% of farmers selling through traders rather than directly to the factories, additional approaches need to be developed to ensure the message scales through the value chain. A farmer-to-farmer DVD is being considered to be developed for CWBD that will be translated into all the major languages with incentives for industry to provide them to farmers Activities under this objective are closely linked to the seed system objective above.

11.5 Evaluate opportunities for value-chain actors to promote adoption of appropriate fertiliser regimes

Initial demand, incentives and potential entry points were evaluated as part of value chain analysis. Farmers and value chain actors actively participated in harvest field days in Sikka, North Sumatra, Dak Lak and Son La and discussed relative merits of improved soil fertility management.
Cassava grown as part of the trial on fertilizers was harvested in January and February of 2019. Fertilizer trials tested five fertilizer treatments in order to identify optimal types and rates of fertilizer application to achieve high fresh root yields and starch content as well as high economic returns. Soil management trials with the aim of identifying intercrops varieties and soil management techniques that were able to deliver improved economic returns and soil erosion control were also conducted.

During the field days farmers expressed interested in applying separate N, P and K fertilizers and thus support was provided to some farmers for employing this fertilization application method.

In addition, trials were also conducted on planting density and harvest times. These two trials were planned based upon the opinion of farmers and cassava companies during the 2017 field days. Both cassava farmers and cassava companies expressed a preference for longer cassava harvest periods which would allow farmers to more easily sell cassava roots while also permitting cassava processors to operate for extended periods during the year. The trials on planting density were conducted to identify suitable planting density for farmers to apply in Son La (normally farmers plant cassava at 0.6m x 0.6m while the recommended area is 1.0 m x 1.0 m).

In Dak Lak three farmer field-day meetings were organized with participation from crops and pest and disease sub-department of Dak Lak (included about 10 staff members), district extension station staff and 50 farmers. Discussion topics included: Spacing and fertilization practices applicable to HLS11 variety, HLS11 variety intercropped with four types of beans, and KM419 intercropped with four types of beans.

12 Appendix 2: Key Agronomic Result Tables

12.1 Dak Lak

Table 12.1: Average fresh root yield (t/ha) of different varieties in two different practices (i.e. Farmers' and MARD recommended) in Dak Lak (2017-18)

	Farmers		MARD	
Varieties	**Acrisol**	**Ferrasol**	**Acrisol**	**Ferrasol**
HLS10	25.96	41.33	33.20	42.07
HLS11	22.93	42.85	32.26	45.13
KM140	26.71	33.91	29.19	36.53
KM419	26.52	40.50	32.72	45.03
KM505	23.30	33.27	26.14	38.30
KM94	30.19	31.72	26.87	34.37
RAYONG9	20.46	33.46	24.57	36.43
Varieties		P<.001		
Practice		P<.001		
Soil type		P<.001		
Varieties x Practice		P=0.006		
Varieties x Soil type		P<.001		
Practice x Soil type		P= 0.360		
Varieties x Practice x Soil type P= 0.050				

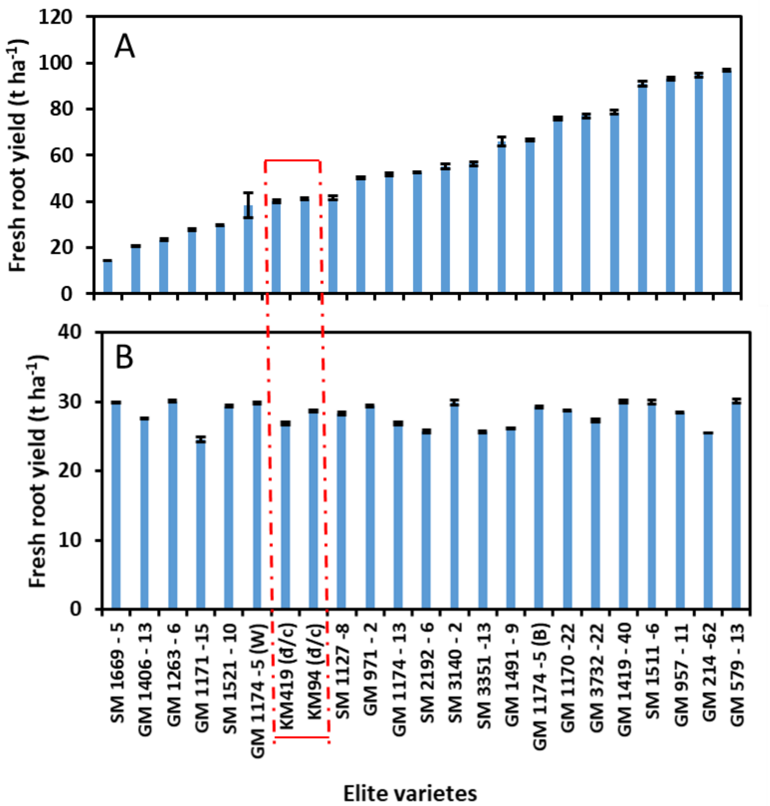

Fig 12.1 Fresh root yield (A) and Starch content of 21 elite lines compared with two popular varieties (in between red dotted lines) after 8 months of growth. Planting density was 1.0 m X 0.8 m (i.e. 12,500 plants ha-1) and 90 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 90 kg K_2O ha^{-1} was applied as fertilizer. Values are means of three replicates with standard error bars. *w=white colour, B=brown colour roots.

Table 12.2 : Average fresh root yield (t/ha) at 5 different fertilizer rates (P0, No fertilizer; P1, 90N-60P2O5-90K2O; P2, 99N-66P2O5-99K2O; P3,108N-72P2O5-108K2O; P4, 117N-78P2O5-117K2O) were compared with Farmers' practice (P4,100kg Phospherous fertilizer + 250kg NPK (15-5-20) kg ha-1). The trials were conducted in two different soil types (i.e. Ferrasol and Acrisol), with three different planting density, high, 15625, medium, 12500 and optimum, 10000 Plants ha^{-1} in two different soil types in Dak Lak (2017-18)

Density/		High		Medium		Optimum	
Fertilizer	Soil_type	Acrisol	Ferrasol	Acrisol	Ferrasol	Acrisol	Ferrasol
P0		19.15	24.29	19.67	32.87	18.31	23.77
P1		28.66	39.40	32.52	44.58	30.96	40.87
P2		30.84	40.30	30.27	44.08	27.55	41.63
P3		37.14	42.64	33.81	44.31	33.93	44.00
P4		35.75	44.04	33.49	45.21	33.17	45.37
P5		24.89	31.30	22.56	37.37	19.56	22.57

Fertiliser P<.001, L.S.D.= 4.244
Density P= 0.213, L.S.D.= 3.001
Soil type P<.001, L.S.D.= 2.599
Fertilizer x Density P= 0.903, L.S.D.= 7.351
Fertilizer x Soil_type P= 0.897, L.S.D.= 5.198
Fertilizer x Density x Soil_type P= 0.271, L.S.D.= 3.675
Fertilizer x Density x Soil_type P= 0.992, L.S.D.= 9.003

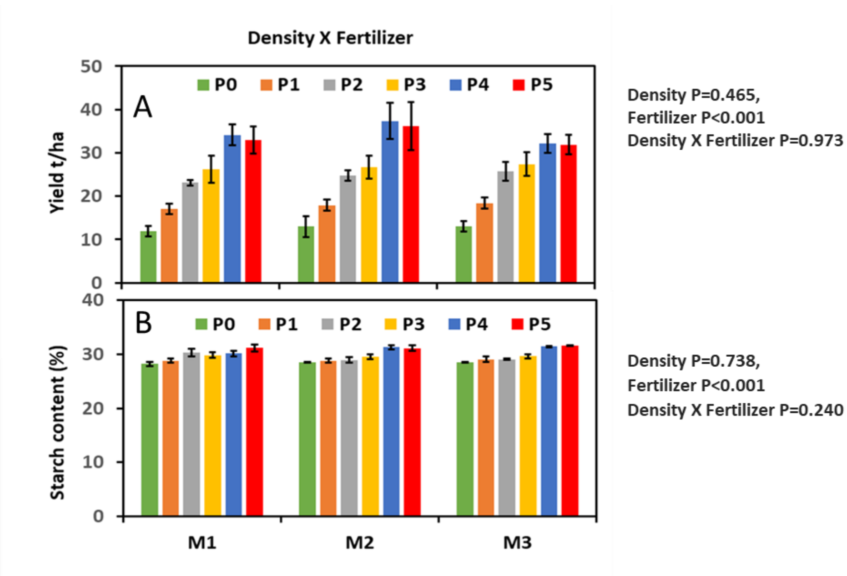

Fig 12.2: Yield (t ha^{-1}) (A) and Starch content (%) (B) of cassava variety HLS11 in response to 5 fertilizer treatment (P0: No fertilizer, P1: NPK 15:5:20 (250 kg ha-1) + 100 kg Phosphorous fertilizer (Farmer's practice), P2: 81N-54P_2O_5-81K_2O, P3: 90N-60P_2O_5-90 K_2O, P4: 90N-60P_2O_5-90K_2O + 1 t bio-fertilizer, P5: 108N-72P_2O_5-108K_2O in 3 different planting density (M1: 10,000 plants ha^{-1}), M2: 12,500 plants ha^{-1} and M3: 15,625 plants ha^{-1}). Means are followed by standard errors (n = 3).

Table 12.3 Presence of Cassava Mosic Disease (CMD) and Cassava Witches Broom Disease (CWBD) symptomatic plants (%) in the experiemnttal plots (2000 m^2) and Fresh root yield and strch content at the end of the season (i.e. 9 months of growth) of three varities, HLS11, HLS12 and HLS14. Plants were grown with two differten treatment, farmers' practices (Treatment 1) (planting density 0.6 m x 0.6 m and fertilizer 250 kg NPK 15:5:20 ha^{-1}) and recommended practice (Treatment 2) (planting density 0.8 m x 0.8 m and fertilizer 90 kg N ha^{-1} 60 kg P_2O_5 ha^{-1} 90 kg K_2O ha^{-1} and 1 ton bio fertilizer ha^{-1}).

Variety	Treatment	CMD (%)	CWBD (%)	Fresh root yield (t ha^{-1})	Starch contents (%)
HLS11	Treatment 1	0.50	0.0	16.5	27.5
	Treatment 2	0.20	0.0	25.2	28.0
HLS12	Treatment 1	0.30	0.0	17.7	28.1
	Treatment 2	0.10	0.0	26.0	28.5
HLS14	Treatment 1	0.25	0.0	18.2	29.2
	Treatment 2	0.09	0.0	27.1	29.7

The experiment was carried out in big plots without any replications.

Table 12.4 Percent of Cassava Mosaic Disease (CMD) symptomatic plants, fresh root yield and starch content of three cassava varieties grown at farmer's field and on factory field for production of clean planting material. Cassava was planted in two different densities.

Variety	Operator	Density (plant ha^{-1})	CMD (%)	Fresh root yield (t ha^{-1})	Starch content (%)
HLS12	Farmer	15.625	0.0	29.1	30.1
HLS14	Farmer	15.625	0.0	36.9	28.2
HLS11	Factory	20,833	95.0	21.8	27.5
HLS12	Factory	20,833	4.0	23.2	28.0
HLS14	Factory	20,833	3.0	25.5	29.0

Table 12.5: Fresh root yield (t ha^{-1}) of two cassava varieties when different legumes were intercropped. Means are followed by standard errors (n = 3).

Cassava Variety	Treatment (Intercropped legumes)				
	Sole	With red beans	With cow peas	With mung bean	With peanuts
KM419	25.9 ± 0.23	33.8 ± 1.74	31.7 ± 2.72	29.1 ± 0.88	30.5 ± 1.31
HLS11	23.3 ± 0.63	27.5 ± 1.04	27.4 ± 1.06	25.1 ± 0.41	26.7 ± 0.09
Treatment	$P<0.001$				
Variety	$P<0.001$				
Treatment X Variety	$P=0.565$				

Table 12.6: Starch content (%) of two cassava varieties when different legumes were intercropped. Means are followed by standard errors (n = 3).

Cassava Variety	Treatment (Intercropped legumes)				
	Sole	With red beans	With cow peas	With mung bean	With peanuts
KM419	28.7 ± 0.16	29.7 ± 0.16	29.6 ± 0.42	29.1 ± 0.54	29.4 ± 0.57
HLS11	29.6 ± 0.32	30.3 ± 0.42	30.4 ± 0.65	30.0 ± 0.51	30.0 ± 0.72
Treatment	$P=0.169$				
Variety	$P=0.006$				
Treatment X Variety	$P=0.996$				

Table 12.7: Yield of 4 different legumes (Kg ha^{-1}) when intercropped with two cassava varieties. Means are followed by standard errors (n = 3).

Treatment Cassava Variety	Intercropped legumes yield (kg ha^{-1})			
	Red beans	Cow peas	Mung bean	Peanuts
KM419	471.7 ± 7.45	452.3± 29.8	366.0 ± 7.57	680.3 ± 13.32
HLS11	462.3 ± 1.86	444.0 ± 32.5	355.3 ± 4.26	634.7 ± 9.94
Legumes	P<0.001			
Cassava Variety	P=0.120			
Legumes X Cassava	P=0.591			

Table 12.8: Yield of intercrop pea nuts, cassava fresh root yield and starch content at four different treatment. Pea nuts was intercropped with Cassava variety HLS11 in two different densities, 10,000 and 12, 000 plants ha^{-1}. Pea nuts were fertilized and un-fertilizer. Finally, Sole cassava at density of 15,625 plant ha^{-1}). Cassava was harvested at 10 months after planting. The experiment was carried out in big plots (2000 m^2) without any replications. Harvest was carried out from randomly selected sites and converted to t ha^{-1} yield for cassava.

Treatment	Density (Cassava plant ha^{-1})	Peanut yield (kg/2.000m^2)	Cassava	
			Fresh root yield (t ha^{-1})	Starch content (%)
Cassava intercropped with fertilizer	10,000	120	38.5	32.0
Cassava intercropped without fertilizer	10,000	90	35.4	32.0
Cassava intercropped with fertilizer	12,500	110	35.7	32.0
Cassava intercropped without fertilizer	12,500	80	33.9	32.0
Sole Cassava	15,625	0	31.8	32.0

Table 12.9 Presence of soil nutrients, N, P_2O_5, K_2O, Ca^+ and Mg^+ at the start of the experiment and at the end of the experiment.

	Density (Cassava plant ha^{-1})	N (%)	P_2O_5 (mg/100g soil)	K_2O (mg/100g soil)	Ca^{2+} (Meq/100 g soil)	Mg^{2+} (Meq/100g soil)
Start of the experiment		0.18	10.79	11.00	1.70	2.12
Cassava intercropped with fertilizer	10,000	0.20	11.16	11.07	1.75	2.12
Cassava intercropped without fertilizer	10,000	0.19	10.93	11.03	1.71	2.10
Cassava intercropped with fertilizer	12,500	0.19	11.05	11.05	1.73	2.11
Cassava intercropped without fertilizer	12,500	0.18	10.84	11.01	1.70	2.09
Sole Cassava	15,625	0.17	10.69	10.89	1.64	2.06

Table 12.10 Fresh root yield and starch content of two cassava varieties, HLS12 and HLS14 at two different densities, 08m x 0.8m -15,625 and 08m x 07m -17,857 plant ha^{-1}. Experiment was carried out in large plots (2500 m^2) without any replicates. Harvest was carried out from randomly selected sites and converted to t ha^{-1} yield for cassava.

Varietiy	Density (plant ha^{-1})	Fresh root yield (t ha^{-1})	Starch contents (%)
HLS12	15,625	39.24	30.15
HLS12	17,857	38.62	30.14
HLS14	15,625	32.45	26.57
HLS14	17,857	31.96	26.44

Table 12.11. Presence of soil nutrients, N, P_2O_5, K_2O, Ca^+ and Mg^+ at the start of the experiment and at the end of the experiment**.**

Variety (density)	N_{ts} (%)	P_2O_5 (mg/100g soil)	K_2O (mg/100g soil)	Ca^{2+} (Meq/100g soil)	Mg^{2+} (Meq/100g soil)
Start of the experiment	0.18	10.79	11.00	1.70	2.12
HLS12(15.625)	0.18	10.76	10.97	1.66	2.09
HLS12(17.857)	0.17	10.53	10.89	1.63	2.06
HLS14(15.625)	0.18	10.78	10,88	1.68	2.11
HLS14(17.857)	0.17	10.65	10.62	1.65	2.09

12.2 Son La

Table 12.12: Average fresh root yield (t/ha) of different varieties in of different varieties in Son La communes

	2017		**2018**		**2019**
Variety	**Chieng Chan**	**Pung Tra**	**Chieng Chan**	**Pung Tra**	**Chieng Ban**
Rayong 9	19.3 ± 2.2	17.2 ± 0.5	11.98 ± 0.4	20.6 ± 2.1	29.0 ± 0.9
13Sa05	24.1 ± 2.9	19.5 ± 2.4	12.53 ± 0.3	23.8 ± 3.0	31.1 ± 0.4
BK	20.1 ± 0.9	18.8 ± 1.0	15.48 ± 0.6	20.2 ± 1.7	32.4 ± 0.5
Sa21-12	15.3 ± 2.4	15.1 ± 2.2	13.14 ± 0.9	15.9 ± 0.2	26.9 ± 1.2
KM94	13.1 ± 0.6	16.5 ± 0.3	16.47 ± 0.8	15.4 ± 0.3	27.5 ± 0.4
La Tre	16.1 ± 0.7	13.7 ± 1.0	12.87 ± 0.8	14.7 ± 0.3	26.9 ± 1.2
Variety	P=0.014				
Commune	P<.001				
Year	P<.001				
Variety X Commune P<.001					

Table 12.13: Starch content (%) of different varieties in of different varieties in Son La communes

	2017*		**2018***		**2019**
Variety	**Chieng Chan**	**Pung Tra**	**Chieng Chan**	**Pung Tra**	**Chieng Ban**
Rayong 9	29.2	29.6	28.0	27.7	27.5 ± 0.5
13Sa05	3.0	28.1	29.8	25.5	25.5 ± 0.2
BK	29.0	28.5	30.0	25.5	25.5 ± 0.6

Sa21-12	30.0	30.0	29.7	25.4	25.4 ± 0.5
KM94	30.0	30.0	28.2	29.2	29.2 ± 0.2
La Tre	NA	27.7	30.0	26.7	26.7 ± 0.5

*Starch company measured the starch content and was not replicated

Table 12.14: Average fresh root yield (t/ha) at 5 different fertilizer rate (P0, No fertilizer; P1, 300 kg ha^{-1} NPK (5:10:3); P2, 600 kg ha-1 NPK (5:10:3); P3, 40N -10P-40K + 80 kg Kali Clorua; P4, fertilizer deep placement, 40N-10P-40K + 80 kg Kali Clorua) in SonLa communes (2018). Variety used KM94.

Fertilizer	Bó Mười	Chiềng chăn	Nà ớt	Pung Tra
P0	23.43	15.91	19.80	12.20
P1	23.21	17.19	21.16	16.28
P2	22.20	18.87	21.59	16.67
P3	18.28	19.53	18.47	22.37
P4	17.10	20.69	15.38	18.37

Fertiliser P<.001, L.S.D.= 1.075
Commune P<.001, L.S.D.= 0.962
Fertiliser X Commune P<.001, L.S.D.=2.151

Table 12.15: Average fresh root yield (t/ha) at 5 different fertilizer rate (P0, No fertilizer; P1, 300 kg ha^{-1} NPK (5:10:3); P2, 300 kg ha-1 NPK (12:5:10); P3, 40N -10P-40K; P4, 60N-15P-60K in SonLa districts (2019). Variety used KM94.

Fertiliser	Bó Mười	Nà ớt	Pung Tra
P0	13.7	12.9	14.7
P1	17.8	16.1	14.3
P2	23.1	21.9	22.2
P3	25.7	22.1	25.2
P4	28.2	22.6	24.3

Fertiliser P<.001, L.S.D.= 1.1.28
Commune P<.001, L.S.D.= 0.99
Fertiliser X Commune P<.008, L.S.D.=2.22

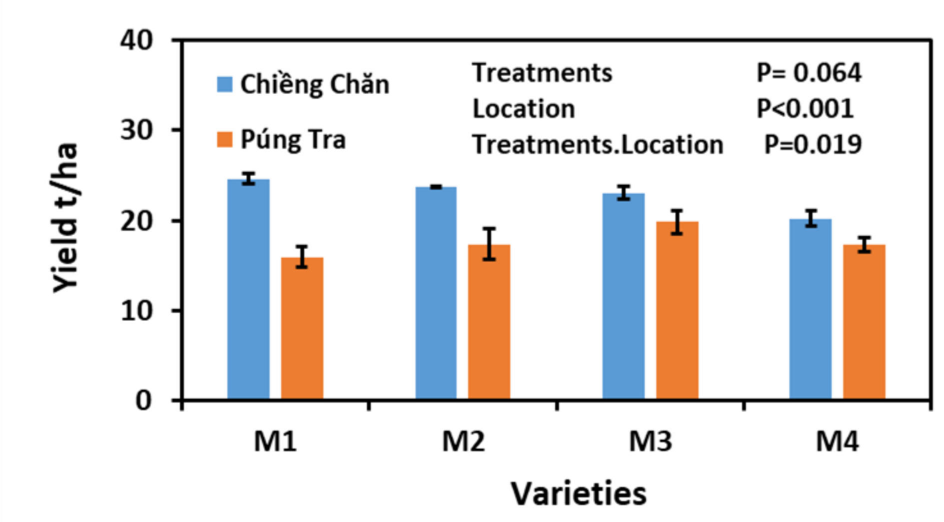

Fig 12.3: Fresh root yield of cassava variety KM94 at 4 different density. M1 (20,800 plant ha^{-1}), M2 (15,600 plant ha^{-1}), M3 (12,500 plant ha^{-1}), M4 (10,000 plant ha^{-1}). Means are followed by standard errors (n = 3). Variety KM94 was used in the trial conducted in 2018.

Table 12.16: Fresh root yield of cassava variety KM94 at 6 different soil management options, Cassava sole cropping (control), Cowpea intercropped, Mung bean intercropped, Peanut intercropped, Grass trip and residues of cassava from previous crop on contour lines. Means are followed by standard errors (n = 5 to 3). Experiments were conducted during 2017, 2018 and 2019 season. There was no significant effect on cassava yield.

Treatment	Chiềng chăn	Nà ớt	Pung Tra	Bó Mười
2017				
Sole	13.8 ± 0.6	18.5 ± 0.6	14.4 ± 0.4	16.7 ± 1.5
Cow pea	14.9 ± 0.8	20.7 ± 1.1	14.2 ± 1.0	14.7± 1.8
Mung bean	15.2 ± 0.6	23.5 ± 0.6	15.3 ± 0.7	14.9 ± 2.1
Peanuts	14.7 ± 0.4	22.8 ± 0.6	15.0 ± 1.6	15.3 ± 1.8
Grass strip	13.8 ± 0.4	21.5 ± 0.8	14.8 ± 1.1	15.4 ± 1.4
Cassava residues	14.7 ± 0.3	21.5 ± 1.0	14.4 ± 0.9	16.4 ± 1.5
2018				
Sole	14.1 ± 1.3	18.0 ± 0.4	15.7 ± 0.7	22.9 ± 0.5
Cowpea	16.3 ± 0.8	19.4 ± 1.3	18.0 ± 1.3	24.1 ± 2.7
Mung bean*	18.0 ± 1.8	18.8 ± 1.8	16.9 ± 0.9	24.9 ± 1.0
Peanuts	16.6 ± 1.6	20.5 ± 2.2	17.9 ± 0.6	24.4 ± 1.8
Grass strips	12.3 ± 1.0	18.3 ± 0.9	16.7 ± 2.1	24.6 ± 0.8
Cassava residues	15.6 ± 1.0	18.5 ± 1.0	16.4 ± 0.7	27.1 ± 1.9
2019				
Sole	12.6 ± 0.8	16.6 ± 0.4	15.8 ± 0.2	
Cow pea	14.4 ± 0.3	18.7 ± 0.6	17.0 ± 0.6	
Mung bean	14.2 ± 0.4	19.6 ± 1.2	17.1 ± 0.8	
Peanuts	15.6 ± 1.0	19.9 ± 1.8	17.0 ± 1.1	
Grass strip	11.5 ± 0.3	16.9 ± 0.9	16.6 ± 0.3	
Cassava residues	13.4 ± 0.4	18.9 ± 0.9	17.4 ± 0.4	

*Mung bean intercropped-Shortly after germination almost mung bean individuals died.

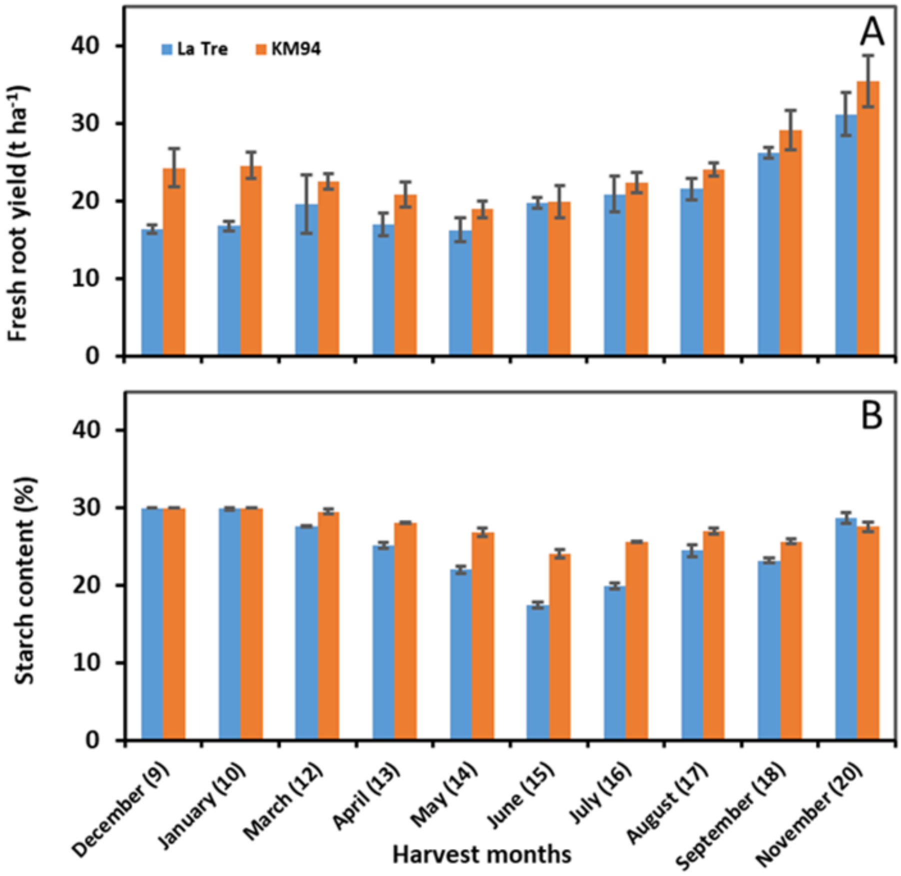

Fig 12.4: Fresh root yield (A) and Starch content (B) of cassava variety La Tre and KM94 at different harvest date (duration of crop in month). Crop was planted at the same time in April of the previous year (i.e. 2018). Means are followed by standard errors (n = 3).

12.3 Indonesia

Table 12.17: Cassava fresh root yield of 15 varieties at germplasm evaluation experiments at Sikka Regency during 2017 season and Siantar, North Sumatra during 2016.

Varieties	Sikka regency				Siantar
	Experimental field		Farmers' field		Experimental field
	Mealy Bugs (%)	Yield (t ha^{-1})	Mealy Bugs (%)	Yield (t ha^{-1})	Yield (t ha^{-1})
Sika Putih (L,S)	20	25.7	n.a.	n.a.	-
Sika Kuning (L,S)	25	26.6	n.a.	n.a.	-
Adria1 (I,B)	41	31.2	100	29.4	36.3
Adria4	-	-	-	-	27.4
Tambak Udang (I,S)	65	32.5	100	28.2	-
Faroka (I,B)	50	36.8	100	34.7	41.7
Cikaret	-	-	-	-	26.0
UB1/2	52	34.8	100	34.2	38.7
UB4472 (I,B)	39	33.6	100	35.7	35.8
Gajah (I,B)	35	45.7	n.a.	n.a.	31.5
Malang6 (I,B)	54	38.5	100	35.2	-
Malang4	-	-	-	-	49.8
Malaysia	-	-	-	-	41.0
Ketan	-	-	-	-	20.6
Kaspro	-	-	-	-	27.8

L=local variety, S=sweet variety, I=introduced, B=bitter, n.a.=not available.

Table 12.18: The adoption of Malang4 variety involved 16 farmers in 4 sub-districts of Simalungun Regency and 1 sub-district of Toba Samosir Regency. The total land area for adoption of Malang 4 variety in 2017 is around 4.68 hectares.

No	Name	Address	Variety	Yield (t/ha)	Area (ha)	Previous	planting system
1	Pak Mukhlis	TapianDolok	Malang4	30.4 t	0.32	Malaysia	monoculture (1 x 0.7 m)
2	Pak RasmenPurba	Kec. TapianDolok	Malang 4	33.06	0.16	Malaysia	monoculture (1 x 1 m)
3	DewiPangaribuan	Kec. TapianDolok	Malang 4	29.57	0.12	Malaysia	monoculture (1 x 1 m)
4	LumonggaSiallagan	Kec. SiantarMartoba	Malang 4	33.45	0.24	Malaysia	monoculture (1 x 1 m)
5	Edison Pasaribu	Kec. TapianDolok	Malang 4	30.00	0.32	Malaysia	monoculture (1 x 1 m)
7	Bu Sirait	Kec. DolokPanribuan	Malang 4	34.75	0.16	ubi roti lampung	intercropping (1.5 x 0.8 m)
8	Pak Naryo	Kec. DolokMerlawan	Malang 4	44.02	0.16	ubi roti lampung	intercropping (1.5 x 0.8 m)
9	Pak Parmin	Kec. DolokMerlawan	Malang 4	38.10	0.16	ubi roti lampung	intercropping (1.5 x 0.8 m)
10	MarolopSitorus	Kec. Uluan, TobaSa	Malang 4	51.0	0.16	Adira 4 (50 t/ha, 12 mo)	monoculture (1.2 x 1 m)
11	MarataSirait	Kec. Uluan, Tobasa	Malang 4	42.5	0.16	Adira 4 (37.5 t/ha, 12 mo)	monoculture (0.8 x 0.8 m)
12	AfnitaSianturi	Kec. Uluan, Tobasa	Malang 4	44.50	0.16	Adira 4 (25 t/ha, 12 mo)	monoculture (1 x 0.6 m)
13	RihardSitorus	Kec. Uluan, Tobasa	Malang 4	48.00	0.16	Adira 4 (25 t/ha, 12 mo)	monoculture (1 x 0.6 m)
14	Jenti M. Manik	Kec. Uluan, Tobasa	Malang 4	50.50	0.16	Adira 4 (30 t/ha, 12 mo)	monoculture (1 x 0.6 m)
16	Anita Manurung	Kec. Uluan, tOBASA	Malang 4	48.00	0.16	Adira 4 (25 t/ha, 12 mo)	monoculture (1 x 0.6 m)

Table 12.19: Fresh root yield of four introduced varieties in demonstrations in different part of project area.

Variety	Root yield (t ha^{-1})	
	East Nusa Tenggara	North Sumatra
Malang4	53.1	30.6
Faroka	46.4	26.3
Tambak Udang	40.9	34.0
Gajah	48.7	37.0
Local	32.4	16.2

Table 12.20: Fresh root yield (kg/plot) of two verities (Malang 4 and Malaysia) with 7 different fertilizer treatments- F1, 200 kg Phonska/ha; F2, Phonska 200 kg + 125 kg Urea + 125 kg KCl/ha; F3, Phonska 200 kg + 5 t manure/ha; F4, Manure 10 t/ha; F5, Phonska 200 kg +25 kg Urea + 50 kg KCl/ha; F6, 100 kg Urea + 100 kg SP-36/ha and F7, 200 kg Urea + 100 kg SP-36/ha in Siantar, North Sumatra district.

Varieties	F1	F2	F3	F4	F5	F6	F7
Malang4	86.7	87.7	74.3	90.7	82.0	87.3	91.7
Malaysia	69.3	61.3	57.0	55.0	96.3	63.0	62.3
Varieties P=0.009, L.S.D.= 14.08							
Fertiliser P=0.724, L.S.D.= 26.34							
Varieties X Fertiliser P=0.577, L.S.D.= 37.25							

Table 12.21: Cassava tuber yield in response to five fertiliser combinations in 5 different sites in North Sumatra during 2018 season. Four different varieties were used in the experiments on farmers' field.

Treatments (NPK)/ Districts	Tuber yield ($t\ ha^{-1}$)				
	[a]Sinaksak	[a]Tanjung Tonga	[b]Siantar	[c]Siantar	[d]Sipasung
*45N: $45P_2O_5$: 45 K_2O kg ha^{-1}	31.7	36.7	23.2	19.8	36.6
90N: $45P_2O_5$: 45 K_2O kg ha^{-1}	31.3	36.9	23.9	21.2	37.6
45N: 45 P_2O_5 115 K_2O kg ha^{-1}	47.1	44.2	28.2	26.3	43.7
60N: $60P_2O_5$: $60K_2O$ kg ha^{-1}	30.4	37.8	24.8	22.7	38.4
Organic manure 10 t ha^{-1}	30.4	36.0	24.8	23.6	36.7

*Farmers' practice, Varities-[a]Malang4, [b]Dacon, [c]Hoybong60, [d]Faroka

Table 12.22. Yield of cassava Malang4 intercropping and gross income with various crops, Siantar 2019.

Treatment	Cassava yield (t/ha)	Yield of intercropped (t/ha)	Gross income Rp/ha
1.Cassava sole crop	.40.27	-	40.270.000
2. Maize	22.25	3.74	35.714.000
3.Mungbean	38.18	1.06	51.430.000
4.Soybean	37.51	1.62	49.697.500
5.Peanut	34.83	3.03	53.010.000
6.Upland rice	31.68	3.30	48.180.000
7.Mellon	40.23	Grow but no fruit at all	40.230.000
8.Red bean	38.37	1.68	56.850.000
9.Cowpea	36.67	1.87	47.920.000
10.Ginger	30.88	4.94	62.990.000

Note: Price of cassava Rp 1000/kg. Maize Rp 3600/kg. Mung bean Rp 12.500/kg. Soybean Rp 7500/kg. Peanut Rp 6000/kg. Upland rice Rp 5000/kg. Red bean Rp 11.000/kg. Cowpea Rp 6000/kg and Ginger Rp 6500/kg. Mellon only able to grow but no fruit at all and damage by natural enemies.

Table 12.23 Indo. Effect of NaCl and NaHCO3 on some chemical properties of Malang4 cassava tuber

Treatments NaCl (5)	NaHCO3 (%)	HCN (mg/kg)	Starch (%)	Protein (%)	Fiber (%)	Fat (%)	Preference
0	0	114.23	26.31	1.63	1.06	0.39	1.26
	5	89.92	26.16	1.62	1.01	0.47	1.93
	10	66.62	26.73	1.56	1.06	0.46	-
4	0	80.36	25.73	1.62	0.95	0.46	1.66
	5	58.92	25.92	1.51	1.04	0.44	2.93
	10	53.5	24.93	1.52	0.92	0.46	-
8	0	75.16	25.79	1.59	1.02	0.46	2.46
	5	52.52	25.7	1.55	1.02	0.45	-
	10	46.37	26.44	1.54	1.03	0.41	3.2
16	0	64.69	25.92	1.56	0.99	0.41	2.66
	5	50.39	25.65	1.54	1.01	0.42	-
	10	44.57	25.42	1.63	1.01	0.43	2.60
Tambak Udang (sweet variety)		26.72	12.35	1.65	0.86	0.42	3.46
Significant at p= 5%			NS	NS	NS	NS	

Table 12.24. The yield of mealybug infested and healthy cassava during 2019 season.

Farmers Name	Address	Variety	Infestation intensity (%) from field area	Yield (kg/10 plants) Healthy	Infested	Beginning infestation (month aft planting)
Rubensia		Malang 4	60	79.10	64.52	8
Jeremius Nurak		Malang 4	60	85.44	82.92	8
Sebastianus Sabul;		Faroka	90	72.50	66.88	7
Angelo		Malang 4	80	30.55	53.40	8
Henderikus Sili		Gajah	100	x	71.50	8
Timotius Poin	Takaplangir, Nita	Local	80	56.40	56.52	7
Tomas Mori		Malang 4	80	61.24	54.92	7
Anelmus Kiok		Gajah	90	85.74	72.48	7
Henderikus Gleko		Local	60	59.24	62.90	8
Yovita Dua	Langir, Kangae	Local	90	68.84	59.20	8
Maria Angelina		Local	100	x.40	50.76	7
Johanis Jonper		Faroka	40	70.60	69.60	7
Masinona Sisilia		Malang 4	40	83.20	90.40	8
G. Karwayu da Md	Lapolima	Faroka	80	68.72	70.80	7
Simpe Rompi	Habi, Kangae	Faroka	80	71.50	60.26	8
Mean				71.04	6.65	

Table 12.25: Effect of fertilizer, intercropping with maize and planting density on the yield of maize and cassava in intercropping system in East Nusa Tenggara in 2018.

Density + intercrop	Fertiliser	Maze yield (t ha^{-1})	Cassava yield (t ha^{-1})
M	0	1.9 ± 0.2	
	N	4.0 ± 0.5	
	NPK	4.3 ± 0.1	
M + C (2m x 1m)	0	1.8 ± 0.1	9.1 ± 0.5
	N	4.2 ± 0.1	20.1 ± 0.4
	NPK	4.7 ± 0.3	24.5 ± 3.4
M + C (1m x 1m)	0	2.0 ± 0.1	17.2 ± 0.6
	N	4.4 ± 0.7	41.5 ± 0.6
	NPK	4.3 ± 0.5	47.5 ± 1.6

Table 12.26: Effect of Nitrogen (N) and Potassium (K) application on the yield of maize and cassava in intercropping system in East Nusa Tenggara in 2019.

Nutrient (kg ha^{-1})		Crop yield (t ha^{-1})	
K_2O	N	Maize	Cassava
0	0	1.75	7.2
	45	2.9	13.42
	90	4.01	22.61
	180	4.42	36.79
25	0	1.7	8.78
	45	2.85	13.28
	90	4.53	25.32
	180	4.68	33.94
50	0	1.87	10.42
	45	3.22	14.78
	90	4.45	25.72
	180	4.27	33.19
100	0	1.91	10.91
	45	2.87	17.2
	90	4.58	25.72
	180	4.58	32.64

Table 12.27: Fresh root yield and Land Equivalent Ratio (LER) of different intercropping system of cassava. The treatments were cassava mono culture (CO), with maize (local practice, TS1), with maize (improved practice, TS2), with pea nut (TS3) and with mung bean (TS4)

Treatment	Yield t ha^{-1}			LER		Total LER
	Cassava	Intercrop	Monoculture	Cassava	Intercrop	
CO	33.2	0	33.2	1.00	0	1.00
TS1	10.4	4.1	4.2	0.30	0.97	1.27
TS2	24.8	4.3	4.2	0.75	1.04	1.78
TS3	27.1	1.3	2.0	0.82	0.63	1.45
TS4	26.3	0.6	1.5	0.79	0.43	1.23

Table 12.28: Yield of maize and cassava of adopter farmers at Sikka district in 2019.

No	Name	Village/subdisdrict	Land area (ha)	Maize yield (t/ha)	Cassava yield (t/ha)
	DISTRICT: Sikka				
1	Frans Don	Worohuler, Koting	0.25	2,98	39.60
2	Rubensia		0.20	3.25	30.55
3	Jeremius Nurak		0.25	3.80	35.72
4	Mateus Hulir		0.25	2.40	36.09
5	Agsutina		0.25	2.46	33.84
6	Sebastianus Sabul;		0.20	2.62	35.25
7	Angelo		0.20	3.80	30.55
8	Henderikus Sili		0.25	2.58	32.90
9	Dorino Noeng		0.25	2.86	35.72
10	Danianus jati		0.20	3.72	34.07
11	Jaja wangsa		0.25	2.70	36.66
12	Zakarias Dili		0.20	3.25	35.50
13	Robinson		0.20	6.50	35.25
14	Timotius Poin	Takaplangir, Nita	0.25	3.80	27.20
15	Tomas Mori		0.20	5.00	27.62
16	Anelmus Kiok		0.20	4.20	31.87
17	Henderikus Gleko		0.20	4.62	27.62
18	Yovita Dua	Langir, Kangae	0.15	3.90	24.42
19	Arnoldus Yansen		0.20	3.82	28.30
20	Herman Hewot		0.20	3.25	28.12
21	Laurensia Gori		0.10	4.08	37.00
22	Afrida Desensi		0.20	4.37	28.30
23	Trifonia Lendi		0.10	3.80	33.30
24	Maria Nona Turce		0.15	4.53	24.28