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Sustainable intensification and diversification in the lowland rice system in Northwest Cambodia

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1 Acknowledgments

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2 Executive summary

A challenge in many development projects is to develop a scaling strategy to ensure that project outcomes are sustainable and continue beyond the life of the project. The CamSID project funded by ACIAR (CSE-2015-044) designed and tested innovations to help rice farmers improve their farming system sustainability and their livelihoods. Scaling of the project's innovations consisted of: (1) Training Cambodian provincial government to train input suppliers (up-scaling), (2) Training of farmer groups (out-scaling) and (3) Connecting private sector providers of machinery services with farmers and government.

Provincial government officers have been provided with technical training in clean (i.e., weed-free), quality seed supplies, fertiliser, pesticide and integrated pest management technologies for rice, mungbean and vegetables and they incorporated this training into their existing 5-day certificate course to input sellers. Over 10 farmer groups and agricultural cooperatives have been trained through lead farmer training schools. Training in improved farming systems has included a combination of face-to-face field days, radio broadcasting and diagnostic advice on Telegram. For example, the project has installed a new seed cleaner at a Farmers' Hub in partnership with two NGOs, the Syngenta Foundation for Sustainable Agriculture (SFSA) and Ockenden Cambodia with technical support from the Cambodian Agricultural Research and Development Institute (CARDI). Innovative mobile Apps have also been developed to help farmers with identifying weeds and weed seed contamination in rice seed kept for sowing and pests and beneficial insects in mungbean. Technical manuals have also been produced for mungbean and rice. The team has also re-packaged radio broadcasts into a podcast series that is being promoted via social media.

In collaboration with the Cambodian Agriculture Value Chain Program (CAVAC) to demonstrate and scale machine direct seeding through private sector service providers, over 18 KID drill seeders have been purchased by Battambang province machinery service providers and agricultural cooperatives and over 700 ha planted using these drill seeders as of December 2020. Field demonstrations of the Cambodian-invented Eli seeder have led to over 433 Eli seeders being sold by the end of 2020. The Prime Minister of Cambodia visited the CAVAC Irrigation Scheme on 21 July 2020 and upon witnessing the performance of the implemented Eli seeder technology, committed to procure 2,000 Eli seeders (both wet and dry seeding) for smallholder farmers using his own budget (of which 250 were delivered by early 2021).

CGIAR has recently established the Excellence in Agronomy (EiA) platform in partnership with the International Rice Research Institute (IRRI) and has chosen direct seeding of rice in Cambodia as one of the cases for scaling of technology. In the coming 18 months, EiA will study scaling patterns and develop an app to inform farmers of service providers. The CamSID approach is innovative as it pivots on novel private-public-producer partnerships to leverage research for development into successful scaled outcomes.

3 Background

The design of this project was informed by an ACIAR-funded Workshop on Sustainable Intensification (SI) of Rice Based Systems in the Lower Mekong (C2014/290). This workshop highlighted the sociological trends in the region which form the context of the proposed work viz. reduced availability of labour on small farms due to movement of both genders (especially in the 15-34 age group) to cities and/or other employment, and the consequent increase in requirements for mechanisation and labour-saving. These trends will, in turn, lead to more cooperation between and aggregation of family farms, which is also an expected consequence of successful implementation of sustainable intensification and diversification (SID). The technology clusters appropriate to the shifting economics and demographics will be researched, and uptake of innovation encouraged through sustainable (mostly private sector) means for farms of all sizes.

Low rice yields and frequent crop failures have disheartened many farmers in Northwest Cambodia, and many have neglected their crops to seek employment in towns and cities. Approximately 80% of families in the region nominated agriculture as the primary source of income, and 65% depended on rice production. There are four main rice production systems in North-West Cambodia that differ according to availability of irrigation and risk of flooding. Direct seeding (mainly by hand broadcasting) is practiced in all four systems. The traditional practice was to plant medium or long duration photoperiod sensitive rice varieties in July with harvesting in December-January in a rain-fed system (Figure 1). With the advent of wet season irrigation schemes, it is now possible for two short-duration rice crops to be grown during the wet season. The first crop is dry-seeded in May-June and harvested in August-September (Figure 1). The second crop is wet-seeded in September and harvested in December (Figure 1). Land is ploughed after the main wet season crop, or left fallow, from December to March.

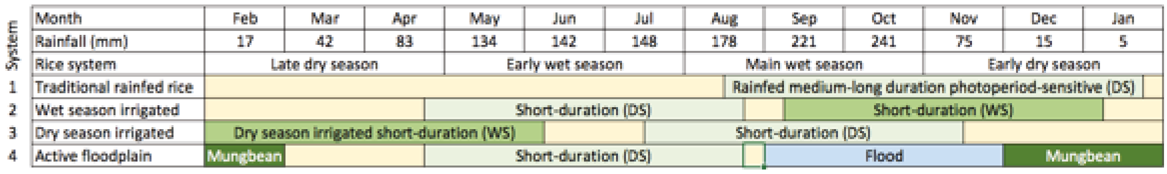

Figure 1. Rice systems in North-West Cambodia (DS = dry seeded, WS = wet seeded)

This project targets rice farming communities in Northwest Cambodia, an area with limited coverage under current ACIAR projects. The target region comprises Banteay Meanchey, Battambang and Pursat Provinces (17% of Cambodia's land area). NW Cambodia has a monsoonal climate, with a rainy season between middle of April and October and a distinct dry season between November and March. The average annual rainfall at Battambang is 1,247 mm, with 101 mm, 391 mm and 755 mm falling in the dry season, early wet season (EWS) and main wet season, respectively.

Insufficient access to improved agricultural technologies, in particular infrastructure for water management of paddy fields, weak training and extension support, lack of credit, business and financial skills and perceptions of risk, have prevented the adoption of more effective farming practices. There has been limited uptake of diversification possibilities (e.g., higher value non-rice crops such as mung bean and vegetables) due to lack of training and knowledge of the available options. In addition to rice, Cambodia's paddy fields have traditionally produced fish and other aquatic animals. These fish are an important source of protein and nutrition, especially for smallholders. Interestingly, gross fish revenue (total value of fish production) per household averages US$194, while input costs are higher at US$297; this is perhaps because most of the fish are eaten by households, and only the surplus is sold. It is therefore important that any intensification of rice production does not result in excessive use of agricultural pesticides which may potentially threaten fisheries in rice fields. Low cattle numbers (averaging 4.1 animals per cattle-keeping household) in the Battambang Province is due to the replacement of draught animals with mechanisation.

Lack of labour is a critical barrier to raising cattle, and households are losing at least US$800 per year from cattle (assuming the current daily wage for farm labour of US$5). Hence, the trend is for farmers either to specialise in cattle production or to stop keeping cattle due to declining availability of labour. The larger farm sizes in Northwest Cambodia relative to Southern Cambodia also facilitate mechanisation.

Farming in lowland areas in Northwest Cambodia is predominantly a monoculture of dry-seeded rainfed lowland rice (one crop per year) due to the lack of access to irrigation infrastructure in over 90% of the land area. There is a mixture of “small” smallholder (<2 ha) and “medium” sized (2-5 ha) farming households - average farm size is 2.5 ha but 90% are around 1 ha and only 6% have access to full irrigation. All farmers face similar issues of rainfed agriculture in an increasingly variable climate (e.g., delayed monsoons), climate change and extreme events of drought (El Niño and positive Indian Ocean Dipole) and floods (La Nina and negative Indian Ocean Dipole). Many farmers, already struggling to maintain livelihoods, have an increasing perception that rice growing is high risk. The difficulty of securing farm labour and increasing rural wages causes reduced profit and livelihood vulnerability. Hence, mechanisation is a possible means to reduce the problem of low income. In addition, mechanisation allows the reduction in time required for farm operations (increased farm labour productivity) and allows more time for intensifying with additional higher-value crops.

At least 90% of harvesting in Northwest Cambodia is done by combine harvesters, but planting is done mostly by hand broadcasting at excessive seeding rates (sometimes >200 kg/ha). High seeding rates are used to compensate for poor seedbeds, loss from vermin and weed competition. Broadcasting also can result in poor crop establishment and weed infestation. Seed used is often of poor quality, and often varieties of low productivity and grain quality. Limited crop rotation is used, relying mainly on rice monoculture. Pesticide and fertiliser use is often inappropriate and unsafe to the user and to the environment.

The project’s approach was to bring researchers, extensionists, teachers, students and private sector organisations into partnership with organised groups or hubs of small-holder farming families, to integrate the latter more effectively into the value chain and to understand fully the technical and socio-economic context of the current system and how it works. All these groups will participate in the research to develop and extend crop and income diversification, using a co-innovation approach. This approach will result in the uptake of identified innovations, potentially through market mechanisms and commercial solutions to enable adoption of intensification and diversification in the rainfed lowland rice system.

The core problem addressed by the “Sustainable Intensification and Diversification in the Lowland Rice System in Northwest Cambodia” project was low productivity and low income in rainfed lowland rice systems in Northwest Cambodia, the result of which is poor livelihoods and food insecurity. There are many challenges to the adoption of innovative intensified and diversified crop production methods. These include biotic and abiotic crop yield constraints, inadequate availability of suitable varieties of good rice seed of suitable varieties and access to markets for non-rice crops. Compounding this is a general lack of knowledge, insufficient skills to implement crop intensification and diversification options, limited training in rural subjects in the educational system, limited business and financial expertise, and uncoordinated educational and extension infrastructure.

Our vision is increased income for farmers and stronger businesses that are more sustainable and resilient, with diversified sources of income in 5-15 years’ time. The central research question is:

What community engagement processes, participatory research processes and local partnerships will engage and sustain farmer and wider stakeholder engagement in developing more sustainable intensification and diversification innovations?

This project addressed the following sub-research questions:

(i). What are the key constraints to farmers and other stakeholders to engage in the development of more sustainable intensification and diversification innovations that will increase productivity and livelihoods?

(ii). How do participatory processes improve effective engagement of farmers and wider stakeholders in the development of more sustainable intensification and diversification innovations?

(iii). What scaling models are most effective for sharing sustainable intensification and diversification innovations?

(iv). How can identified processes for (ii) and (iii) be embedded in extension education and training?

By addressing these questions, we aimed to identify constraints to the uptake of innovations and to increase the adoption of new technologies for sustainable intensification of the rainfed lowland rice system in Cambodia, ultimately contributing to increased income and food security in Northwest Cambodia. The specific objectives were to:

- Identify the local socio-economic and agronomic trends, constraints and opportunities for sustainable intensification and diversification adoption for small and medium farm households;
- Establish participatory on-farm trials to test sustainable intensification and diversification innovations and approaches at field scale and evaluate which approaches are most effective for farmer adoption;
- Comparative evaluation of different scaling model case-studies demonstrating different scaling principles, strategies and approaches for sustainable intensification and diversification adoption at village and community level; and
- Build the capacity of local farming communities and tertiary agricultural educational institutions to implement sustainable intensification and diversification technologies and approaches beyond the life of the project

NW lowland rice systems are a new area for ACIAR projects in Cambodia; this project drew on the results of ACIAR projects in other areas of Cambodia. Our project stimulated the uptake of innovations by large groups of farmers and aimed to sustain it beyond the life of the project through engagement with the private sector and development of market links within the value chain network. The project investigated the needs of farmers; identified best practices for crop rotations and other technologies, through surveys, business and financial skills training, research and demonstrations; and encouraged adoption through farmer participatory research and public-private-producer partnerships. The project acted as a pilot for public-private-producer partnerships as cost-effective and long-term sustainable research and technology adoption models. Team building and operational planning were undertaken early in the project, using a participatory action research framework. Private sector partners were identified after the initial socio-economic survey, where a network analysis of farmers in the target area determined the source(s) of their inputs, including information, value chain linkages and potential to act as business mentors. An analysis of input suppliers and traders, especially their technical capacity, provided leads for improvement of their services to farmers.

The main actors in this project were farming communities, researchers, local universities and other public sector players, and private sector suppliers and traders. The project team was led by the University of Sydney, with in-country support from the Cambodian Agricultural Research & Development Institute and from collaborating scientists at the National University of Battambang, National Meanchey University, Provincial Departments of Agriculture, University of Sydney research sub-grantee, Syngenta Foundation for

Sustainable Agriculture, Stockholm Environmental Institute, Gansu Agricultural University and local private sector partners. Pilot on-farm research was used as a proof of concept for sustainable intensification and diversification for smallholders, as well as for public-private-producer partnerships. Then the project scaled out geographically to other villages, and also scaled up, providing extension and policy briefs to government.

In the target region of this project, there are nearly half a million farming families. There is a mixture of “small” smallholder (<2 ha) and “medium” sized (2-5 ha) farming households. The project focussed on training opportunities in the public and private sectors for the economic empowerment of women, who are frequently the decision makers in smallholder farm families. Diversification and intensification of the farming system in the rainfed lowland through increasing crop yield, including an additional crop per year and production of high value crops such as vegetables, could potentially lift the average family’s farming income from approx. $500 to $2,500 per annum on an average smallholder farm size of 1 ha.

4 Objectives

We aim to identify constraints to the uptake of innovations and to increase the adoption of new technologies for sustainable intensification of the rainfed lowland rice system in Cambodia, ultimately contributing to increased income and food security in Northwest Cambodia. There specific objectives were to:

4.1 Objective 1. Identify the local socio-economic and agronomic trends, constraints and opportunities for SID adoption for small and medium farm households.

1. Conduct foresight study and establish a multi-skilled team and strong governance to oversee the design and implementation of the project
2. Conduct participatory rural appraisals (PRAs) to assess the socio-cultural context formally, identify local needs and opportunities and build cohesion and a shared vision for project staff and stakeholders
3. Conduct a socioeconomic household livelihood and farming system survey based on PRA findings. The diagnostic survey will quantify system components and likely impacts of interventions, make an assessment of market opportunities in the future including value chain network analyses and will include household consumption and production strategies and decision making
4. Refine priority agronomic and institutional research priorities, interactions and interventions based on the survey
5. Conduct a mid-project survey to evaluate which innovations and approaches are more effective for farmer adoption and improved livelihoods
6. Deploy an evaluation survey to all project participants near the end of project to monitor impact in relation to objectives, assess effectiveness of scaling methods adopted and generate recommendations for future research from participants

4.2 Objective 2. Establish participatory on-farm trials to test SID innovations and approaches at field scale and evaluate which approaches are most effective for farmer adoption

2.1 Identify and establish leading farmers, smallholder, input and output supply and local value chain networks (VCNs) to test SID innovations and evaluate effectiveness for adoption. Upskill these networks in farm and business planning and management tools

2.2 On-farm field experiments and demonstrations for rice and other rotation crops [e.g., mung bean, waxy maize and vegetable crops] conducted to refine and adapt successful SID innovations

2.3 Evaluate a new 12-month calendar for rice variety and non-rice crop rotations in appropriate areas

2.4 Optimise direct seeding methods by evaluating conventional drill, no-till direct drill, drum seeding and alternative wet seeding methods for rice compared with traditional broadcast seeding

2.5 Evaluate high quality seed of registered varieties of high value [e.g., Phka Rumduol rice, mung bean, waxy maize and vegetable crops] compared with traditional farmer saved seed

2.6 Evaluate best practice guidelines (e.g., land levelling, crop nutrition, water management, crop protection) for rice and other rotation crops [e.g., mung bean, waxy maize, mushroom and vegetable crops]

2.7 Evaluate available chemical and non-chemical protocols and options for integrated weed, insect and disease management in the crop sequence.

2.8 Evaluate commercially available remote sensing technologies such as low cost Unmanned Aerial Vehicles (UAVs) for measuring yield limiting factors; crop/weed biomass and land levelling. Ground-based EM38 used to detect subsoil constraints and soil water holding capacity.

4.3 Objective 3. Comparative evaluation of case-studies demonstrating different scaling principles, strategies and approaches for SID

3.1 Evaluate most successful farmer-led prototype groups and community-led VCN models to scale up SID to a village/community level

3.2 Support private sector input and machinery suppliers, NGOs and traders to promote SID methods to their farmer clients including analysis of components of input prices and credit provision

3.3 Support local VCNs and the development of self-sustaining agribusiness (input and machinery services) where appropriate to continue to support farmers

4.4 Objective 4. Build the capacity of local farming communities and tertiary agricultural educational institutions to implement SID technologies and approaches beyond the life of the project

4.1 Upgrade curriculum and multilingual teaching materials to use for “train-the-trainer” dissemination of practical knowledge of SID

4.2 Develop and disseminate information tools and messages using extension support materials, radio/TV programs and information and communications technology for local communities, especially targeting the 15-34 age group and women

4.3 Increase the supply of practically trained university, PDAFF and private sector supplier/trader staff to provide support and sustainability for SID adoption by farmers

4.4 Identify key constraints and higher level interventions that cannot be implemented at the local level and make policy recommendations

5 Methodology

The majority of activities were conducted in target villages with some supplementary irrigation water available so that crop intensification and diversification could be achieved, while other activities were conducted in rainfed lowland areas with little water available, especially during the dry season. For the first three years, we mainly conducted on-farm experiments in four key villages (e.g., Battrong, Kouk Tonloap in Banteay Meanchey Province; and Svay Cheat, Praek Traeb and Angsangsak, Battambang Province). In the fourth and fifth (and sixth) year of the project, we scaled out to other villages including Spean Sraeng, Boslouk and Thmor Puok in Banteay Meanchey Province and Ou Ta Nhea, Kampong Preang, Kamping Pouy and Tahen, Battambang Province. Our partners at CARDI also conducted similar experiments at CARDI, Phnom Penh as well as in Pursat Province.

The methodology of the project was divided into 6 groups of activities corresponding mainly to the Objectives/Activities in Section 6 and to the Key Results and Discussion in Section 7. The 6 groups are as follows (the numbers in brackets show the corresponding Objective/Activity in Section 6):

1. Socioeconomic and agronomic analysis of village information (1.2, 1.3, 1.4, 1.5, 1.6)
2. Evaluation of rice intensification options (2.2, 2.3, 2.5, 2.6, 2.7, 2.8)
3. Evaluation of diversification options (2.2, 2.5, 2.6)
4. Scaling case studies (3.1, 3.2, 3.3)
5. Capacity building (4.1, 4.2, 4.3, 4.4)

5.1 Socio-economic and agronomic analysis of village information

1a Baseline (2016) and midline (2018) and endline (2020) village information

Baseline survey

In the baseline surveys in 2016 and 2017, both qualitative and quantitative approaches were used to understand the system in which small holder rice households are embedded in north west Cambodia. This was done to provide the foundation for 5 years of work with target villages and the baseline from which progress could be measured. A Participatory Rural Appraisal (PRA – qualitative) was done in late 2016 involving 144 interviews in 8 villages. A Baseline Study (BS – quantitative) was conducted in early 2017 involving 522 households representing 2685 people in 10 villages (which include the 8 villages in the PRA). The ten selected villages comprised Battrong, Trapaeng Thmor, Kouk Tonlap, Bos Louk and Ta Am in Banteay Meanchey Province and Prey Totoeng, Svay Cheat, Rohal Suong, Svay Chrumm and Praek Trab in Battambang Province (Figure 2). Despite all being classified as in the same lowland environment, most of the villages are located in the Old Alluvial Terrace Ecological Zone whereas Praek Trab (also located next to Angsangsak village) and Rohal Suong are located on the Active Floodplain adjacent to the flooded forest of the Tonle Sap Lake. Each village had approximately 300-350 households with approximately 1,200-1,300 adults per village according to the 2013 census data. These household representatives provided information about members of their households (n=2685, females n=1325, males n=1324, not specified n=36). The survey was conducted again in midline survey in September 2019 (with focus groups) and again in the endline survey in October/November 2021 (mainly by telephone).

Outputs of Objective 1 led into activities of Objectives 2 and 3. For example, surveys and PRA from Objective 1 identified the key lead farmers and agricultural cooperatives (ACs) with whom we engaged in activities of Objectives 2 and 3.

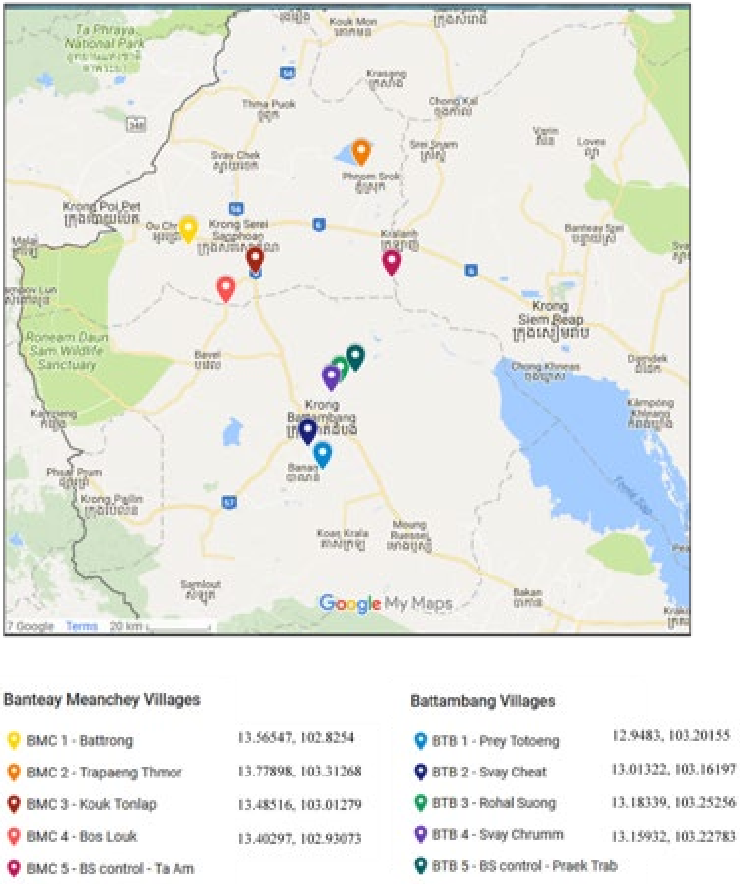

Figure 2. Baseline survey village locations in Battambang and Banteay Meanchey

Midline and endline surveys

This report provides a summary of the key socio-economic and household agricultural production findings of the CamSID project and includes insights from both qualitative and quantitative data capture and analysis. This includes key data from the following methodologies (see Table 1 for an overview, and Table 2 for the villages targeted for each of the quantitative surveys). The CamSID surveys were conducted in key villages that represent both target and scale-out villages. We aimed for a sample of 30 households from each village as this is approximately 10% of total households per village (which is the ideal sample size for a 90% confidence level with 5% margin of error).

Table 1. Socio-economic and farming production data collection

Data collection	Data	Year collected	No of responses	No of villages
Participatory Rural Appraisal	Qualitative	2016	144	8
Baseline survey	Quantitative	2017	524	10
Gender analysis	Mixed method	2018	131	4

Midline survey	Quantitative	2019	196	6
Midline focus groups	Mixed method	2019	56	6
Women's group discussions	Qualitative	2020	58	4
Endline survey	Quantitative	2021	242	8

Table 2. Villages targeted for surveys

Province	Village	**Year conducted: 2017 (n=524)**	**2019 (n=196)**	**2021 (n=242)**
Banteay Meanchey	Battrang	46	37	30
	Bos Louk	52	x	x
	Kouk Tonlap	31	33	28
	Trapaeng Tma	48	x	x
	Ta Am	50	x	x
	Kouk Ballangk	x	36	32
	Spean	x	x	30
Battambang	Prek Trab/Angsangsok	39	30	30
	Prey Totueng	69	x	30
	Rohul Suong	68	x	x
	Svay Cheat	57	33	32
	Svay Chrumm	62	x	x
	Tahen	x	27	x
	Ous Tuk	x	x	30

Survey questions were modified from the baseline questionnaire for subsequent surveys to capture more relevant information and to streamline the survey. However, there are a strong set of core questions that remained the same throughout the project for comparison across the years. Questions covered the following topics: Household members and education; household migration; food security; household assets inventory including livestock and land, household energy and water use, crop production (including: irrigation, land preparation, crop inputs, mechanisation, harvesting drying and selling rice and other crops, gender roles in rice decision-making), aquaculture production, household economics (including income sources, expenditure, credit/loans), and agricultural knowledge and information networks (including extent of involvement in CamSID and in the endline, the impact of Covid-19 on families, farming and livelihoods).

Most questions, especially those regarding agricultural production and income/expenses, were asked for the preceding year. Therefore the 2017 survey (baseline) collected 2016 data and likewise, the 2019 survey (midline) collected 2018 data, with the endline collecting data for the year 2020.

All surveys were deployed digitally using Commcare software and tablets in the field. The baseline and midline surveys were conducted face-to-face with farmers in villages over an intensive period with CamSID staff as well as 20+ students from both National Meanchey University (NMCU) and the National University of Battambang (NUBB). The students received two days of training before executing the survey in villages in groups of two. Approximately 3-4 surveys per group were completed daily with on-ground support to validate responses before uploading. The endline survey was delayed due to Covid-19 but was eventually deployed via the telephone using phone numbers of farmers obtained from other project work, past surveys, village chiefs and local snowballing.

Data were extracted from Commcare and analysed for key trends using excel. Further and more sophisticated analysis via R software is being conducted by Floris van Ogtrop and Van Touch for publication.

1b. Farm household typologies

There are many ways we could categorise households. Dr Grünbühel can provide a rationale for this typology and a more detailed explanation of how it was determined on request. He proposed identifying household types based on impredicative loop analysis (introduced by Giampietro in 2003). The typology approach utilises ideal type households that represent a group of household cases found within the survey. Rather than applying ranges and averages, which may abstract the data to the point that they become unrecognisable, the typology approach uses representations of household, and characterises them according to a limited set of key variables. Impredicative loop analysis (ILA), works with 4 extensive (land, labour, income, energy use) and 4 intensive variables. The intensive variables are intensity or productivity measures drawn from the extensive variables, which are empirically measured (data from the baseline survey). As additional variables, income from cropping only and labour required to conduct rainfed farming have been included (dotted lines). This helps give an indication as to how relevant cropping is for the particular household type. ILA emphasises the total household perspective, not merely the cropping aspect, because they are usually mixed enterprises and cropping can play a variable economic role in the household. This better related to the households' lifeworld experience, which does not separate the farm operation from other livelihood activities.

1c. Social network analysis

The social network analysis (SNA) formed part of an honours thesis by Aaron Junjian Zhang in partial fulfilment of the requirements for the Bachelor of Engineering in Civil Engineering at the University of Sydney. The correlations between social network properties and technology diffusion in rural Cambodian settings. Quantitative data were collected from January to February 2018 in Angsangsak village (adjacent to Preaek Trab village), Battambang Province. Data were analysed using three statistical tools: Pearson's product-movement correlation; independent sample t-test; and the Ordinary Least Square regression model.

1d. Gender analysis of the rice and vegetable value chains

To examine gender roles in the rice and vegetable value chains and female involvement in the agricultural cooperatives in collaboration with Voluntary Services Organisation (VSO), mixed methods involving both quantitative and qualitative data was used to generate data. The gender analysis was conducted across four villages in Battambang province using focus group discussions led by Rebecca Cross and Flavia Ciribello, VSO. A total of 119 women and 12 men participated in this student; women were targeted as the main participants in order to capture their perspectives on gender roles. Focus groups captured information on gender divisions in activities in the rice value chain as well as changes over time and opportunities for increasing women's participation; gender divisions in decision-making about value chain activities; gender roles in agricultural cooperatives as well as factors that inhibit or facilitate increase involvement from women and gender divisions in training offered via the agricultural cooperatives. Rebecca Cross organised a Gender and Social Research Workshop in September 2018 in Battambang and another workshop in February 2019 in Sisophon as a follow-up. Field visits were organised to visit successful low-input vegetable growing and crop rotations from Women in Agriculture Network (WAgN) facilitator, Ms Channaty Ngang in collaboration with Prof Ricky Bates' WAgN project led by Penn State University and Kansas State University and funded by USAID. In February 2020, we conducted focus groups with the women's groups (47 total participants: 10 women in Prey Tetueng (BTB), 7 women in Svay Cheat (BTB), 13 women in Spean (BMC) and 17 women in Battrong (BMC) to understand more on women's learning needs in vegetable production and integrated pest management.

1e. Changes in weed management practices in rice from 2017 to 2020

Two-hundred rice farming households from eight lowland rice villages in Battambang village were surveyed in 2020 using a structured questionnaire with the objectives to determine changes in farmers' knowledge, weed management practices and weed seed contamination in seed kept for sowing since a similar survey in 2017.

1f. Survey of vegetable production in northwest Cambodia

A total of 112 randomly selected vegetable farmers were interviewed across the Battambang province in Northwest Cambodia. In Battambang, vegetable production is concentrated on the alluvial soils along the Sangkae River in Banan and Aek Phnum districts, therefore interviews were predominantly completed in these districts. Along with Aek Phnum and Banan, farmer surveys were also conducted in Rukhak Kiri, Sangkae and Thmar Koul districts. The surveys were completed over a five-month period from January 2019 to May 2019 with farmers surveyed in relation to all vegetable crops grown in 2019 and the most recent or current crop cycle for surveys conducted in January 2019. The surveyed farmers included former participants in the USAID HARVEST project to assess the extent of adoption of improved vegetable production technologies. The survey comprised range of quantitative and qualitative questions where farmers provided information on production of the main diversification crop that was currently grown. This section included questions on sources of advice and information, water supply and irrigation, sources of inputs, experiences with previous extension programs and marketing and sales. The survey also collected details on the cropping calendar. Income from each harvest/picking was recorded as well as the variable costs. All the data were recorded in the local units of measurement and converted during analysis of the results. The information gathered was used to perform an economic analysis (gross margin) of the crop.

1g. Value chain studies for rice, mungbean and vegetables

Value chain studies for rice, mungbean and vegetables were undertaken by University of Sydney Bachelor of Agribusiness and Food students mainly using additional value chain interviews during the baseline survey. Yi Ling Ng conducted 11 independent rice value chain interviews while Ashley Rootsey conducted surveys with different actors in the mungbean supply chain, including two exporters in Phnom Penh. Kim Hour San, a Cambodian student enrolled at the University of Sydney conducted the vegetable value chain surveys on key participant groups consisting of farmers, wholesalers and retailers within the cooperative and traditional market. Key provinces such as Battambang, Siem

Reap and Phnom Penh were chosen based on the proximity to the country's border, distribution centres and volume of vegetable cultivation performance.

5.2 Evaluation of rice intensification options

2a. Cropping calendars

Crop simulation experiments were run using historical climate data from Veal Bek Chan Meteorology Station at Battambang town (13°05' N, 103°13' E) and future climate projection from BC1-CSM1.1 General Circulation Model (BC1) under high Representative Concentration Pathway scenario (RCP 8.5) of the fifth phase of the Coupled Model Intercomparison Project (CMIP 5), which was chosen because of its high capability of climate projection for the study area. The parameters of a Toul Samroung soil, and short and medium durations of rice maturities were used in these simulations. Plant density used was 230 plant per square metre. The simulation experiment was designed to investigate monthly yield effects under past and future climate projection conditions grouped into four timeframes; including 2000s (2000-2009), 2010s (2010 – 2019), 2020s (2020 – 2029), 2030s (2030 – 2039). Soil fertility was reset at each sowing time to avoid confounding with the effects of declining soil fertility. This allowed us to see yield responses to the effects of climate and soil residual water.

2b. Rice planting machinery and sowing rate experiments

This research for development work on drill seeders builds on previous ACIAR funded projects (e.g., CSE-2007-027 and CSE-2009-037). Most known drill seeder options have already been tested in Cambodia. A key strategy in CSE-2015-044 was to focus on improving and promoting existing drill-seeder options rather than rely on Absent Solutions (e.g., testing new imported seeders from other countries).

A series of "near identical" rice planting machinery experiments were conducted by the CamSID team in 2017 and 2018 at Banteay Meanchey and Battambang Provinces as well as in CARDI at Phnom Penh (see Table 3). CARDI experiments were long term experiment that went from 2017 to 2021. **The early wet season (EWS) rice was usually direct drilled using the Kid seeder** (or CARDI drill by CARDI and Ockenden Cambodia) **into dry soil and compared with hand broadcasting while the main season rice (MWS) was usually wet seeded with pre-germinated seed using the mechanised drum seeder or Eli seeder and compared with traditional hand broadcasting.** There are sometimes exceptions to the rule where the rain comes early, and it is possible to sow seed into wet soil in the early wet season (e.g., in 2017) or where supplementary irrigation is available during the dry season.

Table 3. List of main planting machinery experiments during 2017 and 2018 at Battambang (BTB) and Banteay Meanchey (BMC) provinces.

Year	Location	Planting date	Harvest date	Comments
2017	Svay Cheat, BTB	28/06	10/10	Phka Rumduol variety planted in EWS. Drum seeder compared with Eli seeder and hand transplanting (farmer practice)
2017	Don Bosco, BTB	7/07	18/10	Chul'sa variety planted in EWS. Drum seeder compared with Eli seeder and hand broadcast (farmer practice)
2017	Kuok Tonloap, BMC	10/07	13/10	Sen Kra Ob variety planted in EWS. Mechanised drum seeder compared

				with manual drum seeder and hand broadcast (farmer practice)
2017	Svay Cheat, BTB	14/09	-	Sen Kra Ob variety planted in MWS. Drum seeder compared with Eli seeder and hand broadcast (farmer practice)
2017	Daksasa village, Ou Mal Commune, BTB	30/10	-	Sen Kra Ob variety planted in MWS. Mechanised drum seeder compared with Eli seeder and hand broadcast (farmer practice) – demonstration (with 95 farmers attending).
2017	Kuok Tonloap, BMC	30/09	03/01	Sen Kra Ob variety planted in MWS. Mechanised drum seeder compared with Eli seeder and hand broadcast (with farmers 180 attending).
2018	Kuok Tonloap, BMC	25/04	17/08	Sen Kra Ob variety planted in EWS. Kid seeder at 20, 40, 60, 80 kg/ha compared with hand broadcast at 180 kg/ha
2018	Kuok Tonloap, BMC	5/05	24/09	Sen Kra Ob variety planted in EWS. Mechanised drum seeder at 20, 40, 60, 80 kg/ha compared with hand broadcast at 180 kg/ha
2019	Oambal Sisophon City, BMC	15/01	28/03	Sen Kra Ob variety planted in dry season. Mechanised drum seeder at 20, 40, 60, 80 kg/ha compared with hand broadcast at 180 kg/ha

A common set of fertiliser rate by sowing rate experiments were conducted both by CamSID at Kouk Tonlap Village, Banteay Meanchey province and CARDI at Pursat Province. The objective was to determine the effects of varying fertiliser and seeding rates on rice yield and its components and incidence of disease and insect pests. The experiment was in a split-plot design with three levels of fertiliser, five seeding rates and three replications. Main plots were fertiliser rates (low: N-50, P-40 and K-30 kg/ha; medium: N-75, P-60, K-40 kg/ha, and high: N-100, P-80 and K-50 kg/ha. The fertiliser was applied in two applications; the first at mid-tillering and the second at one week before flowering (note: this application should be made at panicle initiation). Subplots were seeding rates: 20, 40, 60, 80 kg/ha drill seeded by Kid seeder and 180 kg/ha (hand broadcast).

2c. Rice best management package

Site-specific nutrient management (SSNM)

On-farm field demonstrations were conducted with rice growers in Svay Cheat village during the main wet season for the 2018 growing season. In the 2019 growing season, more field demonstrations were conducted in Svay Cheat, Kampong Preng and Tahen villages in Battambang province for the early wet season. The fertiliser N estimated with SSNM varied across locations due to variations in the indigenous soils N supply (Figure 3). Fertiliser N was top-dressed at the panicle initiation stage across seasons and locations. Other neighbouring farmers imitated our practice by applying more fertilisers to maintain similar green canopy cover in the fields as they observed in the NDVI and N-rich plots.

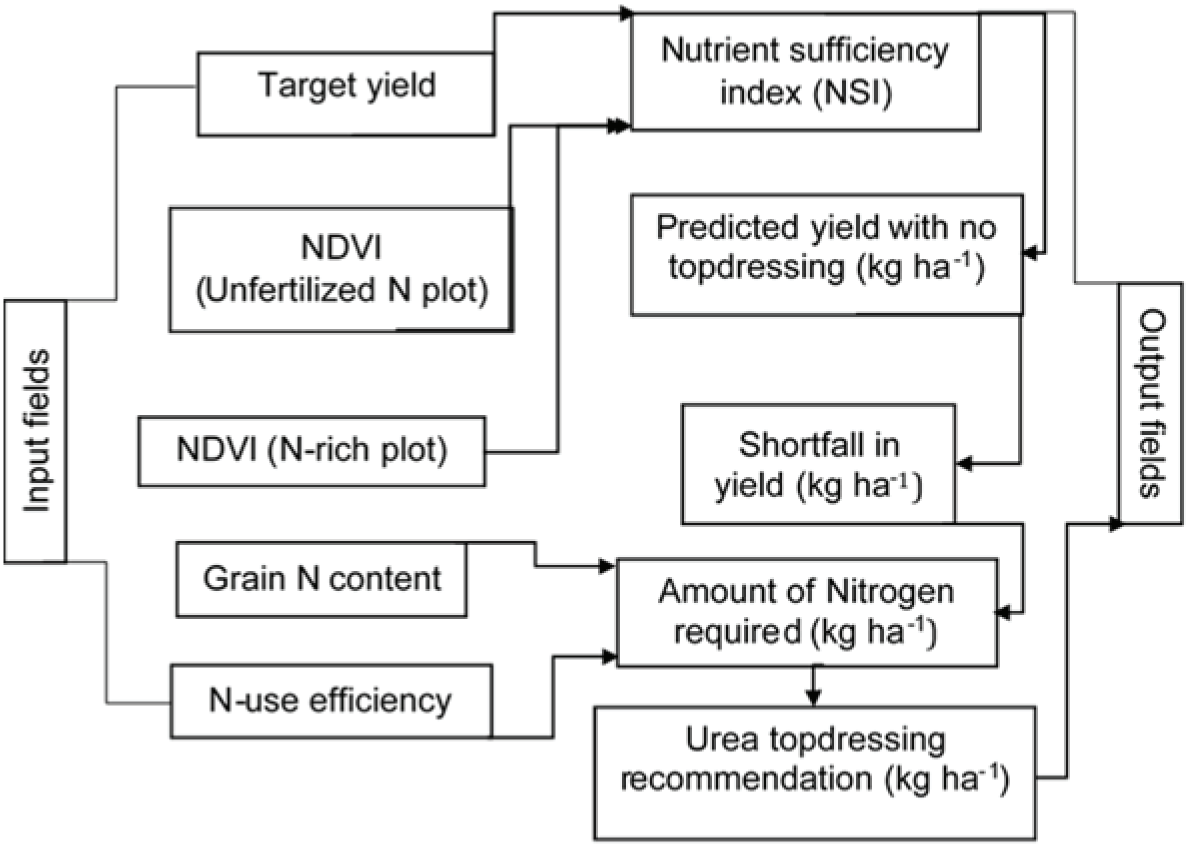

Figure 3. Flowchart of SSNM showing the input and output parameters used for estimating N fertiliser topdressing (Credit: Chinaza Onwuchekwa-Henry).

NDVI readings were collected from N-rich plots and farmer's plot at the panicle initiation (PI) stage. Measurements were also taken from the NDVI plot in the transect of each treatment by holding a GreenSeeker at 0.6 m above rice canopy to obtain a representative value. The mean NDVI values obtained from both N-rich and unfertilised plots were used to estimate the amount of urea N to be top-dressed in the SSNM plots in each field by following the procedures described above.
Grain yields were obtained using 1 m^2 quadrat in each plot at harvestable maturity 14% moisture content. The descriptive statistics of the grain yield from the SSNM plots were calculated for both the 2018 and 2019 growing seasons. Gross margin (GM) and total N fertiliser cost (TFNC) were estimated using the different fertiliser treatments (equations 1 and 2).

$$\mathrm{GM} = \mathrm{TVC} * \mathrm{PR} * {}^{\mathrm{GY}}/_{1000} \qquad \text{———— ——— —(equation 1)}$$

$$\mathrm{TFNC} = \mathrm{PN} * \mathrm{FN} \qquad \text{—— ———————(equation 2)}$$

The grain yield in the unfertilised plots for each field calculated the indigenous N supply. The agronomic efficiency (AE) and partial factor productivity (PFP) were estimated as useful measures of nitrogen use efficiency for each N treatment as described in equations 3 and 4.

$$\mathrm{AE} = \frac{\mathrm{GY_f} - \mathrm{GY_0}}{\mathrm{TN\ applied}} \qquad \text{— — ——————— —(equation 3)}$$

$$\mathrm{PFP} = \frac{\mathrm{GY_f}}{\mathrm{TN\ applied}} \qquad \text{— ————————— (equation 4)}$$

GY is rice yield (t ha^{-1}), TVC means total variable cost (US\$ ha^{-1}), PR is the price of rice (US\$ ha^{-1}), TFNC is total fertiliser cost N (US\$ ha^{-1}), PN means the price of N fertiliser (US\$ ha^{-1}) and FN means fertiliser input (kg ha^{-1}). Then, GYf and GY0 represent grain yield from the fertilised and unfertilised plots, respectively. AE means units of yield increase per unit of nutrient applied (kg kg^{-1}), and PFP indicates units of crop yield per unit of nutrient.

Pre-emergence herbicides for dry direct seeded rice in the early wet season

During a survey in 2017, it was noted that most smallholder farmers were reliant on post-emergence herbicides to control weeds and no farmers actually used any pre-emergence herbicides for dry direct seeded rice during the early wet season. A series of experiments with pre-emergence herbicides were conducted at both CARDI (Phnom Penh) and CamSID Battambang team at Don Bosco Agri-Tech Center, Battambang (during June and October 2019, 2020) to compare four pre-emergence herbicides for dry direct seeded rice. The pre-emergence herbicide treatments were butachlor, oxadiazon, pendimethalin and pretilachlor + fenclorim +/- post-emergence bispyribac-sodium arranged in a randomised split-plot design in four replications with post-sowing pre-emergence herbicide treatments as the main plots and pre-emergence herbicide as the sub-plots.

2d. Collaboration with CAVAC on Unmanned Aerial Vehicles (UAVs)
Initially, CamSID proposed that UAVs (drones) could be used for mapping land levels for use with laser levelling. However, the drone land levels are not accurate because constant height above the ground cannot be maintained. Satellite land levels are more accurate than drone. We also calibrated drone Normalised Difference Vegetation Index NDVI against ground-based NDVI (GreenSeeker®) and found that drones can be used to estimate crop biomass using NDVI.
Since 2019, drone technology has been rapidly adopted and it is estimated that there are now more than 200 commercial spray-drone operators in Cambodia. On 29th June 2021, Bob Martin met with Mr Sourn Sophoan, CAVAC in Battambang to discuss collaboration between CamSID and CAVAC. A survey was conducted by Dr Bob Martin on behalf of CamSID and CAVAC to learn about experiences of service providers as early adopters of the use of Unmanned Aerial Vehicles (drones) in rice cropping systems in Cambodia. The possibilities include application of agricultural chemicals and aerial seeding of rice. We sought to learn more about their experiences as an owner or service provider for agricultural drone. We asked detailed questions about their assessment of the advantages and disadvantages of drone applications, how it can be improved and the potential for increased adoption. Twelve drone service providers have been interviewed by phone so far.

5.3 Diversification: Mungbean varietal evaluation

During consultation with smallholder farmers (in Objective 1), farmers wanted to access mungbean varieties that had large seed (for sprouting) and also non-shattering (for machine once-over harvest). Hence, we conducted the varietal evaluation in consultation with the rice-mungbean farmers.
A series of experiments and demonstrations were carried out over four years from 2018 to 2021 as described below.

Experiments in 2018
Replicated experiments were conducted at the National University of Battambang (NUBB) (13°05’05” N; 103°13’11” E) and Don Bosco Agro Technical School (DBAS) (13°04’37” N 103°10’24” E) in Battambang province. The nine mungbean varieties included in the experiments were: CARDI Chey, CMB-3 (Cambodia); CN-36, SUT-1 (Thailand); DXVN-07, V-94208, XANH-044 (Vietnam); and locally grown varieties DX 208 (Vietnam) and KPS-2 (Thailand). The experimental design was a randomized complete block with four replicates. The plot size was 1.8 * 6 m with mungbean seed planted in 6 * 30 cm rows, 25 cm spacing between hills and three seeds per hill giving a target plant population of around 400,000

plants ha^{-1}. Assuming a mean of 17,300 seeds per kg, this gave an estimated seeding rate of 23 kg ha^{-1}.

Experiment in 2019
A Cambodian government import certificate was obtained for eleven Australian public mungbean varieties. The mean weight of the samples was 22 g with an estimated mean of 397 seeds which was sufficient to plant approximately 13 m^2. The small quantity of seed available ruled out the possibility of replication of the Australian varieties. A field experiment was designed to include the locally grown varieties (DX-208, KPS-2) and the Cambodian varieties (CARDI Chey, CMB-1, CMB-2, CMB-3).

Seed increase demonstration in 2020
A seed production demonstration was located at DBAS in a 1.2 ha field following rice. The field was divided into six plots of 0.2 ha each for the variety treatments: CARDI Chey; CMB-1; CMB-2; CMB-3, DX-208 and KPS-2. The demonstration was planted on 25th December 2019 into a dry seedbed using a 4-row tractor-drawn disc planter set up in 60 cm rows to give a seeding rate of 23 kg ha^{-1}. This would achieve a plant population of 25 plants/m^2 assuming a 100 seed weight of 7.0 g, 95% germination and 80% establishment. The isolation distance between plots was 3 m with four rows of sunn hemp (*Crotalaria juncea* L.) planted in the isolation zone. Row spacing of the sunn hemp was 60 cm and planted at the same rate as the mungbean.

Experiments in 2021
One experiment was located at DBAS on the dry season and another at Catholic Mission, Tahen in the wet season. The previous crop at DBAS was rice which was combine-harvested at the end of October 2020. The experiment was laid out in a randomized complete block design with four replicates. Plots were 1.5 * 5.0 m with four rows at 30 cm spacing. Single seeds were planted at 15 cm spacing within rows (22 seeds m^{-2}). The experiment in the wet season was located in a non-rice area on Toul Samroung soil. The experiment was laid out in a randomized complete block design with four replicates. Plots were 2.0 * 6.0 m with five rows at 40 cm spacing and within-row plant spacing of 10 cm. (25 seeds m^{-2}).

5.4 Diversification: Watermelon

Watermelon variety trials in 2018
Watermelon variety trials in Svay Cheat Village and Sisophon, Banteay Meanchey during the dry season in 2018. At Svay Cheat village, BTB, the demonstration was conducted in 2,100 m^2 on Mr Wantha’s rice field with two varieties Superman and C 29. They were demonstrated using two different protocols (full and partial protocol) compared with farmer practice. The detailed technologies and treatments are shown below (Table 4).

Table 4. Comparison of different technologies for watermelon production.

No	Technology Protocol	Full technology	Modified technology	Farmer practice
1	Raised seedbed	0.3 m height	0.3 m height	Not done
2	Plastic mulching	Full surface Covered	Partial surface covered	Not mulching
3	Plant density & spacing	10,000/ha (0.4 x 0.4 m)	10,000/ha (0.4 x 0.4 m)	5,000/ha (1 x 1m)
4	Pruning, pollination and fruit selection	Manually, 1 fruit/plant	Manually, 1 fruit/plant	Manually, 1 fruit/plant
5	Irrigation, Fertilization & Pesticide	Same as at MCU	Same as at MCU	Same as at MCU

At Sisophon, BMC, the experiment was established in the dry season on a farmer's field next to Meanchey University (MCU). The objectives were to evaluate eight (8) watermelon varieties including two from Syngenta (Superman and Hoang Chau), two from East West (EW06, CB05), two from Agriance (Red Moon and 020 F1) compared to two Thai varieties (C28, C29) currently planted by farmers in NW Cambodia. The seedlings were planted into raised seedbed with plastic mulch and irrigated using drip irrigation. Pruning was manually done; pollination was done by insects and wind; and kept to one fruit per plant (according to Vietnamese technique).

Watermelon agronomic experiments in the dry season at Banteay Meanchey in 2019
In the dry season, watermelon was planted on 14th January and harvested on 10th March 2019. The treatments (with four replicates) were:
T1 – Direct seeding into hole
T2 – Plough, flat planting
T3 – Plough, raised seedbed – bare soil
T4 – Plough, raised seedbed – straw mulch
T5 – Plough, raised seedbed – plastic covering (black and silver).

5.5 Diversification: Fish and fingerling production

Mr. Yann Sophon, 65 years old who is experienced in growing rice for over 30 years, is an outstanding farmer living in Battrang village, Samraong commune, Ou Chrov district, Banteay Meanchey Province. He is also a leader of Seed Production Group which started in 2013, lately upgraded as an Agricultural Co-operative in 2019, named Samraong Meanchey Seed Production Agricultural Co-operative.
In 2017, CamSID organised for lead farmer, Mrs Champey to train six farmers in raising Nile tilapia (*Oreochromis niloticus*) at Battang Village in February 2018. Nile tilapia had a high demand from Cambodian weddings and social ceremonies. However, the fish were dying at high stocking rates and an experiment was set up to determine optimum stocking densities:
Layout: the experience with 3 treatments and 3 replicates were designed as Completely Randomized Design (CRD).
Density: small size Tilapia (about 14-18 g/fish) were released at 3 densities: 50 fishes/cage, 75 fishes/cage, 100 fishes/cage in the pond without aeration.

5.6 Diversification: Using a soil penetrometer to identify lowland rice soils suitable for growing non-rice crops

Soil pits were dug and soil profile descriptions were completed for six CamSID field sites in February 2020. Kouk Tonloab, Os Tuk, Svay Cheat and Ta Haen Muoy were classified as Toul Samroung (Luvisol) and the soil at Preaek Trab was classified as Kein Svay (Fluvisol). The area of mungbean and other diversification crops planted after harvesting rice in lowland rice areas in Cambodia is constrained by hard pans, or plough pans, on the majority of soil groups. It was originally proposed to use EM 38 in CamSID to support the use of APSIM to evaluate subsoil constraints and soil water holding capacity. However, soil penetrometers are a more effective tool that can be used to measure the extent and depth of sub-surface soil compaction. A soil penetrometer (Eijkelkamp®) was used to determine the strength of sub-soils down to 50 cm at five CamSID experimental locations and to estimate potential rooting volume on soils in the project focus region. The penetrometer can be fitted with cones of 1.0, 2.0, 3.3 or 5.0 cm^2 surface area. The small cone is used for high resistance values and the larger ones for low values. The larger the cone, the more accurate the value of the resistance measurement. Depending on the cone size, the cone resistance in Neutrons/cm^2 can be read from a chart. We used the 3.3 cm^2 cone.

Penetrometer readings were taken when the whole root-accessible soil profile is most likely at/or above field capacity under saturated soil conditions. The idea behind using the penetrometer when the soil is saturated is that this is the best-case scenario for root development. It is expected that the soil profile will be in a similar condition at the time of planting diversification crops following rice harvest at the end of the wet season. During this period, roots will be able to penetrate soil that has low penetration resistance. Penetration resistance will increase when the soil dries out, and root growth can then be expected to be limited. A total of 950 soil strength readings were taken. These were at five depths (10, 20, 30, 40, 50 cm) at 10 locations per field in four fields at Don Bosco, Os Tuk, Preaek Trab and Svay Cheat and in three fields at Ta Haen Muoy. Readings were taken every 15 to 20 m, depending on the shape and size of the field.

5.7 Scaling case studies

From the baseline survey, it was evident that Banteay Meanchey Province was a much poorer and "remote" province with very few foreign aid projects. It was mainly serviced by an NGO, Ockenden Cambodia and most aid organisations such USAID, CAVAC and IRRI did not operate in Banteay Meanchey. Battambang Province on the other hand, had numerous aid organisations such as ASPIRE, CAVAC, CIRAD, IRRI, JICA, USAID, HARVEST and VSO projects operating.

Hence, in Banteay Meanchey Province, Syngenta Foundation (SFSA) and Ockenden Cambodia worked to establish SFSA farmer hubs to facilitate existing farmer groups better in seed production and machinery contracting. The initial key case study villages focussed on were the target villages, Battrang and Kuok Tonloap. This was scaled and expanded to Spean Sraeng, Boslouk, Thmor Puok and Kuok Ballangk (serviced by Ockenden Cambodia) with farmer field schools.

On the other hand, at Battambang province, CamSID collaborated with VSO, IRRI and CAVAC to scale the planting machinery (e.g., Kid and Eli) to existing farmer groups. The initial key villages were Svay Cheat, Praek Trab and Angsangsak and this was expanded to the Catholic Mission at Tahen and the Kamping Puoy and Kampong Preang Agricultural Cooperatives (ACs).

Both strategies in each province were complementary based on the needs of smallholder farmers in each province and focussed on improving best management practices including the use of planting machinery.

5.7.1 SFSA hubs case studies at BMC

"*SFSA has 'created' Farmers' Hubs from existing farmer groups and Agricultural Cooperatives; specifically designed to provide multiple services to smallholder farming communities such as the purchase of inputs including seeds, selling farm produce, and access to machinery. Farmers' Hubs are initiated to develop a self-sustaining profitable business. They are not a one-size-fits-all solution but a method for determining what is missing in terms of services in a local community and developing a business model for how this gap could be filled*".

In North West Cambodia, SFSA rolled-out a three-year plan (from 2019 to 2021) to establish two Farmers' Hubs to

- Deliver high quality seeds: rice seed production and processing unit upgrade - Yann Sophon, Battrong village
- Provide mechanized services (rice land preparation and direct seeding) - Chiv Sarith, Banteay Neang commune, Kuok Tonloap village.
- SFSA investigated for the establishment of a farmer hub dedicated to Vegetable seedling production but could not anchor this hub to a robust vegetables value chain

Even though individual entrepreneurs are the focus of training and skills development, they have developed business models that use the existing cooperative relationships.

We are now at the end of the implementation phase (Figures 4.1 and 4.2). The final year, 2021 was dedicated to the write-up of pitch document (including the main parts of the plan hereunder) and a satisfaction survey to evaluate the performance of each Farmer Hub to identify potential investors to scale-up this "*solution delivery vehicle*" approach in Cambodia.

The two farmer hub pilots are conclusive. The income generated is profitable and sustainable for the farmer hub owners. The services provided are cost-effective and satisfactory for the farmers. And the whole farming community is benefiting from this created momentum which contributes to increase rice productivity and Household income.

The two farmer hubs pilots are proven "scalable". SFSA is now looking for partners to take-over this concept and support the establishment of hundreds of farmer hubs delivering the same services and high-quality seeds to farmers in Cambodia support more farmers if possible.

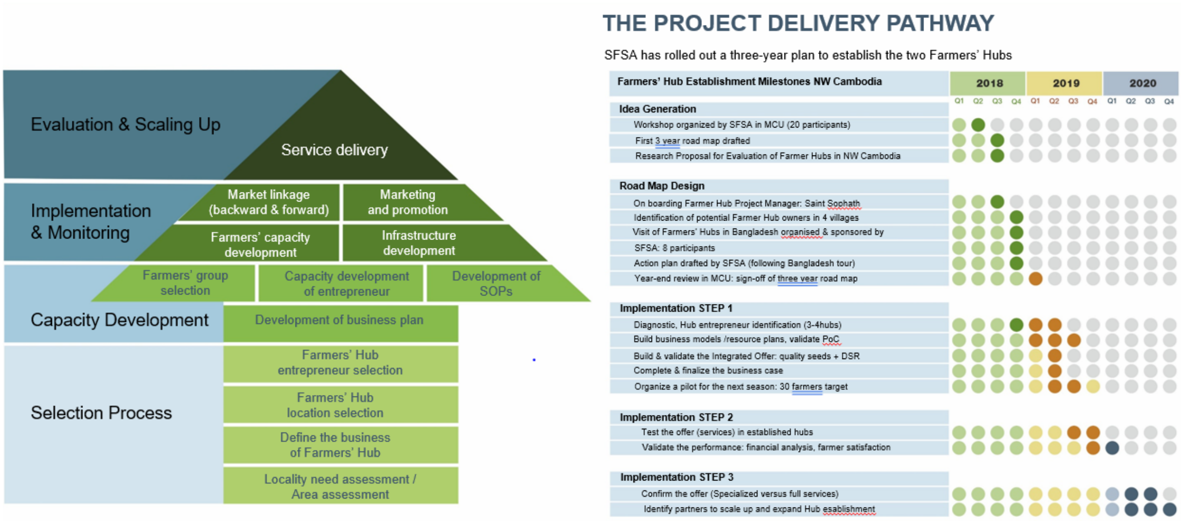

Figure 4.1. Delivery pathway of Syngenta Foundation farmer hub activities at Banteay Meanchey Province.

Total rice acreage in Northwest Cambodia is around 200,000 Ha. Assuming 30% adoption at farm gate in 2025, 60,000 Ha could be serviced by the Farmers' Hub integrated offer.

It would represent the following activity:	Land Prep & DSR	High quality seeds
Ha reached by 1 Farmers' Hub at peak	120 Ha	1200 Ha
Number of Farmers' Hub needed at peak to reach 30% ha adoption (60,000ha)	500	50
Total gross income generated by all Farmers' Hub	$ 7.98 M	$ 2.88 M

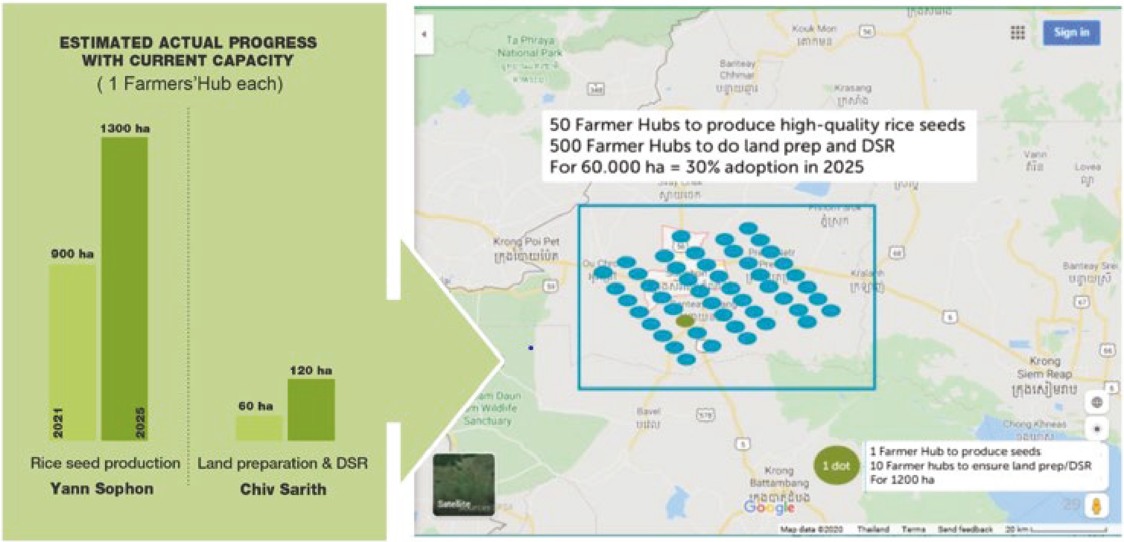

Figure 4.2. Scalability plan of Syngenta Foundation farmer hub activities at Banteay Meanchey Province.

Video of Syngenta Foundation farmer hubs:

https://www.youtube.com/watch?v=xcEJRekIL2k

5.7.2 Planting machinery scaling case studies with farmer groups at Battambang

Planting machinery (e.g., Kid and Eli planters) have been tested and scaled to the target villages such as Svay Cheat village since 2017. In 2018-2019, CAVAC provided support for the purchase of the Kid and Eli planters by community groups in the form of a 30% subsidy. Initially, Mr Makara Wantha led the Eli planter demonstrations and contracting but he took on agricultural drone contracting. Mr Makara trained a replacement Eli contractor which has enabled Eli planting to continue in Svay Cheat and other villages. A field day was held on 5 June 2019 attended by nine farmers interested in machine planters.

During the scaling out phase, Tahen village and two agricultural cooperatives (ACs) outside the CamSID target villages have become active CamSID hubs, especially for the scaling out of machine planters in Battambang province. They are the Kampong Preang AC and the Kamping Pouy ACs. Both of these ACs received business management training from CamSID partner, VSO since 2017. The Kampong Preang AC has successfully established its service provision business for the Kid seeder, so CamSID has been focussed on assisting the Kamping Pouy AC in 2020 and 2021.

CamSID collaborated with the Catholic Mission (https://www.catholicmission.org.au/) Tahen project, funded by Rural Funds Management, Australia (https://ruralfunds.com.au/) from 2019 to 2021 to demonstrate drill seeding and improved practices for rice. CamSID has loaned a Kid drill seeder to the Tahen project and the Tahen farmers did the planting. Th Tahen project has since purchased their own Kid seeder and have planted around 50 ha of rice with the Kid since 2019. They have also used the Kid to plant cowpea, maize, mungbean, soybean and sunn hemp with minimum and no-tillage. **CAVAC provided a 30% subsidy for purchase of the Kid seeder (in which around 18 Kid seeders were purchased mainly by service providers).** There are 10 key farmers affiliated with the Tahen project and so far, they have received training from CamSID on:

- Reduced tillage and soil moisture conservation;
- Seed cleaning, seed dressing and seeding rate;
- No-till fallow management and pre-emergence herbicides;
- Operation of the Kid seed drill and Eli air seeder;
- Spray drone application of pre-emergence herbicides to rice;
- Improved varieties and integrated pest management (IPM) for mungbean.

The Tahen farmers initially expressed interest in the Kubota broadcasting machine but after comparisons with the Kid in 2019, they stopped using the broadcasting machine.

The Kamping Pouy Hub has 158 farmer members with a total of 810 hectares of rice. The Kid contract price is now $27.50. The Hub plans to plant >600 ha with drill seeders in 2020. The Hub would like to see a lower seeder contract rate/ha. They can work this out between themselves. Machinery service providers operate in a highly competitive environment and generally offer services that eat into profit margins and sometimes are below break-even. Contract rates based on ownership costs, operating costs, depreciation and profit margins are given in Table 5. Under the current arrangements, some service provision businesses are not viable.

Table 5. Calculations of contract rates based on the full costs of machinery operation

Calculating a contract rate per hour	Rate/hr	Laser leveller	Disc plough	Rotavator	Broadcast machine	Kid Rice Drill	Kubota Rice Drill
Tractor horespower		80	80	80	80	80	50
Ownership + operating costs (tractor + implement)		$ 24.10	$ 21.48	$ 21.59	$ 21.23	$ 22.40	$ 17.98
Labour required	$ 1.00	2	1	1	1	1	1
Machine repairs and maintenance rate (%)		10%	10%	20%	10%	15%	10%
Machine repairs and maintenance rate (%)		$ 1.14	$ 0.23	$ 0.53	$ 0.14	$ 0.83	$ 0.20
Costs plus labour and maintenance	$ 1.00	$ 27.24	$ 22.71	$ 23.12	$ 22.37	$ 24.23	$ 19.18
Contingency margin (5% of job cost sub-total)	5%	$ 1.36	$ 1.14	$ 1.16	$ 1.12	$ 1.21	$ 0.96
Profit margin (20% job cost sub-total)	20%	$ 5.45	$ 4.54	$ 4.62	$ 4.47	$ 4.85	$ 3.84
Margins sub-total		$ 6.81	$ 5.68	$ 5.78	$ 5.59	$ 6.06	$ 4.79
Hourly contract rate		$ 34.05	$ 28.39	$ 28.90	$ 27.96	$ 30.29	$ 23.97
Width of machine (m)		3.2	1.6	1.9	10.0	2.1	10.0
Speed (km/h)		0.04	6.00	6.00	8.00	5.00	1.00
Work rate (ha/hr)		0.13	0.96	1.14	5.00	1.00	1.00
Efficiency rate (%)		80%	90%	80%	80%	80%	80%
Actual operating speed (ha/hr)		0.10	0.86	0.91	4.00	0.80	0.80
Hectare contract rate		$ 333	$ 33	$ 32	$ 7	$ 38	$ 30

The Kamping Puoy AC is moving to plant more Phka Rumduol rice in 2020 (600 ha). The AC received support on business management from VSO and they have a contract to deliver Phka Rumduol rice to the Battambang Rice Investment Company (BRICo) mill. They follow Sustainable Rice Platform (SRP) protocol and they are seed producers. In May 2020, CamSID provided Kid and Kubota planters on loan the Hub and left them to decide their own service provision models. There is no single planting service provider in Kamping Pouy and the planters are being passed from one member to another as required.

Quite a few hectares have been planted but, being typical farmers they have immediately wanted to change things. The operator of the Kid wanted to take the rollers off and the Kubota operator wanted to increase the seeding rate. Operating the machines at excessive speed is also a problem. These are typical scaling-out teething problems but the Kamping Pouy Hub is progressing well with adaptation and adoption of mechanised seeding. A set of adjacent fields has been set up in the Kamping Pouy Hub to allow comparison of the Kid, Kubota, Eli seeders with hand broadcasting (Figure 5). Herbicide experiments are also established in the Kid and Kubota planted fields.

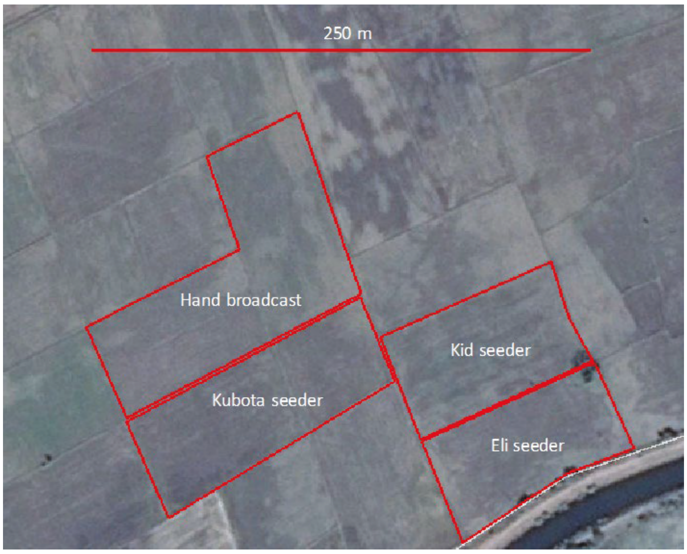

Figure 5. Kamping Pouy Hub seeder demonstration site

Machine row planting (dry seeding) and pre-emergence herbicide demonstrations for rice in Battambang (2021)

A series of demonstrations were conducted in a collaboration between CamSID and the IRRI EPIC project. The purpose of these demonstrations was to scale-out machine row planting of rice together with elements of best practice recommendations developed by CamSID and EPIC for direct-seeded rice. The best-practices included: (a) use of pre-sowing herbicides and reduced tillage; (b) reduced seeding rates and use of quality seed; (c) seed treatment with insecticide and fungicide; (d) application of pre-emergence herbicide; (e) tactical application of post-emergence herbicide, (f) use of biological pesticides.

The demonstration treatments were not replicated but the demonstration has been established in 12 fields so far on 10.6 ha in six villages (Table 4). Four more demonstrations are planned for Ou Ta Nhea (2) and Tahen (2) villages. Field 1 was planted with a Kubota seed drill, field 11 was planted with the Eli planter and fields 2-10 were planted with a Kid seed drill at 75 kg/ha in 30 cm rows (see Table 6).

Table 6. Details of demonstration sites established in Battambang Province (2021)

No.	District	Commune	Village	Area (ha)	Date sown	Pre-em applied
1	Aek Phnum	Preaek Norint	Rohal Suong	0.5	3-Jun	3-Jun
2	Aek Phnum	Preaek Norint	Rohal Suong	1	2-Jun	3-Jun
3	Aek Phnum	Preaek Norint	Rohal Suong	0.5	2-Jun	3-Jun
4	Banan	Bay Damram	Prey Toteung	1	13-May	Not done
5	Battambang	Ou Mal	Ou Mal	2.9	24-May	25-May
6	Battambang	Ou Mal	Boeng Reang		11-Jun	12-Jun
7	Sangkae	Kg Preang	Os Tuk	0.7	28-May	30-May
8	Sangkae	Kg Preang	Os Tuk	0.5	28-May	30-May
9	Sangkae	Kg Preang	Som Bok Ork	0.7	15-May	16-May
10	Sangkae	Kg Preang	Som Bok Ork	0.9	20-May	21-May
11	Sangkae	Reang Kesei	Svay Cheat	1.2	11-May	12-May
12	Sangkae	Reang Kesei	Svay Cheat	0.7	28-May	29-May

Pre-emergence herbicides for dry drill-seeded rice (butachlor, oxadiazon) were applied using Unmanned Aerial Vehicle (UAV) drones 1 day after sowing at 1 L/ha in all the demonstrations. Pre-emergence herbicides were applied using an UAV in a water volume of 14 L/ha (Table 7).

Table 7. Pre-emergence herbicide treatments

Pre-emergence treatment	Active ingredient (g/kg)	Rate/ha
Nil	-	-
Antaxa 250 EC (oxadiazon)	250	1.0 L
Kago 62 EC (butachlor)	620	1.0 L

Sen Kra-ob rice variety was planted on the demonstrations with the Thai Kid planter on 11th May at 75 kg/ha and pre-emergence herbicides (butachlor and oxadiazon) applied on 12th May. Establishment counts and Canopeo readings were taken during crop growth. Canopeo is an image analysis tool using colour values in the red–green–blue (RGB) system. Farmer Field School (FFS) events were held during crop stages and final yields were obtained from cooperating farmers.

Pre-emergence herbicide demonstrations in wet direct-seeded rice with BB2C Eli planter (2021)

Farmers in the Kampingpuoy irrigation area have begun to adopt post-sowing pre-emergence application of pretilachlor + fenclorim in wet-seeded rice. The IRRI recommendation for wet direct-seeded rice is to apply pretilachlor + fenclorim safener prior to weed emergence at 1 to 3 days after sowing (DAS)
. The safener, fenclorim, mixed with pretilachlor enhances herbicide tolerance in cultivated rice without affecting herbicidal susceptibility in the target weed species, including weedy rice [1]. Currently in Cambodia, there are six registered products containing pretilachlor + fenclorim as well as four products containing pretilachlor only (Table 8). However, most farmers in Battambang are using the products containing pretilachlor without fenclorim only because they are cheaper.

Table 8. Registered herbicide products containing pretilachlor

Registration No.	Expiry date	Trade name	Active ingredient	Manufacturer
FR01 2289/0920 SPK-DAL	05/04/2024	A-Bomb 500 EC	Pretilachlor	Dot Green, China
FR01 5506/0719 ADC-DAL	24/07/2022	Dietman 360 EC	Pretilachlor	Allied Development, Vietnam
FR01 1462/0419 MAP-DAL	04/05/22	Map Famix 30 EC	Pretilachlor	Map Pacific, Vietnam
FR01 5295/0419 YBA-DAL	29/04/2022	Yellowsof 300 EC	Pretilachlor	Nanjing Ecofarm, China
FR01 3526/1119 NLD-DAL	20/09/2019	Lifit 360 EC	Pretilachlor + Fenclorim	Nileda,
FR01 2081/0919 GRA-DAL	02/09/22	Bigson-Fit 300 EC	Pretilachlor + Fenclorim	Cong Ty, Vietnam
FR01 1417/0619 THC-DAL	13/06/2022	Dodofit 300 EC	Pretilachlor + Fenclorim	Cong Ty, Vietnam
FR01 3164/1119 HP-DAL	27/11/2022	Elipza 300 EC	Pretilachlor + Fenclorim	Horizon Pacific, Vietnam
FR01 0100/0719 AG-DAL	24/07/2022	Sofit 300 EC	Pretilachlor + Fenclorim	Syngenta, Vietnam
FR01 2014/0619 HAI-DAL	13/06/2022	Tomtit 360 EC	Pretilachlor + Fenclorim	Hai Agrochem, Vietnam

During the early wet season in 2021, a series of demonstrations of pre-emergence herbicide options for dry-seeded rice were established using a 4-wheel tractor Kid drill planter (Table 9). If farmers agree, these fields will be re-planted using a BB2C Eli version 3.0 2-wheel tractor air seeder in September 2021. These demonstrations were in collaboration with IRRI in the new Excellence in Agronomy (EiA) CGIAR project.

Table 9. Site details for pre-emergence herbicide demonstrations with BB2C Eli seeder

No.	Village	North	East	Area (ha)	Planting date
1.	Svay Cheat	12.939574°	103.252330°	0.7	31-Aug
2.	Prey Toteung	12.938417°	103.201972°	1.0	14-Sep
3.	Svay Cheat	12.923976°	103.247620°	1.2	14-Sep
4.	Preaek Norint	13.184186°	103.232550°	0.5	1-Oct
5.	Rohal Suong	13.188141°	103.245357°	0.5	Not rice
6.	Som Bok Ork	12.929878°	103.295693°	0.9	1-Oct
7.	Svay Cheat	12.924042°	103.242877°	0.7	5-Oct
8.	Som Bok Ork	12.929472°	103.245357°	0.7	15-Oct
9.	Ta Haen Muoy	13.080397°	103.269394°	3.5	15 Oct
10.	Rohal Suong				30-Oct
11.	Os Tuk	12.963441°	103.344778°	0.7	5-Nov
12.	Os Tuk	12.966767°	103.345220°	0.5	5-Nov

Herbicides were applied using an Unmanned Aerial Vehicle (UAV), drone, with an effective spray width of 6 m and runs per treatment plot will vary according to the length and width of the field. The tank capacity is 16 L and the water volume used is typically 10-12 L/ha.
Pre-emergence herbicides (pretilachlor and pretilachlor + fenclorim) are applied 1 to 3 days after sowing (DAS) (Table 10).

Table 10. Pre-emergence herbicide treatments for wet-seeded rice

Pre-emergence treatment	Active ingredient (g/kg)	Rate/ha
Nil	-	-
A-Bomb (pretilachlor)	500 g/L EC	1.0 L
Lifit (pretilachlor + fenclorim)	360 + 120 g/L EC	1.0 L

Survey on factors affecting the adoption of the Kid planter

Trials with the Thai Kid machine planter were commenced in 2016 in Battambang and Takeo by Harvest Center Cambodia and CAVAC. CamSID Battambang initiated scaling-out partnerships in 2017 with Voluntary Service Overseas (VSO) and CAVAC focussed on Agricultural Cooperatives (ACs) such as Kampong Preang to implement Activity 3.1 “most effective farmer group approach identified for scaling up and out”. VSO provided support to the ACs for governance, group development and the Sustainable Rice Platform (SRP) to underpin business ventures and collective marketing contracts with rice mills. CAVAC provided a 30% subsidy for purchase of the Kid machine planter for service provision to members. This opened up business opportunities such as pure seed production for the ACs. CamSID’s role was to provide training and demonstration of SID production technologies developed and refined by the project. A survey of factors affecting the adoption of the Thai Kid machine planter for rice was carried out in four ACs and an IRRI group in Battambang province where the Thai Kid had been adopted. Between October and December 2020, we interviewed 10 AC “adopters” of machine planting and 10 AC “non-adopters”. A third group of 10 non-AC members was also interviewed in each village (Figure 6).

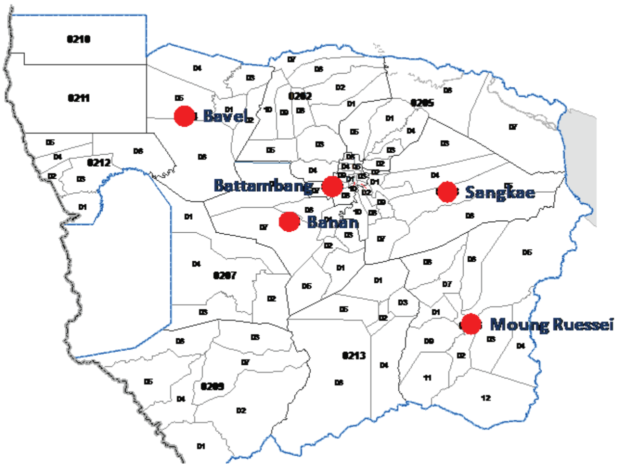

Figure 6. Districts where the survey was carried out

The objectives were to:

1. Analyse the differences between (a) AC member adopters, (b) AC member non-adopters and (c) non-AC member farmers with respect to factors affecting adoption of machine planting of rice;
2. Identify and explore alternative community networking options to overcome barriers to adoption of machine planting.

A total of 144 households were interviewed including 62 (43%) Kid adopters and 82 (57%) non-adopters (Table 11). Where possible, the interviews were conducted by phone, thus avoiding unnecessary visits to villages during the COVID-19 pandemic. Farmers credited the ACs as the primary source of information with farmer-to-farmer transfer being a significant second. Donors (CamSID, CAVAC, IRRI, VSO) were also strongly acknowledged by farmers. No attempt was made to apportion credits to individual Donors because they were working collaboratively.

Table 11. Survey of adoption of Kid machine planters, Battambang

District	Village	Total	Member AC	Aware of Kid	Adopted	Source of information on Kid		
						AC	Other farmers	Donor[1]
Banan	Ou Ta Nhea	31	21	25	11	15	8	9
Battambang	Boeng Reang[2]	16	0	10	9	0	2	7
Bavel	Prey Sangha	31	20	25	11	15	4	4
Moung Ruessei	Ta Nak	38	27	33	18	18	5	6
Sangkae	Os Tuk	28	18	23	13	7	14	3
Total		144	86	116	62	55	33	29
Percent		100	60	81	43	36	23	20

CAVAC, VSO, IRRI, CamSID. IRRI group.

Survey on Kid service providers (in 2021)

This survey sought to learn more about the experiences of all of the known Cambodian Kid planting machine owners and service providers. The total known number of Kid planter operators in Cambodia is 22. We sought to obtain service provider assessment of the performance of machine planters for rice, how planters can be improved, potential for increased adoption, training needs and appropriate training media options. In 2021, we interviewed 14 Kid owners, 65% of the total area.

Survey on Eli and Kubota service providers (in 2022)

Six rice fields were selected with three planted by Eli and three broadcast at Ou Ta Nhea village Battambang. The fields were not ploughed but were prepared by two rotavations and two levelling operations before planting on 31st January 2022. Farm-kept seed, variety OM 5451, was soaked for 12 h and incubated for one day before planting. The seeding rate was 110 kg/ha. Pre-emergence herbicide (pretilachlor 500 g/L) was applied at 1 L/ha 2-3 days after sowing. The hand-broadcast fields were not ploughed but were prepared by one rotavation and one levelling operation before planting. The seeding rate was 300 kg/ha for hand-broadcasting. Establishment counts were done on 9th February 2022 in three 0.5 * 0.5 m quadrats in each field. A harvest field day was held on 5th May 2022, 94 days after sowing.

Evaluation of scaling case studies in BMC and BTB

During the mid-term survey in September 2019, additional focus groups were structured (by an independent socioeconomic team led by Rebecca Cross and Van Touch) to elicit information on major changes to farming practice in the first 2 years (including what they changed from and to, how many in the focus group had changed, percentage of villagers they perceived had made this change, why the change was made, what information helped make this change, whether they are happy with the change, the benefits and challenges associated with the change in practice and barriers to widespread adoption of this practice.

5.7.3 Engagement with PDAFF and input sellers

Strong network connections exist in northwest Cambodia between farmers and agricultural input sellers, including information transfer through value chain linkages. There is potential to engage input sellers as qualified sources of technical advice. A survey of input sellers was conducted by PDAFF on behalf of CamSID in three districts in Banteay Meanchey province and five districts in Battambang province in northwest Cambodia. A total of 179 agri-businesses were surveyed, 82 in Banteay Meanchey and 97 in Battambang province. Businesses had an average of 67 farmer customers, 61 in Banteay Meanchey and 73 in Battambang. A technical meeting on selecting CamSID findings for adding into input seller training was conducted on 19th June 2020 with a follow-up meeting on 22nd December 2020. Furthermore, CamSID also directly engaged with input seller companies to provide rice and mungbean technical packages to be used for private company training.

5.8 Capacity Building

8a. Farmer school training

Following the mid-term review, the BMC CamSID team initiated a series of three consecutive field days (trilogy) at (1) planting time, (2) maximum tillering stage and (3) in four BMC villages, Battrang, Spean Sraeng, Boslouk and Kork Tonlaop villages resulting farmers increasing their intention of adopting new technologies from 50% to 80% in 2019. However, during the COVID-19 outbreak in 2020/21, training was done with small groups of 5-10 farmers with masks and social distancing.

CARDI organised the scaling-up of dry-drill seeders by Cambodian Seed Drill fitted Two Wheel Tractor (2WT) which was conducted in Por village, Khea commune, Moung Reusey District, Battambang province on a 2-ha farmer's field (Chay Choy) and another farmer's field was in Oroung village, Boeng Khna commune, Bakan district, Pursat province on 0.4 ha (Chhum Plou). Two seeding rates 60 and 80 kg/ha with Phka Rumduol rice variety, with the fertilizer rate based on CARDI's recommendation for Toulsan Rong and Bakan soil types. The demonstration conducted on 10th July 2020 and 11th July 2020.

8b. Curriculum development

Curriculum development at both the National University of Battambang (NUBB) and the National Meanchey University (NMCU) were primarily through the UNICAM Master in Sustainable Agriculture (MSA) program. All project staff as well as NGOs and PDAFF were enrolled and trained through the MSA program (as it was also developed using the CamSID outputs). The CamSID team also incorporated CamSID outputs into the curriculum of St Xavier high school and other schools as well. The curriculum was also enriched through the series of Crawford Fund training as well as soil analysis and climate station infrastructure installation and training for both NUBB and NMCU.

8c. Information tools

The project developed a couple of mobile Apps, one for weed identification in rice and one for pest identification in mungbean. In addition, there was also a pest diagnosis program on Smartphone telegram networks at Tahen, Battamang province. In Banteay Meanchey province, there was a radio broadcasting program providing agronomic advice supporting the farmer field school which was also turned into a podcast program. The radio broadcasting program was also evaluated through a farmer survey.

8d. Policy and extension briefs

Drs Try and Van have submitted a policy brief to the Ministry of Environment on adaptation to climate change. Dr Bob Martin drafted a Quality Declared Seed (QDS) for mungbean document for implementation by CAVAC and GDA. Dr Martin was successful in an invitation to the Australian Ambassador to visit Battambang in September 2021 and as a result Dr Martin was requested by the Department of Foreign Affairs and Trade (DFAT) in October 2021 to submit an assessment of "Key challenges and opportunities for modernisation in the agricultural sector in Cambodia" to advise post-CAVAC planning.

6 Achievements against activities and outputs/milestones

Objective 1: Identify the local socio-economic and agronomic trends, constraints and opportunities for SID adoption for small and medium farm households.

No.	Activity	Outputs/ Milestones	Completion date	Comments
1.1	Conduct foresight study and establish a multi-skilled team and strong governance to oversee the design and implementation of the project	1.1.1: Foresight study and stakeholder engagement completed	31/3/17	Foresight study and stakeholder engagement completed during the inception workshops on 6-8th November 2016. Collaborative agreements have been signed with NGOs, VSO for Battambang Province and Ockenden for Banteay Meanchey Province.
		1.1.2: Workshop report on foresight study and project initiation meeting submitted	31/3/17	Inception workshop report on foresight study and project initiation meeting was submitted on 8 December 2016.
		1.1.3: Monitoring and evaluation framework developed and human research ethics approved	31/6/17	Monitoring and evaluation framework developed and submitted on 20 June 2017. Bill Rathmell and Peter Ampt visited project sites during October/November 2017 for monitoring, evaluation and learning. Human Research Ethics Committee (HREC) approval obtained on 24 November 2017 (Project No. 2016/882) and regularly updated by Rebecca Cross.
1.2	Conduct participatory rural appraisals (PRAs) to assess the socio-cultural context formally, identify local needs and opportunities and build cohesion and a shared vision for project staff and stakeholders	1.2.1 PRA report submitted	30/9/17	The PRA was completed over a 13-day period in Nov-Dec 2016. 144 interviews were conducted in 8 villages across the Battambang (BTB) and Banteay Meanchey (BMC) Provinces. Preliminary PRA report submitted on 20 February 2017.
		1.2.2 Socio-economic and farming system survey completed using PRA	31/10/17	Socio-economic and farming system analysis in progress. This analysis will include the PRA data as well as baseline survey data.
		1.2.3 Traditional/indigenous technologies identified and documented	31/10/17	Identification of indigenous technologies in progress. There have been indigenous planting machine manufacturers identified, e.g., Eli and Lunheng seeders.
		1.2.4 Prototype business models within value chain network (VCN) to meet local needs developed	31/10/17	Work completed by value chain task force led by Drs Bob Martin, Yorn Try, Van Touch, Ratha and Sophea. Dr Bob Martin has developed a business model for quality declared rice seed production in collaboration with CAVAC.
1.3	Conduct a socioeconomic household livelihood and farming system survey based on PRA findings. The diagnostic survey will	1.3.1 Protocol developed for baseline diagnostic survey and MCU students trained on survey methodology	30/6/17	The protocol was developed for the baseline diagnostic survey in early May 2017. Over 60 MCU and UBB students were trained in using CommCare software (mobile acquired data technology).

	quantify system components and likely impacts of interventions, make an assessment of market opportunities in the future including network value chain analyses and will include household consumption and production strategies and decision-making.	1.3.2 Survey on land tenure, farm types, livelihood consumption and production strategies (including remittances from migrants), and current technologies completed for 90 households	31/12/17	Approximately 524 households were interviewed in 10 villages across BTB and BMC in May 2017. The data is being checked for inconsistencies by Dr Rebecca Cross and will be available for analysis by 17 July 2017. Drs Peter Ampt, Rebecca Cross and Van Touch led this analysis for the same 524 households with support from Prof Thilak (UQ).
		1.3.3 Future farm household strategies and scenarios (stepping out, stepping up) and future technology needs determined for 90 households	31/12/17	Dr Clemens Grunbuhel has completed this analysis for the same 524 households.
		1.3.4 Network value chain analysis data collected and analysed using Social Network Analysis	31/12/17	Social network analysis of Angsangsak village completed. Led by USYD honours students, Aaron Zhang and Kirstan Xing – supervised by Dr Petr Matous
		1.3.5 Using Social Network Analysis, map and measure relationships, information-knowledge flows that affect farmers' decision making	31/12/17	Social network analysis of Angsangsak village completed. Led by USYD honours students, Aaron Zhang and Kirstan Xing – supervised by Dr Petr Matous. This research has been published. https://www.tandfonline.com/doi/full/10.1080/14735903.2020.1769808
		1.3.6 Develop a communication strategy based on the Social Network Analysis	31/12/17	Social network analysis of Angsangsak village completed. Led by USYD honours students, Aaron Zhang and Kirstan Xing – supervised by Dr Petr Matous
1.4	Refine agronomic and institutional research priorities and interactions and interventions based on the survey	1.4.1 Agronomic and institutional research priorities refined in workshop	31/12/17	This was done during the Annual Progress Meeting at BTB in February 2018.
		1.4.2 Survey results published in scientific journals and ACIAR workshop proceedings	31/3/18	Survey results being prepared for publication – led by Dr Van Touch, Dr Rebecca Cross and Dr Clemens Grunbuhel.

		1.4.3 Women's livelihood consultative groups (four groups) established in target villages with regular meetings for the life of the project to provide ongoing formative advice on whether strategies are on track to improve household incomes and improve quality of life	31/3/18	Dr Rebecca Cross led this activity, including longitudinal case studies. Dr Cross has completed a preliminary visit during June/July 2018 to work with Flavia Ciribello (VSO) to finalise the consultation. In Sept 2018, 12 focus groups were conducted across BTB and BMC. A gender analysis in rice value chains report was produced in 2019. Gender and social research capacity building workshops were attended led by Dr Cross and attended by key PDAFF staff, university students and staff, CamSID and VSO staff, as well as other NGO and collaborating partner staff. These were conducted in BTB July 2018 and BMC February 2019. In February 2019, a series of workshops with the women's groups was held to determine gender priorities and needs for improved agricultural livelihoods. In February 2020, a series of workshops on vegetable production and chemical use were conducted with the women's groups. **We have encouraged companies like the manufacturer of the Eli seeder, BB2C and new projects like EiA to include gender equity/equality into their culture. For example, BB2C is now considering strategies to engage women, e.g., providing subsidies to women who purchase the Eli seeder.**
1.5	Conduct a mid-project survey to evaluate which innovations and approaches are more effective for farmer adoption and improved livelihoods (USYD, CARDI, AIT)	1.5.1 Effectiveness of innovations and approaches for 90 households and 36 agribusinesses evaluated through focus group discussions with farmers, input and output suppliers	31/12/19	This mid-project survey (197 surveys in 8 target villages) and MEL (8 focus groups in target villages and approximately 10 participants per group) was led Rebecca Cross in September 2019. The data has been analysed.
		1.5.2 Interim survey results published in scientific journals and ACIAR workshop proceedings	31/3/20	A paper on diversification trends and the risks of and opportunities for diversification is in preparation, led by Dr Rebecca Cross in collaboration with Van Touch, Daniel Tan and other CamSID staff.
1.6	Initiate another survey near the end of project to monitor impact in relation to objectives, assess effectiveness of scaling methods adopted and generate recommendations for future research from participants	1.6.1 Mid-project survey report for noting any changes in baseline areas and effective scaling methods for 90 households and 36 agribusinesses	30/9/21	Final survey has been designed by Dr Rebecca Cross and the project team and is being carried out by telephone during Sept-Oct 2021 due to the COVID-19 pandemic.
		1.6.2 Final survey results published in scientific journals and ACIAR workshop proceedings	31/12/21	Draft manuscript is being prepared.

PC = partner country, A = Australia

Objective 2: Establish participatory on-farm pilot trials to test SID innovations and approaches at field scale and evaluate which approaches are most effective for farmer adoption

No.	Activity	Outputs/ Milestones	Completion date	Comments
2.1	Identify and establish leading farmers, smallholder, input and output supply and local value chain networks (VCNs) to test SID innovations and evaluate effectiveness for adoption. Upskill these networks in farm and business planning and management tools (USYD, SFSA, NUBB)	Output 2.1.1 Four pilot leading farmers or farmer groups selected and identified (two in each of Banteay Meanchey and Battambang)	31/1/18	Leading farmers and farmer associations have been identified during the PRA survey. SFSA together with the BMC team is in the process of developing a road map for the farmer hub initiative. BTB team continued to work with existing farmer groups led by VSO.
		2.1.2 Key credit, market access to inputs, soil, water, nutrient and biotic constraints identified for the four focus villages	28/1/18	BTB team led the collection of biophysical data while VSO assisted with the collection of Sustainable Rice Platform (SRP) data from smallholder farmers.
		2.1.3 Key farmer group leaders, university staff and PDAs trained in farm and business planning and management skills and tools	30/6/18	Training (train-the-trainer) provided to key staff and NGOs through the Crawford Fund training activity from 16 October to 1 November 2016. Crawford Fund mentor, Dr Peter Batt led a second Crawford Fund Masterclass workshop on skills and methods for examining vegetable value chains during 21-25 October 2019.
2.2	On-farm field experiments and demonstrations on rice and other rotation crops [e.g. mung bean, waxy maize, and vegetable crops] conducted to refine and adapt successful SID innovations	2.2.1: Pilot demonstrations of alternative rice sequences and crop rotation options to compare traditional practice of one rice crop per year with two wet season rice crops and options for rotation crops after rice	28/2/18	Pilot demonstrations started with planting equipment (including Eli air seeder, mechanised drum seeder, manual drum seeder, hand broadcasting) on 28 June 2017 at Svay Cheat Village (comparison with transplanting for seed production) and on 7 July 2017 at Don Bosco, BTB and 10 July 2017 at Kuok Tonlaop Village during the early wet season. A seeder trial was planted on 14 Sept 2017 at Svay Cheat Village to compare mechanised seeders with broadcasting and on 30 Oct 2017 at Omal Village and on 30 Sept 2017 at Kuok Tonlaop Village during the main-wet season (second rice crop) In 2018, Dry seeding experiments with KID seeder for planting density/weed management were established at Kuok Tonlaop Village (planted 25 April 2018 and harvested on 17th Aug 2018) and Svay Cheat Village (planted June 2018). Rice husk ash (DB) and nutrient omission experiments have also been established at BTB.

		2.2.2: Alternative rice and non-rice crop varieties evaluated for local conditions	31/12/20	Mungbean lines have been obtained from CARDI, Thailand and Vietnam with the focus on short-duration lines for mechanical harvesting and for use of residual soil water after the flood or main wet season rice crop. Farmers are also looking for lines that resist pod shattering (led by Dr Bob Martin). **Cambodian varieties identified for seed increase include CARDI Chey and CMB2.** Farmers were not keen on open pollinated CARDI watermelon varieties (e.g. REACHNY and CHAN AMRETH) as the Cambodian vegetable/watermelon industry is based on hybrid varieties. Dr Cuong led the watermelon variety and best practice trials. The best performing watermelon varieties during the dry season experiment were: **Variety 020 F1, Hoang Chau, Superman and EW 06 averaging 28 t/ha. Thai variety C 29 was best on taste and good texture** as Cambodians were used to the taste of the local variety. Seyma and Hong led fish demonstrations with Mr Yann Sophon at Batrong. Tilapia and carp fingerlings now being produced and sold.
		2.2.3: Guidelines for rice intensification and rotation crop options produced	31/12/20	Dr Yorn Try compiled a fact sheet for rice production for NMCU and NUBB students as well as for input sellers. Guidelines for rice intensification and rotation crop options have been produced and have been scaled to PDAFF, input suppliers, farmers and universities.
2.3	Evaluate new 12-month calendar for rice variety and crop rotations in appropriate areas	2.3.1: New cropping calendars established and evaluated. Climate risks evaluated using APSIM modelling	31/12/19	APSIM modelling showed that for short duration rice, the preferred sowing dates are July, followed by June and August. Without supplementary irrigation, it is not recommended to plant rice from Sept to March because there is a fairly high probability of getting very low yield and crop failure.
		2.3.2: Economics of new cropping calendars developed based on Yr 2 trials and validated in Yr 3 trials	31/12/20	CARDI has completed the economics work on cropping calendars.
		2.3.3: Market analysis for new rotation crops	31/12/19	Work documenting the mungbean and vegetable market chains has been completed.
		2.3.4: Cropping options developed for farmers subject to soil type, water availability and market access	31/12/20	Plans for rice-mungbean rotational experiments completed. Mungbean crop was an opportunity crop in KTL and this crop was planted to capitalised on the residual soil moisture in the rice field. There were few farmers growing mungbean after rice rotation at KTL. The project team in consultation with farmers made them aware that mungbean can be planted during early wet season. The farmers in Boslouk have already adopted this practice and got high yields. Scaling of rice-mungbean rotations are in progress in the active floodplain villages (BTB) of Angsangsak and Praek Trab by the BTB team.

2.4	Optimise direct seeding methods by evaluating no-till direct drill, conventional drill, drum seeding and	2.4.1: Farmers consulted and technologies for on-farm research identified	31/1/18	Farmers were extensively consulted during the PRA and baseline surveys. Follow-up surveys on diversification crops after rice have been completed by Dr Bob Martin, Ratha and Sophea.

	alternative wet seeding methods for rice compared with traditional broadcast	2.4.2: Optimal seeding methods and seeding rates evaluated and developed in relation to soil type, crop residue management and water availability	31/12/18	Pilot demonstrations have started with planting equipment (including Eli air seeder, mechanised drum seeder, manual drum seeder and hand broadcasting) on 28 June 2017 at Svay Cheat Village and on 7 July 2017 at Don Bosco, BTB and 10 July 2017 at Kuok Tonlaop Village during the early wet season. Similar demonstrations on 14 Sept 2017 at Svay Cheat Village and on 30 Oct 2017 at Omal Village and on 30 Sept 2017 at Kuok Tonlaop Village during the main-wet season (second rice crop) Dry seeding experiments with KID seeder for planting density/weed management established at Kuok Tonlaop Village (planted 25 April 2018 and harvested on 17th April 2018) and Svay Cheat Village (planted June 2018). Rice husk ash (DB) and nutrient omission experiments have also been established at BTB. The aim is to replace hand broadcasting (for paddy rice production) and transplanting (for quality seed production) with mechanised seeding at optimal seeding rates. Further seeding trials by CARDI in 2019 confirmed that seeding rates of 60 to 80 kg/ha produced higher yields compared with 180 kg/ha. Scaling of the planting machines have been very successful. Scaling partner, CAVAC has reported that over 15 KID drill seeders have been purchased by Battambang province machinery service providers and agricultural cooperatives and over 600 ha planted using these drill seeders (as of December 2020). Field demonstrations of the Cambodian-invented Eli seeder have led to over 490 Eli seeders being sold. Prime Minister of Cambodia, H.E. Hun Sen visited the CAVAC Irrigation Scheme on 21 July 2020 and he liked the Eli seeder so much that he ordered 2,000 Eli seeders for smallholder farmers using his own budget (of which only 250 Eli seeders have been delivered to farmers by early 2021). Hence, the CamSID team has been successful in scaling work in collaboration with CAVAC. https://www.phnompenhpost.com/national/pm-thanks-oz-years-support-farming https://drive.google.com/file/d/1mC56KS9YYYxmJr1So0vewCeYr3DxdIPF/view?fbclid=IwAR1mAZPEojVBM1qP4nGRF5QigjkFJP7GREYjYOtkpGpKsdFs3REDlQnEXqA Hence, there is an opportunity here to work with the Cambodian Government for scaling CamSID technologies as the government is actively trying to simulate the economy post-COVID. A machinery field day was held in Battambang in August 2020 to obtain feedback from farmers and contractors on the Kid and Kubota rice planters and 34 participants completed a questionnaire. A machine combining the best features of both machines was defined by farmers and CARDI engineers are currently modifying the Kubota planter to fit a fertiliser box and press wheels.

		2.4.3: Most effective land preparation, crop residue and seeding methods/rates	31/12/19	Minimum tillage for mungbean after rice were trialled at Tahen.
2.5	Evaluate high quality seed of registered varieties of high value [e.g. certified seed of approved rice varieties, mung bean, waxy maize and vegetable crops] compared with traditional farmer saved seed	2.5.1: High quality seed and varieties of high value evaluated in comparison with farmer practice	31/12/18	A survey of weed seed contamination in rice seed kept for sowing has been published in Weed Research. Although farmers can reduce weed contamination by 60%, the project can help them reduce the level further. A significant proportion of 'Certified' seed lots tested were found to be heavily contaminated by weed seeds and weedy rice.
		2.5.2: Explore options for contract cooperative marketing of quality assured produce with potential buyers	31/12/18	BTB team has partnered with VSO to explore use of the SRP standard to underpin contracts between Chamroeunphal FA and AMRU rice mill. BMC team has worked with SFSA and Ockenden to establish functional farmer hubs in BMC.
		2.5.3 Supply chain network (seed producers, input suppliers, farmers and markets) for high quality seed and varieties of high value linked up with local VCN	31/12/19	Bob Martin contributed to a program for quality declared seed (QDS) production with CAVAC and BTB PDAFF with Svay Cheat (Chamroeunphal - rice) and Angsangsak (mungbean) as a pilot in 2020 and 2021. This was scaled to other BMC hubs in 2021 led by Herve and Dr Try. The development of QDS for mungbean (and rice) was done in collaboration with the Department of Crop Seed (DCS). In fact, on behalf of CamSID, Bob Martin was invited to attend the Dissemination Workshop on National Variety Release Committee at the Phnom Penh Hotel on 15th December 2021. CAVAC has driven the process of introduction of the FAO Quality Declared Seed (QDS) system by the General Directorate of Agriculture (GDA) and this led to the formation of a new Department of Crop Seed (DCS) in GDA. Attendance at the workshop provided Bob the opportunity to meet with Dr Mak Chanratana, Deputy Director of DCS on Friday 17th December to discuss commercialization of high performing mungbean varieties in CamSID trials between 2018 and 2021.
2.6	Evaluate best practice management (e.g. land levelling, crop nutrition, water management, crop establishment, crop protection) options for rice and other rotation crops [e.g. mung bean, waxy maize, mushroom and vegetable crops]	2.6.1: On-farm demonstrations of best management packages established with four farmer groups	31/12/18	Demonstration of machine seeders for wet seeded rice commenced in 2017. Experiments completed on optimising N topdressing and calibration of NDVI reflectance meter and free smartphone App, Canopeo – led and monitored by PhD student, Chinaza. Good correlations between Canopeo readings and NDVI.
		2.6.2: Most effective crop agronomy methods to farmers and private sector showcased in field days and practical training workshops	31/12/19	Eight field days completed for demonstration of wet seeding machines. In 2018, the Thai KID seeder has been trialled for dry seeding in both BTB (Svay Cheat) and BMC (Kouk Tonloap) for EWS rice. CARDI and NUBB have completed fertiliser rate by sowing rate experiment in Pursat and Kuok Tonloap, respectively to fine-tune recommendations for rice best practice management.

		2.6.3: Best practice guidelines for crop agronomy established	31/12/19	Mungbean production manual has been produced . https://www.aciar.gov.au/sites/default/files/2021-03/ART-MN214-2020-WEB.pdf. A manual for weed management in DS rice is being produced. Dr Try has drafted a best practice leaflet (6-pages) for smallholder farmers.
2.7	Evaluate available chemical and non-chemical protocols and options for integrated weed, insect and disease management in the crop sequence	2.7.1: Most effective integrated pest management methods showcased to farmers and private sector in field days and practical training workshops	31/12/18	USYD PhD student, Lucinda Dunn (Indi) has completed her PhD on integrated pest management for rice in March 2022. A fungicide and rice husk ash (to provide silicon/silica) experiment has been completed to manage rice blast at Don Bosco farm (planted in June 2018). The experiment was led by USYD honours student, Dan Howell (who is now enrolled in a PhD) and supervised by A/Prof Rosanne Quinnell. There was little evidence of efficacy of rice husk ash for control of rice blast due to low incidence of rice blast in EWS. Pre-emergence herbicide options for dry seeded rice have been trialled by BTB team in Don Bosco farm and concurrently by CARDI in Pursat in 2018 and 2019. Pre-emergence herbicides such as oxadiazon or butachlor show promise.
		2.7.2: On-farm demonstrations of integrated weed, disease and insect management practices established with four farmer groups	31/12/18	A manual on Integrated Crop Management is being compiled by Dr Yorn Try. Dr Try and Dr Cuong have also drafted an integrated crop management book chapter on watermelons to be published by the USAID SIIL team. The teaching material is already being used for teaching master students in NUBB for two cohorts (promotions) so far and continue for the next coming cohort (promotion).
		2.7.3: Databases and identification kits published for the major weeds, diseases and insect pests in the rice system	31/12/19	Weed identification App has been developed by Masters student, Yehezkiel Henson and now available to smallholder farmers in Khmer (on IOS devices). Mungbean pest identification App developed by Honours student, Isabel Hinchcliffe and now available to smallholder farmers in Khmer (on IOS and Android devices)
2.8	Evaluate the use of low cost Unmanned Aerial Vehicles (UAVs) for measuring yield limiting factors: land levelling, crop establishment and crop/weed biomass. Ground-based EM38 used to detect subsoil constraints and soil water holding capacity (USYD, CARDI)	2.8.1: On-farm maps of Normalised Difference Vegetation Index (NDVI) developed using UAVs to predict rice yields and to monitor changes at field scale in farmers' fields before and after SID adoption. EM38 used to evaluate subsoil constraints and soil water holding capacity	31/12/18	UAV trials piloted. However, UAV from Waypoint company is not always reliable as the company is not able to fly the UAV at the required crop developmental stages. The focus has now turned to developing a real-time NDVI-based N-topdressing calculator to avoid over- and under-fertilisation in rice in 2018 and 2019.

		2.8.2: on-farm research designed with fertiliser rates based on management zones to develop optimal fertiliser rates based on soil type for maximum nutrient use efficiency	31/12/20	Experiments commenced to optimise N topdressing rate and timing with regards to rice crop needs and target yield. Comparison of NDVI reflectance and IRRI LCC and Canopea smartphone App for estimating N topdressing needs. Soil strength has also been measured at Sala Balat (Don Bosco), Svay Cheat, Kampong Preang, Tahen and Preaek Trab, BTB using a penetrometer to detect subsoil constraints.
		2.8.3: Evaluate the use of UAV NDVI imagery to provide early warning of emerging weed, disease or insect pest outbreaks in farmers' fields	31/12/20	UAV trials piloted. However, UAV from Waypoint company is not always reliable as the company is not able to fly the UAV at the required crop developmental stages. **In 2021, BTB team collaborated with CAVAC and BTB PDAFF to demonstrate herbicide spraying with UAV alongside BB2C Eli seeder demonstrations.**

PC = partner country, A = Australia

Objective 3: Comparative evaluation of different scaling models - case-studies demonstrating different scaling principles, strategies and approaches for sustainable intensification and diversification

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Evaluate most successful farmer-led prototype groups and community-led VCN communication models to scale up SID through local VCNs	3.1.1: Most effective farmer group approach evaluated with four farmer groups for scaling from pilot results and through farmer focus group discussions (including using IAT modelling)	31/3/19	SFSA and BMC team now working on pilot farmer hubs at BMC from 2019. Two hubs are now in operation: (1) To deliver high quality seeds: rice seed production and processing unit upgrade for Mr Yann Sophon at Battrong; and (2) To provide mechanised services (rice land preparation and direct seeding) by Chiv Sarith, Banteay Neang, KTL. However, the KID seeder was not popular/economical at KTL and the service provider reverted back to mechanical seed spreading. There is also an NGO Ockenden Cambodia seed producing group supported by SFSA. By Dec 2020, despite the challenges of COVID-19, droughts and floods in 2020, Yann Sophon has achieved 50% of his sales plan and Chiv Sarith has achieved 65% of his business plan. The Petkus seed cleaner was also donated by SFSA and being installed at Battrong Seed Cooperative in Dec 2020. This has resulted in interest in seed cleaners leading to another $30,000 seed cleaner being acquired by Chamroeunphal Agricultural Cooperative (donated by JICA) at Svay Cheat Village, Battambang Province. Japan International Cooperation Agency (JICA) is also providing seed cleaners to agricultural cooperatives in four provinces, Prey Veng, Takeo, Kampong Chhnang and Battambang, https://www.khmertimeskh.com/50953573/jica-provides-post-harvest-facilities-and-machinery-to-prey-veng-agri-community/ In addition, the BMC team has also started a series of three consecutive field days (trilogy) at (1) planting time, (2) maximum tillering stage and (3) in four BMC villages, Botrong, Spean Sraeng, Boslouk and Kork Tonlaop villages resulting farmers increasing their intention of adopting new technologies from 50% to 80%. However, during the COVID-19 outbreak in 2020/21, training was done with small groups of 5-10 farmers with masks and social distancing. BTB team worked with existing farmer groups led by VSO. Over 112 vegetable farmers have been interviewed and farmers were found to have adopted crop rotation and irrigation practices. The mid-term survey in September 2019 also demonstrated that both BMC and BTB teams are making significant impact on farmer adoption of SID technologies. Evaluation of the different scaling methods was conducted by Drs Rebecca Cross and Van Touch in September 2019 which demonstrated that both BMC and BTB teams are making significant impact on farmer adoption of SID technologies.

		3.1.2: Scale-up farmer groups to at least 9 villages in 3 provinces completed (Battambang, Banteay Meanchey, northern Pursat) (MCU, SFSA). Evaluated using IAT modelling.	31/12/20	The scale-up is in progress. In BMC, the engagement has expanded from the original two villages of Botrong and Kork Tonlaop to Sprean Sraeng, Boslouk, Kouk Ballangk and Banteay Chhmar (Ockenden Cambodia). In BTB, the engagement has expanded from the original two villages of Svay Cheat and Angsangsak to Preaek Trab, Kampong Preang, Tahen, Ou Ta Nhea and Kamping Pouy. IAT analysis was led by Dr Van Touch (assisted by Sophea Yous) but was terminated as Van left the project at the end of October 2021.
		3.1.3: Use participatory network mapping to identify and overcome barriers to the flow of information to communities beyond the project target groups	31/12/20	A survey of adopters and non-adopters of rice machine planters was done in 6 machine planter hubs in Battambang. Barriers to adoption were false assumptions about costs and unsuitability of the Kid planter for uneven seed beds.
3.2	Support private sector input and machinery service suppliers, NGOs and traders to promote SID methods to their farmer clients through local VCNs including analysis of components of input prices and credit provision	Output 3.2.1: Negotiate with PDA to include relevant project outputs into the existing 5-day Input Seller Certificate Course	31/12/19	Dr Try and Bob have successfully negotiated MOU with PDAFF (in both BTB and BMC) regarding engagement with private sector. Workshop has been held on 19th June 2020 with PDAFF to include CamSID findings into the Input Seller Certificate Course. CamSID training of Banteay Meanchey and Battambang PDAFF staff on CamSID outputs relevant to input suppliers was conducted at Battambang on 22 December 2020.
		3.2.2: Effectiveness of PDA staff evaluated and farmers surveyed on whether suppliers and NGOs are servicing them more effectively	31/12/20	PDAFF staff have surveyed the input suppliers in both BMC and BTB in 2019. Training materials have been prepared to train the input suppliers. PDAFF in both BTB and BMC have adopted CamSID findings as a training tool to train input sellers (presumably in consultation with the Department of Agricultural Legislation, DAL) and then input sellers have provided technical consultations to farmers who buy their products. Ockenden Cambodia have been working with CamSID team in BMC to work with their target farmers using all CamSID findings in their field in Koukbalin and Banteay Chhma. This survey on effectiveness was not done due to the COVID-19 pandemic.
		3.2.3: Communicate with input sellers, machinery contractors and collector-traders and overcome barriers to adoption of SID technologies	31/12/20	This activity was not carried out due to the COVID-19 pandemic which made in person communication difficult.
		Output 3.2.4: Support service provision for rice planting services (e.g., by providing new Kid service providers with a temporary service subsidy) to increase market demand.	30/06/22	Continuing demonstrations with Kid seeder in both BTB and BMC. It is worthwhile noting that a new leading farmer, Mr Chao Bunthoeun in Thmor Pouk district has purchased a second hand Kid seeder and he has provided on-going planting service for over 240 ha for smallholder farmers from March to June 2022 (without any subsidy).

		Output 3.2.5: Link potential purchasers of machines with credit providers. Explore microfinancing options with YLP, AEON and Agricultural and Rural Development Bank (ARDB)	30/6/22	There are microfinance and banks such as ARDB, Canadia, ACLEDA, that provide small loans on agricultural investments; ARDB is a public bank providing funds for agriculture and provide loans with mortgage; YLP is a new microfinance based in Thmor Pouk district which provide loans to smallholder farmers; they provide around US$250 without collateral and interest. CamSID has done important facilitation to bring farmers to engage with YLP to get loans for agriculture. As a result, several farmers received loans from microfinance and technical support from CamSID staff. Mr Chao Bunthoeun is a farmer in Thmor Pouk who received a loan from ARDB to buy a used Thai Kid seeder from Battambang for dry seeding service provision in Banteay Meanchey Province.
		Output 3.2.6: Conduct a survey on service providers and farmer clients for both the Eli and Kubota seeders to identify the barriers and constraints to adoption.	31/03/22	Fifty and fifty-one AgriSmart Eli seeders were donated by Prime Minister Hun Sen for distribution in each of Battambang and Banteay Meanchey provinces, respectively. By June 2022, only one unit in each province had been used as no training, demonstration or technical support was provided and the lack of use of these machines is not surprising. There are no service providers for the Kubota planter, so a survey was not possible. The main barrier to scaling of the Kubota planter is that Kubota dealers, at least in Battambang, seem unwilling to display or promote it, whereas broadcasting machines are being promoted.
		Output 3.2.7: Evaluate unmanned aerial vehicle (UAV) technology for pesticide application. Outputs of the collaboration with CAVAC II will be shared with CSE/2019/145.	31/03/22	A detailed evaluation on UAV (drones) has been done and shared with CSE/2019/145. The Project Leader, Daniel Tan was also invited to give a webinar presentation on Drones and Digital Integrated Pest Management (IPM) on 9 December 2021 which was jointly organised by the ASEAN Fall Armyworm Action Plan and Grow Asia https://www.aseanfawaction.org/drones-and-digital-ipm. This is a link to the video recording of the workshop: https://www.youtube.com/watch?v=O2XIr13T-I8
		Output 3.2.8 Collaborate with PDAFF for seed increase of improved mungbean varieties identified (e.g., CMB2, CMB3). This work will be aligned with existing state-of-the-art seed production facilities managed by PDAFF.	30/06/22	Bob Martin was invited to attend the Dissemination Workshop on National Variety Release Committee at the Phnom Penh Hotel on 17th December 2021. CAVAC has driven the process of introduction of the FAO Quality Declared Seed (QDS) system by the General Directorate of Agriculture (GDA) and this led to the formation of a new Department of Crop Seed (DCS) in GDA. Attendance at the workshop provided Dr Bob Martin the opportunity to meet with Dr Mak Chanratana, Deputy Director of DCS on Friday 17th December to discuss commercialization of high performing mungbean varieties in CamSID trials between 2018 and 2021. Dr Ponh Oudam, Vice Director PDAFF Battambang, has allocated a seed increase field for mungbean varieties at the PDAFF Battambang seed production station. However, DCS has not yet followed through with FAO funded support.

3.3	Support local VCNs and the development of self-sustaining agribusiness (e.g. input and machinery services) where appropriate to continue to support farmers through local VCNs	3.3.1: Niches in the local VCN for opportunities for development of agribusiness identified	31/12/19	Our scaling partner, CAVAC has been working with partners including CamSID to introduce affordable and commercially available seed plants. There are now 15 KID planters operating in the Battambang province and 490 Eli seeder units have been sold across Cambodia. CAVAC provided a 30% subsidy for the purchase of KID and Eli planters. A joint BTB/BMC field day in Ou Ta Nhea was held on 12 August 2020 to educate farmers, machinery dealers and agribusinesses on planting machinery. This field day was also featured on Cambodian national television (TV): There was a CNC News report on TV on the field day on weed management and machinery at Oh Tanhea village, Battambang https://www.facebook.com/CambodiaSID/videos/656255671907136
		3.3.2: Technical and business and financial skills training support provided to new start-up agribusinesses	31/12/20	Training of agricultural agribusinesses including Five Star Co. Ltd and Agreebee Cambodia PLC is in progress. In addition, three agribusiness companies have trained their staff in using CamSID technical packages and produced 20,000 leaflets to share with input sellers and leading farmers.

PC = partner country, A = Australia

Objective 4: Build the capacity of local farming communities and tertiary agricultural educational institutions to implement SID technologies and approaches beyond the life of the project

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Upgrade curriculum and multilingual teaching materials to use for “train-the-trainer” dissemination of practical knowledge of SID	4.1.1: Market needs for graduate staff analysed and criteria for training syllabus developed to suit	31/12/18	Curriculum of agronomy has been developed to meet job market needs. The agronomy curriculum for Meanchey University (MCU) has been completed (incorporated CamSID outputs). The agronomy curriculum is still being developed together with the National University of Battambang under the Higher Education Improvement Project (HEIP) funded by the World Bank. Workshop on soils analysis and soils curriculum held by GAU in February 2018 training over 13 scientists from NUBB and NMCU A weather station was also set up in Meanchey University with training on downloading data provided by Mr An Kim Heng from the Royal University of Agriculture during May 2019. Crawford fund training on the value chain and marketing of vegetables was provided to 18 participants from educational institutions by Professor Peter Batt in Sisophon during 21-25 October 2019. English language training (IELTS) was also provided for NMCU students and CamSID staff during 17th to 22nd November 2019. Integrated Analysis Tool (IAT/CLEMS) training was provided by Cam McDonald in Sydney during 17th to 18th November 2019.

		4.1.2:Training syllabus developed for best practice management	31/12/19	Four young agronomy lecturers have been trained in rice disease, entomology, and integrated pest management at NMCU Three NUBB students have completed their research projects on rice pests (e.g., rice leaf folder) with Dr Try.
		4.1.3: Training workshops provided for regional universities and PDAs in Cambodia to share SID technologies	31/12/20	Four BMC PDAFF staff have been trained in disease, entomology, and integrated pest management. Low seeding rate is the main message from CamSID for PDAFF extension staff to scale out and scale up.
4.2	Develop and disseminate information tools and messages using extension support materials (e.g. radio/TV programs) and information and communications technology for local communities (PDA, MCU, USYD)	4.2.1: Most effective information tools for dissemination of SID techniques evaluated	31/12/20	The radio system (over weekends) has been implemented in Banteay Meanchey Province since early February 2020 and also available on podcasts (see below). Available on smartphone at: https://anchor.fm/camsid. Also available on spotify and ApplePodcasts. Evaluation of the radio system has been evaluated with 40 respondents interviewed. 12.5% of the respondents (all leading farmers) have been listening to the radio program whereas the other 87.5% have not. Leading farmers (77 farmers altogether) were trained (as part of train-the-trainer program) on rice production techniques in several villages from April to June 2020. However, due to COVID-19 restrictions, only small groups of 5 to 10 leading farmers could be trained at each village. Smartphone networks have been established (using Telegram) and functioning in 8 focus villages in Battambang to link farmers with technical experts for pest / problem ID, diagnosis and advice
		4.2.2: Pocket guides on integrated nutrient and pest management strategies developed	30/6/21	Weed identification App has been developed by a Masters student, Yehezkiel Henson and now available to smallholder farmers in Khmer (on IOS and Android devices). A new mungbean IPM App has been developed by honours student, Isabel Hinchcliffe.
		4.2.3: Simple phone based apps or chart based tools developed to enable farmers to plan cropped based on residual soil water, water storage or seasonal climate forecasting	30/6/21	Validation of NDVI N-topdressing calculator for site-specific nutrient management for dry-season rice at Ou Ta Nhea and Boeng Reang villages.
4.3	Increase the supply of practically trained university, PDA, private sector suppliers/trader staff to provide support and sustainability for SID adoption by farmers	4.3.1: Local university, PDA and private sector staff trained and supporting farmers	30/6/21	Bob Martin and Dr Try were invited to prepare course materials and deliver the Master program in Sustainable Agriculture (MSA) unit on Integrated Pest Management (MSA207) at the University of Battambang. The teaching material has been shared to all master students and incorporated in the UBB curriculum for the next cohort (promotion).

		4.3.2: Evaluate the establishment of an on-the-job training program for final year MCU students during vacations	30/6/21	Three NUBB final year undergraduate students have engaged in research thesis projects on mungbean varietal evaluation and mungbean IPM.
4.4	Identify key constraints and higher level interventions that cannot be implemented at the local level and make policy recommendations	4.4.1: Policy and extension briefs (at least 2) provided to key decision makers in government and private sector	30/6/21	Drs Try and Van have submitted a policy brief to the Ministry of Environment on adaptation to climate change.
		4.4.2: Policy recommendations briefs (at least 2) made to industry leader through the Cambodian Rice	30/9/21	Dr Bob Martin has drafted a QDS (Quality Declared Seed) document for implementation by CAVAC and GDA.

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7 Key results and discussion

7.1 Socio-economic and agronomic analysis of village information

7.1.1 Baseline (2016) and midline (2018) and endline (2020) village information

In the lowland regions of NW Cambodia, rice production continues to dominate smallholder agricultural production and therefore underpins rural livelihoods. These livelihoods are operating in poverty with up to 70% of farming income spent on food (Resosudarmo & Chheng, 2021) despite rice yields tripling since the 1990s (Castilla et al., 2020). This has led to an increase in off-farm income and an increase in household members migrating internationally and regionally to supplement incomes (Jacobson et al., 2019). Arguably there is much potential to focus on improving agricultural practices with the aim of optimizing farming by intensifying rice (up to three crops per year in places with irrigation) and diversifying farm production. The most appropriate strategy for a farming household is dependent on the farming context, including available capital, resources, labour, access to markets and the agronomic environment.

The benefits of intensification include more efficient use of inputs, including irrigation, seeds and fertilisers as well as efficient use of land by increasing its productive potential and reducing the need for farm expansion as a strategy to overcome poverty. Many studies have compared conventional rice with sustainable intensification of rice and have found that the yield increases are on average 20%-40% while water use is approximately 20-50% less and seed inputs are 50-70% less (see review of papers in Lee and Kazuhiko 2018). The former reduction in water use is particularly important in Cambodia where only 24% of cultivatable land is irrigated (Resosudarmo & Chheng, 2021).

The benefits of diversification include diversification of income which can lend to increased resilience in farming by reducing the vulnerability associated with reliance on one crop or commodity. In the NW of Cambodia, secondary crops used for diversification include mungbean (Campbell-Ross, 2019), sesame and peanuts in the lowlands and maize and cassava in the uplands (Kong & Castella, 2021). Vegetable and fruit production are also diversifiers, however these are restricted to areas which have access to irrigation and farms which have a higher availability of labour (Kong & Castella, 2021). Furthermore, livestock and aquaculture are further forms of on-farm diversification that are often used for quick cash injections into households.

This report aims to unpack dimensions of farming households in the North-West of Cambodia, highlighting trends over a five year period during which the CamSID project conducted interventions to promote adoption of sustainable intensification and diversification of rice farming. The following offers a summary of socio-economic and household agricultural production trends over the time period 2016-2020. However, there were some key events that affected farmers during this time, including severe drought in 2016 and devastating flooding (Phy et al., 2022) in 2020, as well as the impact of Covid-19 in 2020.

Household capacity trends

Information about household members revealed two key changes between 2016 and 2018. The first of these relates to increased migration rates in both provinces. In Banteay Meanchey, the average percentage of households with members migrating permanently or temporarily for work doubled over this time period with an increase from approximately 10% to 20% (see Table 3). In Battambang this percentage more than doubled with an increase from approximately 4% to 15%. In 2020 the number of household members migrating for work dropped significantly, back to approximate 2016 numbers with the Covid19 lockdowns severely impacting the ability of households to access these particular sources of off-farm income.

The data also revealed that while reliance on financial loans remained the same between 2016 and 2018 (37% of households), there was a dramatic increase in the average size of loans (from approximately 2000USD to 5500USD) with some decrease in interest rates (down from 2% to 1.6% on average). This data implies that households over this time became increasingly reliant on both income from migration and financial loans. In comparison to 2020, there was a 10% increase in the number of households with loans, with almost 50% of households relying on loans to supplement incomes. The average loan in 2020 was approximately $1300 less that 2018 with comparable interest rates. A key difference illustrated in Table 12 is the significant increase in membership of a community group, jumping from around 10% of respondents to 17.3% of respondent. It is presumed that this is due to the lockdowns and the return of household members to villages, increasing reliance on community groups for communications and potentially other resources, such as participating in savings groups or accessing charitable donations of rice.

Table 12. Household comparisons

	2016	2018	2020
Average age of respondents	47.9	48	49
Average number of household members	5.1	4.6	4.5
Member of a community group	9.19%	9.9%	17.3%
Percentage of household migration (permanent or temporary)			
BMC	10.4%	19.9%	10.2%
BTB	4.1%	14.7%	4.4%
CREDIT			
Percentage of sample with loans	37%	37%	47.9%
Average loan	2000USD	5523USD	4183USD
Average interest rate	2% per month	1.6% per month	1.5% per month

Figure 7 captured data for 2018 on the average time spent working on the farm for all household members over the age of 16. This revealed that only 30% of household members' time was spent working on the farm fulltime (81-100% of the time) with approximately 20% not working on the farm at all. Figure 8 reflects the impact of lockdowns and flooding of rice fields with a large increase in the % of household members not working on the farm, and perhaps instead, doing local, off-farm work to supplement household incomes.

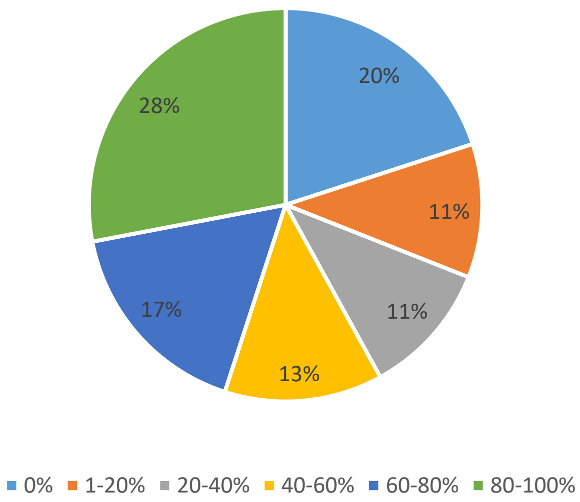


Figure 7. Average time spent working on the farm by all household members (2018)

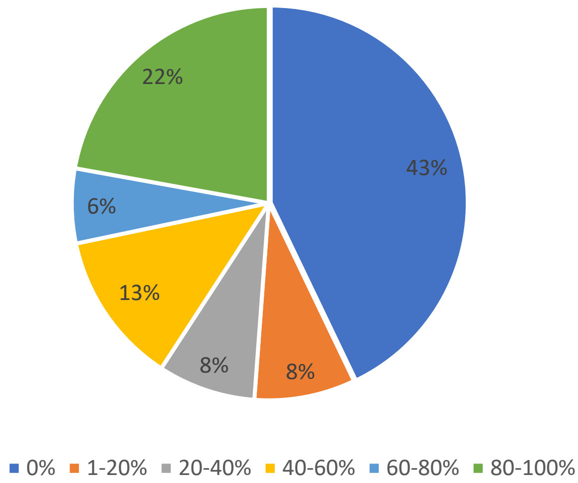


Figure 8. Average time spent working on the farm by all household members (2020)

Access to land either via ownership or through renting land is captured in Table 13. This table suggests that there have been increases in the percentage of households relying on renting land and demonstrates a clear drop in households that only rely on land owned outright (down from approximately 75% to 63% between 2016 and 2020). While average land rented and owned seems to have increased in land size steadily over this time period, the average of total land used by households stayed relatively stable around 3.85 ha per household between 2016 and 2018 but jumped significantly in 2020 and average of 5 ha per farm in line with increases in land owned and land rented during this time indicating significant farm expansion between 2018-2020.

Table 13. Access to land

	2016	2018	2020
% of households that rent land only	3	4.6	3.3
% of households that rent and own land	22.1	31.6	33.5
% of households that own land only	74.9	63.8	63.2

Average ha land rented	2.2	2.5	3.1
Average ha land owned	2.9	3.1	3.9
Average land size total (ha)	3.9	3.8	5

Table 14 depicts data on irrigation use between 2016, 2018 and 2020. This shows that there has been an increasing reliance on rainfed crops and a decreasing reliance on irrigation over the 2016-2018 time period. In both 2016 and 2018 these provinces in NW Cambodia experienced periods of drought – with the worst being in 2016 (Sreynith 2019), so the decreased reliance on irrigation over this time could be a factor of these climatic stressors. In 2020 there was a significant increase in the percentage pf farms relying on both rainfed and irrigated crops – this is due to the significant rainfall in this year that resulted in loss of crops through flooding.

Table 14. Access to irrigation

	2016	2018	2018	2020
	For all land	For all land	For rice only	For all land
Rainfed only (ha)	45%	46.5%	47%	39%
Irrigated only (ha)	40%	26.5%	25%	17%
Rainfed and irrigated (ha)	15%	26.5%	28%	44%

Agricultural production systems

When comparing on-farm diversification in terms of crops and comparing rice crops with vegetable and fruit crops, Figure 9 shows some minor changes between 2016-2018, with a slight increase in total reliance on rice and some decrease in reliance on vegetables. In 2020, there is a clear shift in the data with the number of households relying on rice and vegetables jumping from approximately 13% to about 43%. This is mirrored with a decreased reliance on rice crops only dropping from approximately 83% down to 55%.

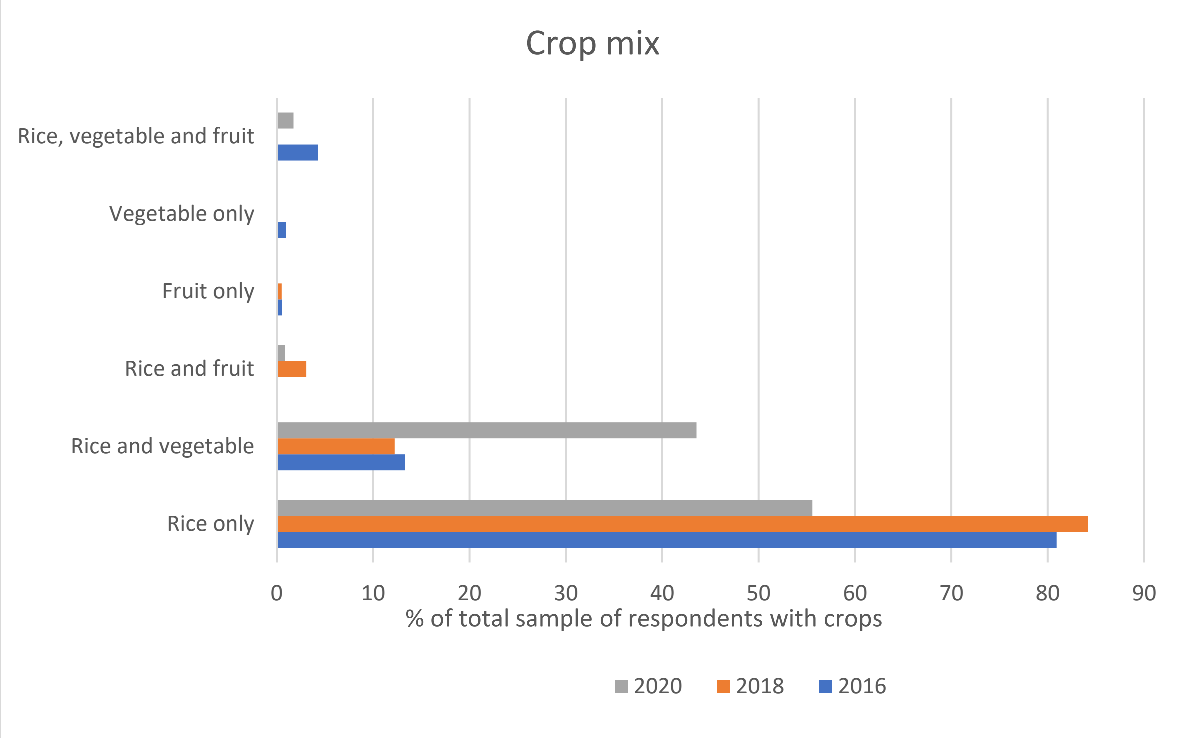


Figure 9. Reliance on rice in comparison to other food crops

Rice intensification

Reliance on rice crops between 2016 and 2018 is further illustrated in Figures 10, 11 and 12. Figure 10 shows a clear increase in rice intensification over this period with those relying on two rice crops per year more than doubling between 2016-2020 and those relying on 3 crops increasing greatly in Banteay Meanchey. However, the data for 2020 may reflect rice crops sown but lost to floods and therefore is not necessarily an indication that more farms are growing 3 crops of rice per year. Despite this, there is clear evidence for increasing intensification of rice production during the life of the CamSID project in this province. In Battambang, we see a different trend (see Figure 11) with those reliant on 3 and 2 rice crops per year dropping slightly between 2016 and 2018. However, the data for 2020 indicates similar evidence for increased intensification of production, albeit flooding also affected this province and resowing to make up for lost crops could be reflected in these figures. Figure 12 indicates that there has been overall, slightly more rice intensification in Banteay Meanchey in comparison with Battambang for the year 2020, with approximately 20% of households in this sample sowing 3 rice crops.

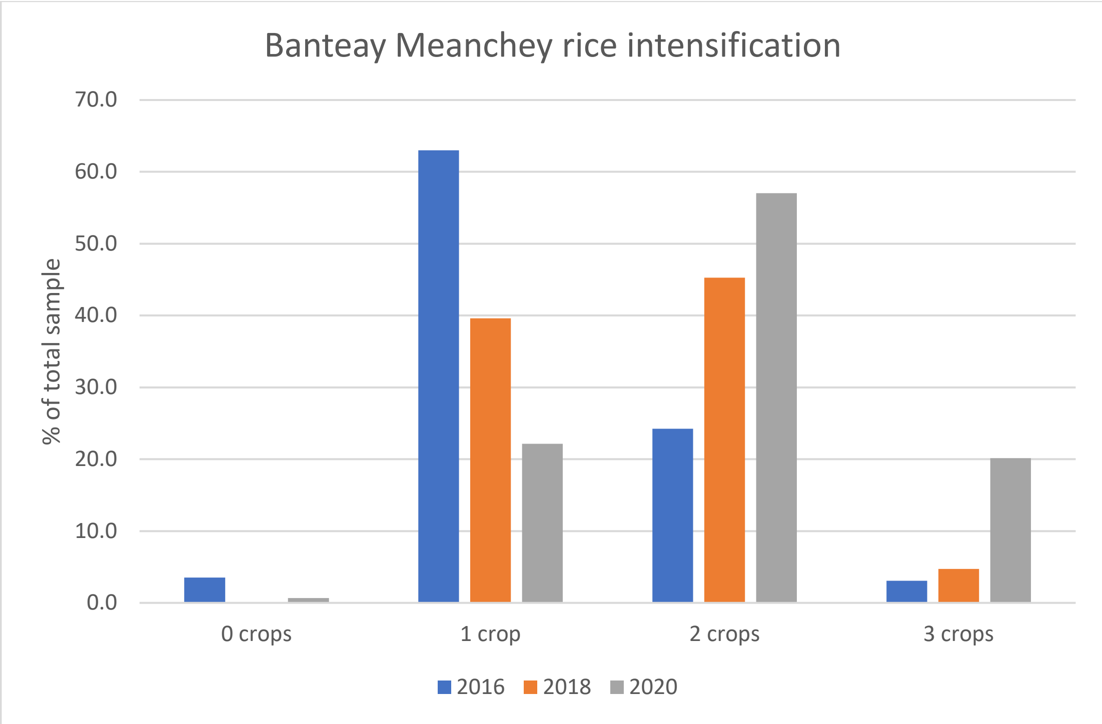


Figure 10. Rice intensification in Banteay Meanchey

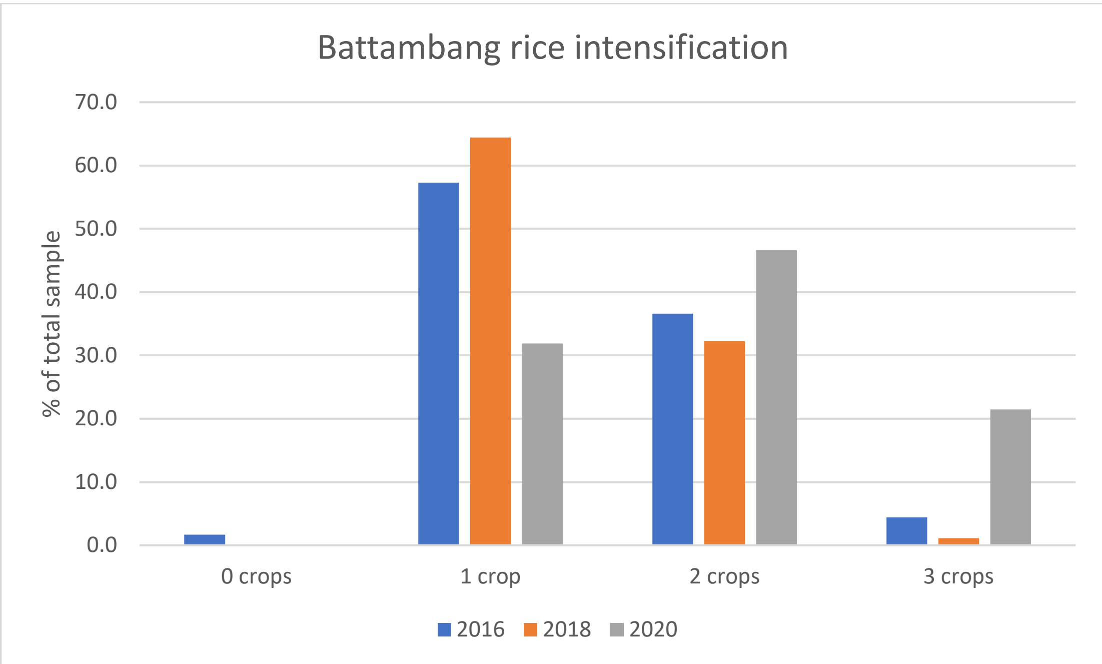


Figure 11. Rice intensification Battambang

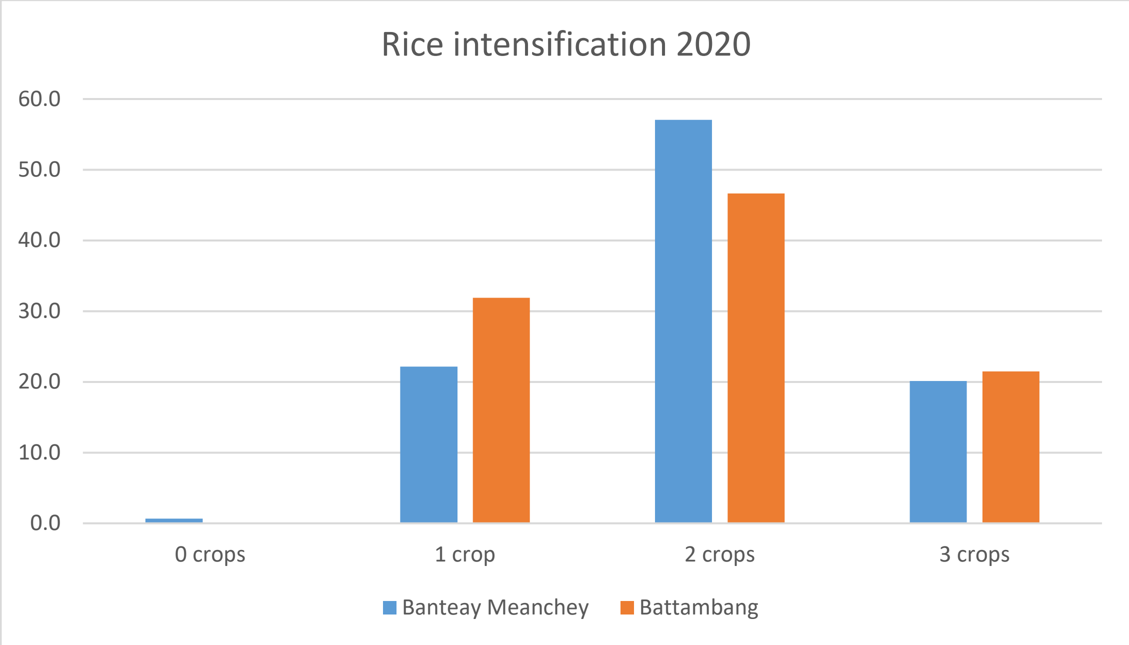


Figure 12. Rice intensification comparison between provinces 2020

Table 15 highlights average rice yields over this period and allows for comparison at the village and province levels. In Banteay Meanchey, yields rose on average by 0.5 t/ha and in Battambang yields rose by 0.8 t/ha between 2016-2018. This shows an overall increase in rice yields from 2.8 t/ha in 2016 to 3.4 t/ha in 2018. While 2016 yields were most likely impacted by the severe drought, 2018 yields are on par with the national average for rice yields (Cramb et al. 2020). In 2020, the average in Battambang remained on par with 2018, with farmers attracting 3.8 t/ha on average, despite extensive flooding in the wet season. In contrast, rice yields in Banteay Meanchey were severely impacted by both weather extremes, drought followed by flooding, as illustrated by an average of 2 t/ha. Table 16 depicts rice prices per kilogram and indicates that there was a rise in the price households were receiving for rice from $0.16 USD to $0.21 USD to $0.23 USD in 2020.

Table 15. Average rice yields in all villages surveyed

	2016	2018	2020
	Rice yield t/ha		
Battrong	2.7	3.4	2.1
Bos Louk	3.4	-	-
Kouk Tonlap	3.6	3	2
Trapaeng Thma	2.2	-	-
Ta Am	1.5	-	-
Kouk Balangk	-	3.5	2.3
Spean	-	-	1.6

AVERAGE Banteay Meanchey	2.7	3.2	2
Praek Trab	2.6	4	3.9
Prey Totueng	3.3	-	3.6
Rohul Suong	2.6	-	-
Svay Cheat	3.8	3.6	4.4
Svay Chrumm	2.5	-	-
Tahen	-	3.4	-
Ous Tuk	-	-	3.3
AVERAGE Battambang	2.9	3.7	3.8
AVERAGE OVERALL	**2.8**	**3.4**	**2.9**

Table 16. Average rice prices in all villages surveyed

	2016	2018	2020
	Rice price USD/kg		
Battrong	0.18	0.20	0.28
Bos Louk	0.18	-	-
Kouk Tonlap	0.14	0.21	0.23
Trapaeng Thma	0.15	-	-
Ta Am	0.19	-	-
Kouk Balangk	-	0.19	0.21
Spean	-	-	0.21
AVERAGE Banteay Meanchey	0.17	0.20	0.23

Praek Trab	0.17	0.22	0.18
Prey Totueng	0.17	-	0.23
Rohul Suong	0.15	-	-
Svay Cheat	0.14	0.20	0.26
Svay Chrumm	0.11	-	-
Tahen	-	0.21	-
Ous Tuk	-	-	0.24
AVERAGE Battambang	0.15	0.21	0.23
AVERAGE OVERALL	**0.16**	**0.21**	**0.23**

Agricultural diversification

While Figure 3 indicated that there was an increase in reliance on growing rice between 2016-2018, the data also reveals this trend reversed, with an increased reliance on diversification between 2018-2020. This increase in diversification is evident as in 2016 and 2018, 14.5% and 16% of farmers surveyed had other crops, while in 2020 47% of farmers had other crops. This jump in diversification could be attributed to the pandemic and the need for local food supplies. The data also reveals that in 2016, 48% of this commercial diversification was dedicated to mungbean production, while in 2018, only 25% of diversification was attributed to mungbean (see Figure 13). In 2020 this dropped to approximately 16% of diversification attributed to mungbean, with cucumber also representing 16% of diversification. The 2020 data (Figure 14) also illustrates an increase in the number of different crops that were commercialized in comparison with previous years.

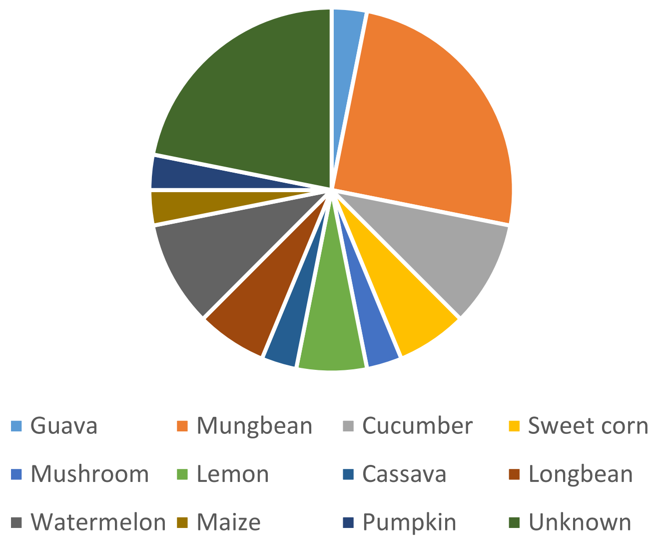


Figure 13. Crops grown other than rice in 2018

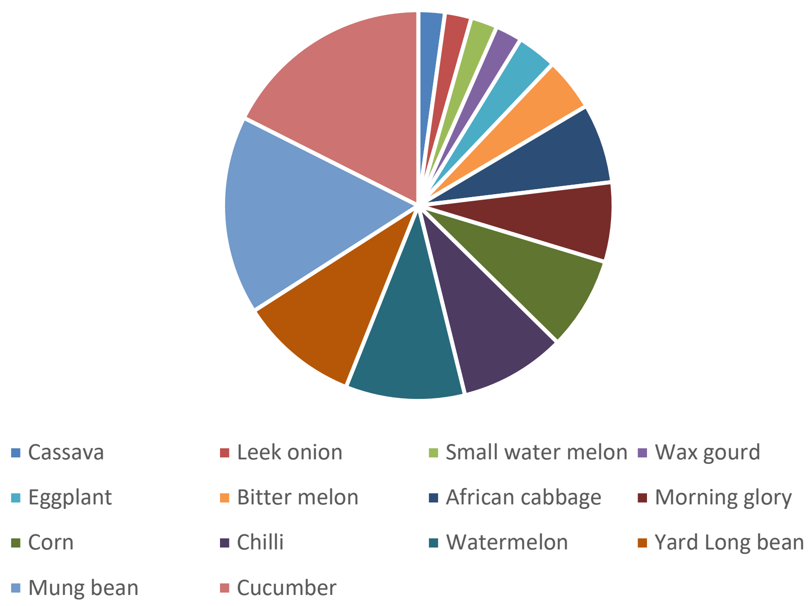
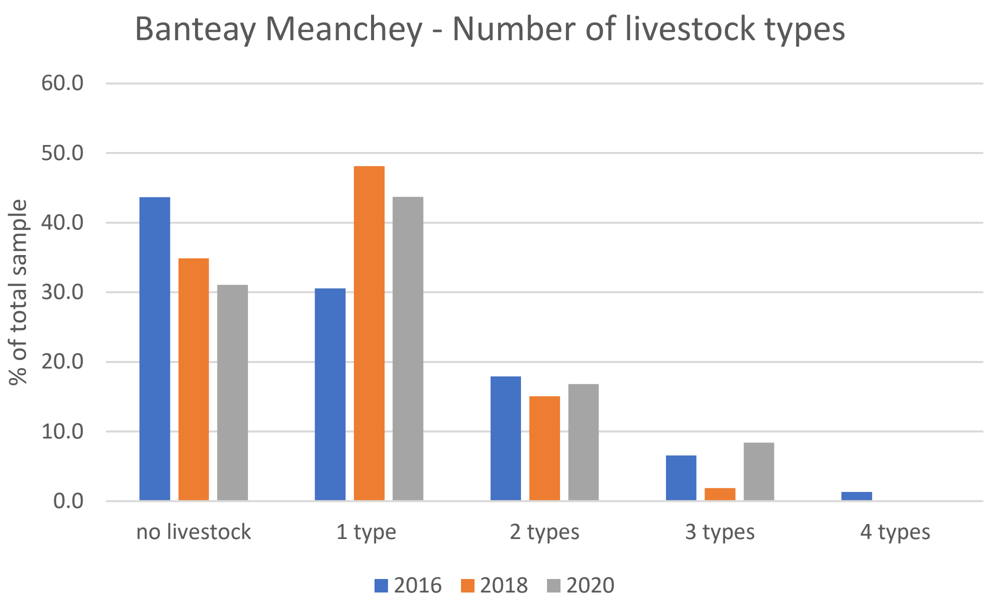


Figure 14. Crops grown other than rice in 2020

Figures 15 and 16 respectively depict livestock numbers in Banteay Meanchey province and Battambang province. Both provinces illustrate similar trends over this time period, with an increase in reliance on livestock which suggests this is still a strategy in household livelihood diversification. Figure 17 suggests that between 2016-2018 there was a decrease in buffalo, pigs and cattle (the decline in pigs could be attributed to outbreaks of African Swine Fever in 2018 (Woomwong et al.) and an increase in ducks and chickens with the latter increasing significantly. Between 2018 and 2020 however, there was a decreased reliance on poultry and increasing numbers of cattle, pigs and buffalo (albeit buffalo numbers are still extremely small) were identified.



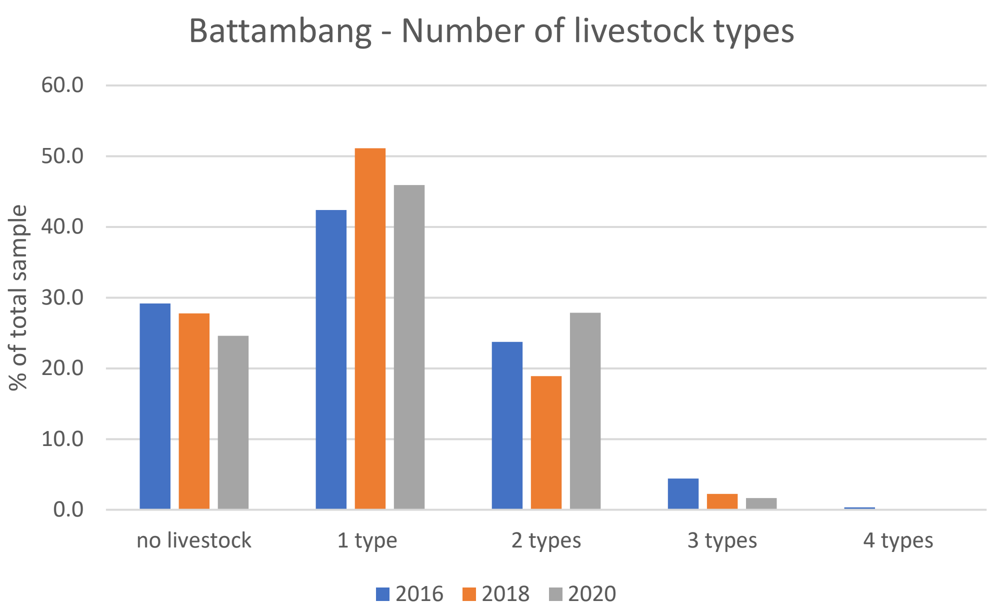


Figure 15 & 16. Changes in number of livestock types in each province

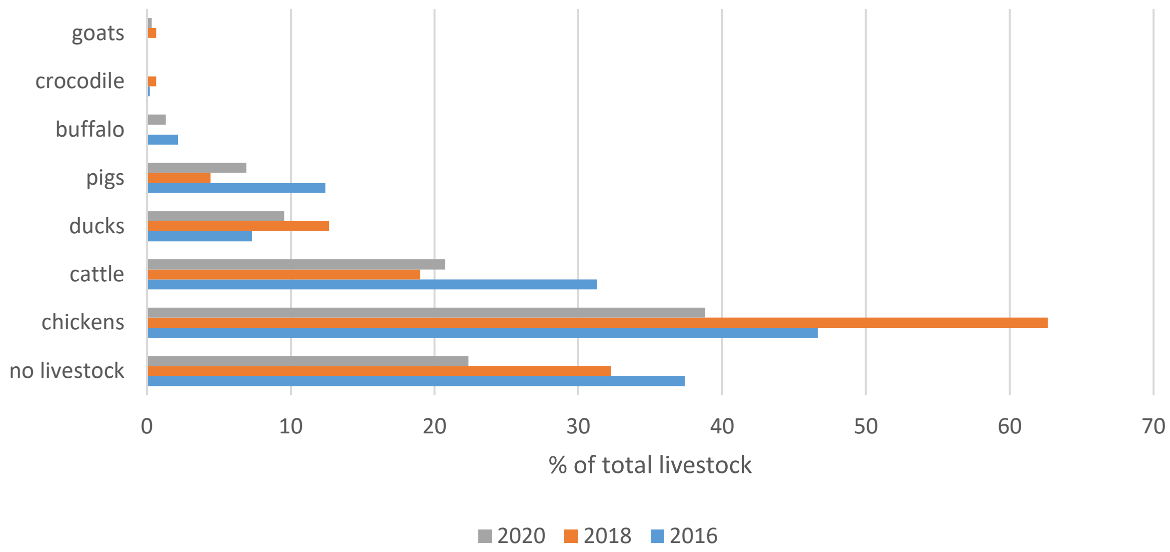


Figure 17. Changes in livestock types

Household incomes

Figure 18 depicts a comparison between income from rice, agriculture and non-agricultural activities between 2016, 2018 and 2020. The data here reflects increases in rice intensification, yield and rice price with all households across the two provinces more than doubling their rice income over the two years between 2016-2018 (although as pointed out, this trend is likely influenced by the impact of the 2016 drought). However, in Banteay Meanchey, there was a drop in non-agricultural related income resulting in total income comparisons being approximately $3,850 USD in 2016 and $4,800 USD in 2018 – an increase of $1,000 USD. In comparison, households in Battambang improved their non-agricultural related income resulting in a doubling of their annual income (from approximately $4,000 USD in 2016 to $8,000 USD in 2018). In comparison with 2020, Banteay Meanchey participants produced rice and agricultural incomes similar to 2016 (which is understandable considering the extreme climatic events they endured in 2020), producing overall less income in 2020. Battambang was also affected by climatic events and evidenced by the drop in income between 2018-2020, but still produced better rice and agricultural incomes in comparison with 2016 and overall a slightly higher annual income than 2016.

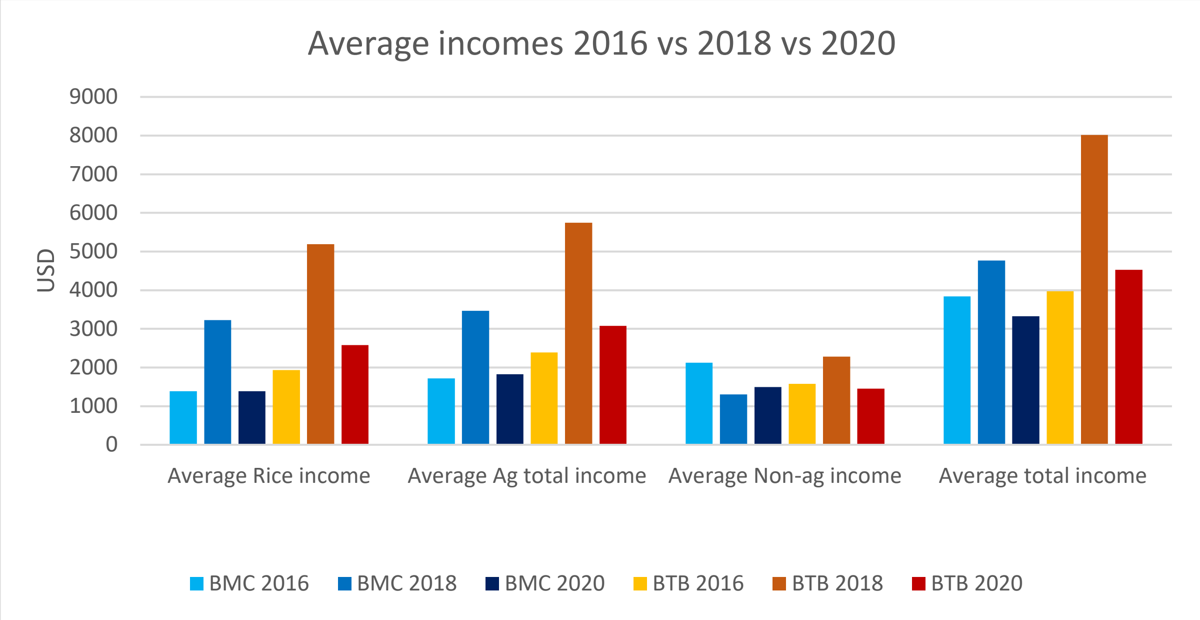


Figure 18. Comparing income from sources across provinces and across baseline, midline and endline surveys

Figure 19 further breaks down sources of income in 2018 and shows that rice underpins and dominates income in most villages. In Banteay Meanchey, the villages are comparable with Battrang slightly more reliant on rice income in comparison to Kouk Ballangk which has higher levels of remittance. In contrast, Kouk Tonlap has much lower rice income, yet has higher reliance on income from livestock. In the Battambang village of Svay Cheat very high reliance and returns on rice are evident (the dataset indicates that there are higher levels of land ownership and land leasing in this village too that enable high rice incomes). In contrast, Prek Trab has the largest percentage of income from crops other than rice, which correlates with the on-ground expansion of mungbean in this village. Tahen also relies less on rice income with higher levels of income derived to some extent from livestock, but predominantly from off-farm income. In comparison with 2020 (see Figure 20, recognizing that the Figures 19 and 20 have different y axes which abstracts their visual comparison), it is evident that in Banteay Meanchey province, Battrang village and Kouk Ballangk village illustrate a marked increase in livestock income while Kouk Tonlap exhibits an increased reliance on off-farm income (a key feature of this village anyway as it is positioned close to the main highway). Figure 20 reflects that half the villages surveyed in Banteay Meanchey are still reliant on rice income while the other half are more reliant on off-farm income in 2020. In Battambang, all villages exhibited incomes underpinned by rice production. Prek Trab village produced more income from other crops and livestock in 2020 while Svay Cheat did not see the same average income from rice production in 2020 as compared with 2018 and relied more on off-farm income.

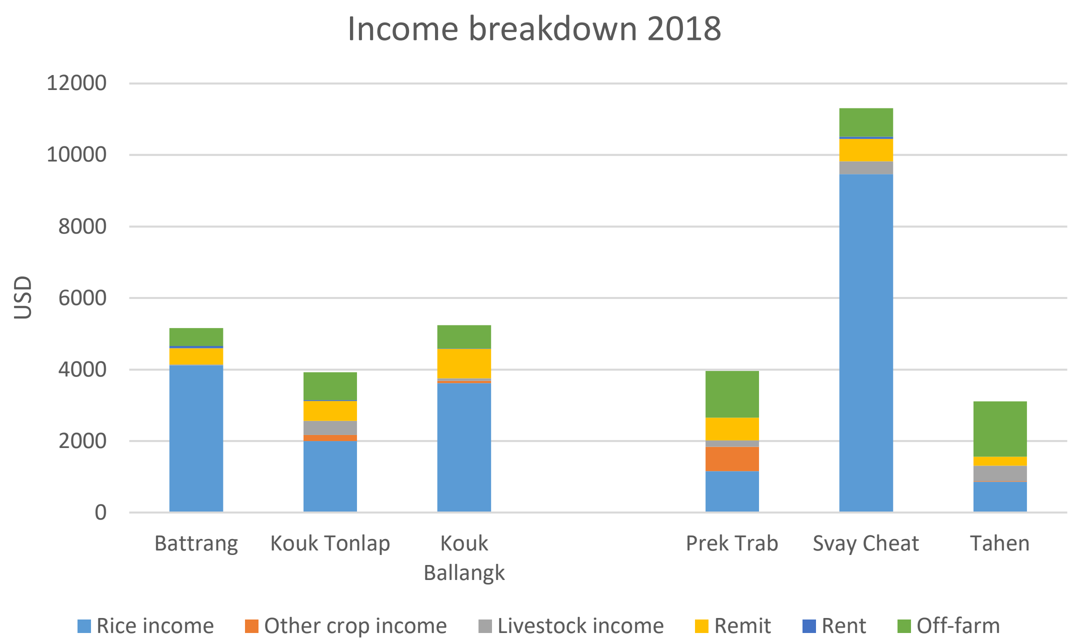


Figure 19. Village level breakdown of sources of income for 2018

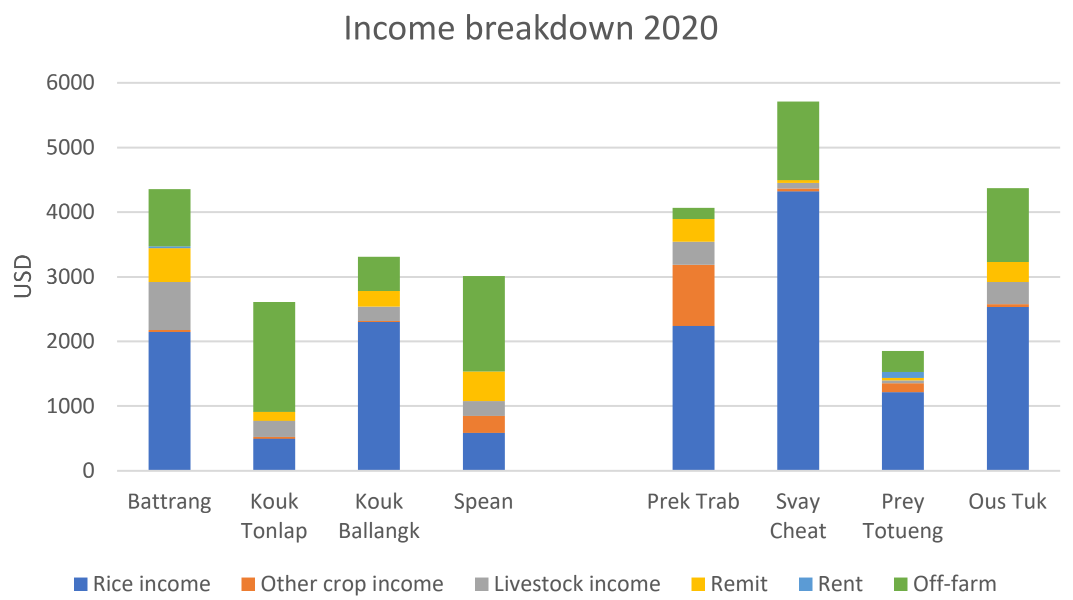


Figure 20. Village level breakdown of sources of income for 2020

Figure 21 compares income with expenditure in across the five years. This reveals that both incomes and spending were higher across the sample of households in 2018 as compared with 2016. However, in 2016, households were in approximately $350 USD deficit while in 2018 households were approximately $580 USD in surplus. In 2020, income was comparable with 2016 while expenditure was considerably less (which may be due to the confluence of the pandemic and climatic events resulting in less expenditure on major purchases like vehicles/tools and vehicle maintenance as well as leisure activities and social functions, noting also the increase in loans offsetting any deficits in income. This resulted in a 2020 surplus of approximately $1,500USD despite an increase in expenditure on crop inputs (as reflected in the increased number of times crops were sown in 2020).

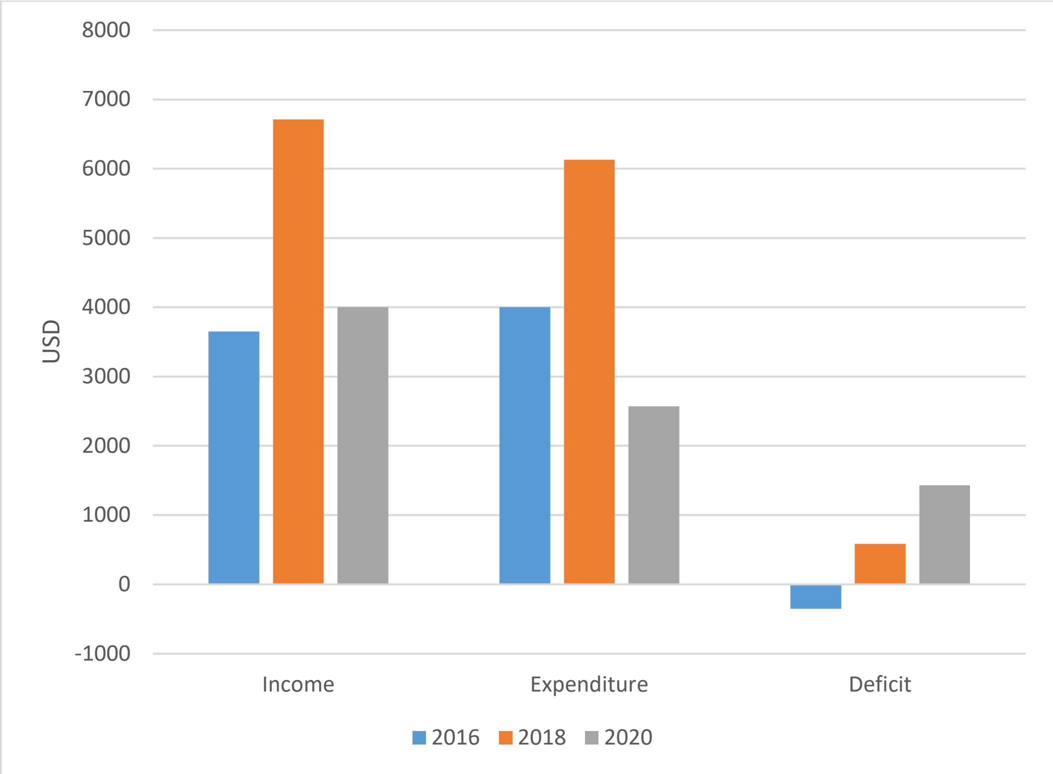


Figure 21. Comparing incomes and expenditures over 5 years

Practice change and mechanisation

During the midline survey, we concurrently conducted a mid-project evaluation using focus groups in each village to determine the major changes in production that had taken place since the inception of CamSID. The key results of this are reflected in Table 17 which indicate that there have been major changes with reduced seeding rates, land preparation and sowing methods as well as better pesticide, herbicide and fertiliser applications in both target and to a lesser extent, scale-out villages. These changes could also be attributed and correlated with higher rice yields in 2018 as compared with 2016, albeit the climatic conditions of 2016 (see Table 17).

Table 17. Focus group key findings from the mid-project evaluation in 2018

Village name	Extension type	Approximate Length of CamSID engagement	Major change 1	Major Change 2	Major change 3	Major change 4
Battrong, BMC	Leading farmer	2.5 years	Seeding rates (farmers along the canal have changed)	Fertiliser application (most aware, not all have adopted)	Land preparation (approx 50%)	Pesticide and herbicide application (leading farmers do this)
Kouk Tonlap, BMC	Leading farmer	2.5 years	Seeding rates (approx 90% of village)	Land preparation (approx 50-60% of village)	Pesticide and fungicide application (approx 50% of the village)	Fertiliser application (approx 80% of the village)
Svay Cheat, BTB	AC/Farmer group	2.5 years	Sowing method (approx 4 people adopted mechanised seeding)	Pesticide, fungicide and herbicide application (approx 10-50%)	Land preparation (approx 100% of the village)	
Prek Trab/Angsang Sok, BTB	AC/Farmer group	1.5 years	Fertiliser application (approx 95%)	New mungbean varieties (15 villagers)		
Kouk Ballangk, BMC	NGO	1.5 years	Seeding rates (approx 50% of village)	Land preparation (approx 90% aware, 50% have changed practice)	Fertiliser application (approx 100% of the village)	
Tahen, BTB	NGO	6 months	Sowing method from hand broadcaster to Kid seeder (approx 3% of village)			

Some key results that emerged from the midline focus groups are further reflected in data obtained from the endline survey. This includes the emergence of mechanized broadcasting which, as reflected in Figure 22, emerged largely in Banteay Meanchey with some occurrence in the village of Praek Trob in Battambang. The emergence of the Kid seeder in Battrang, Kouk Tonlap and Ous Tuk further reflects some adoption of mechanized seeding. Both these emergences can be attributed to decreased seeding rates, although it also seems that hand broadcasters were likewise reducing seeding rates, which can be directly attributed to the influence of CamSID in these villages. Despite the emergence of mechanized seeding in these villages, there was no evidence that the Eli Seeder was employed in 2020, and overwhelmingly, the data indicates that the majority of farmers are still very reliant on hand broadcasting.

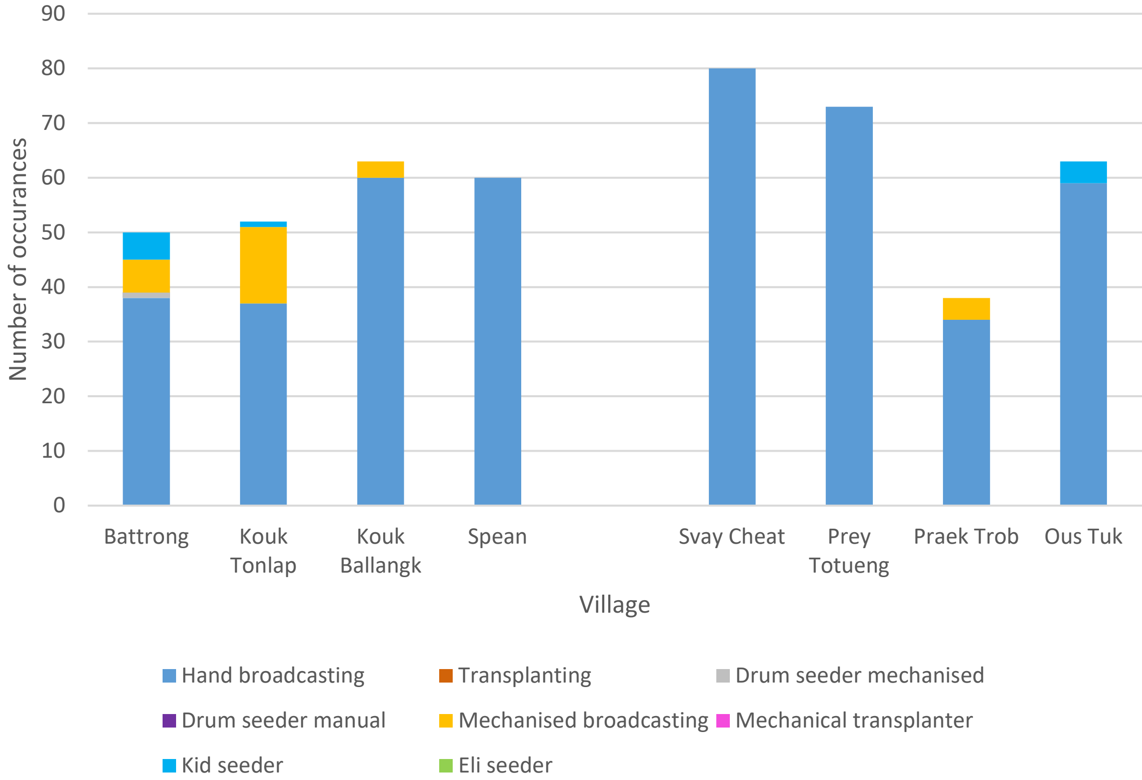
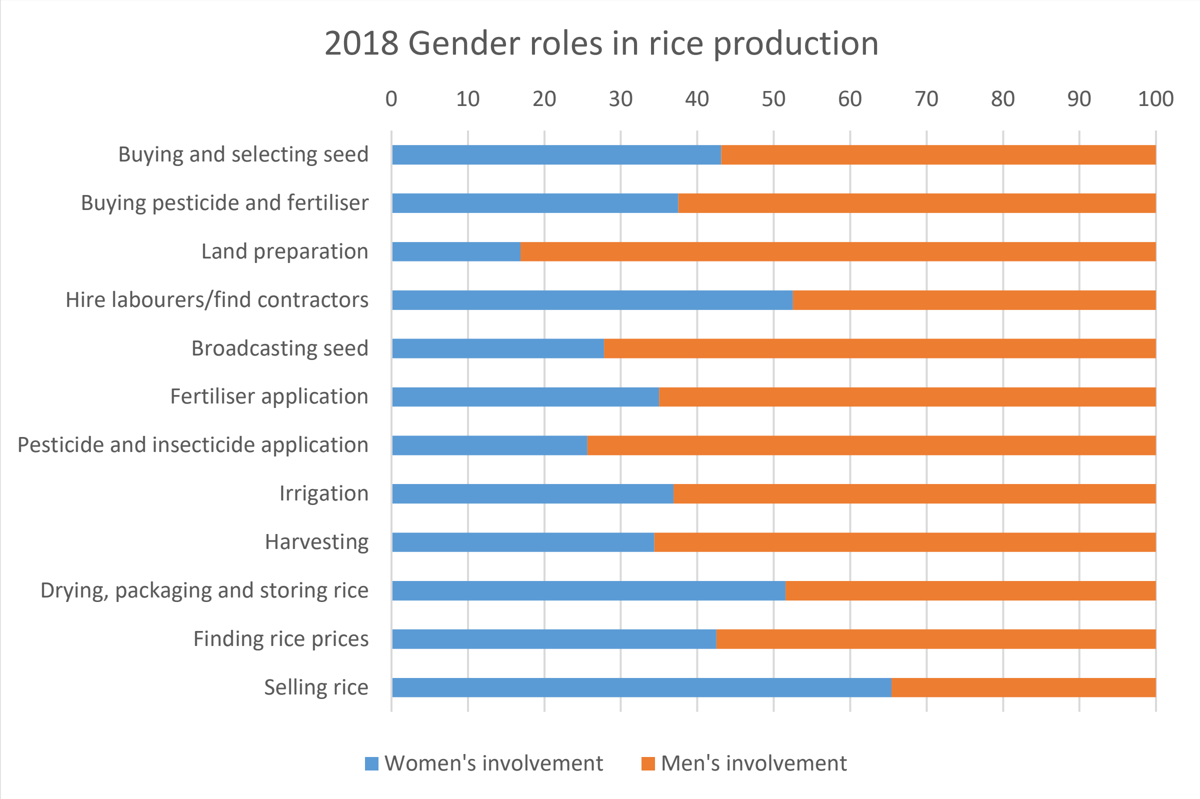
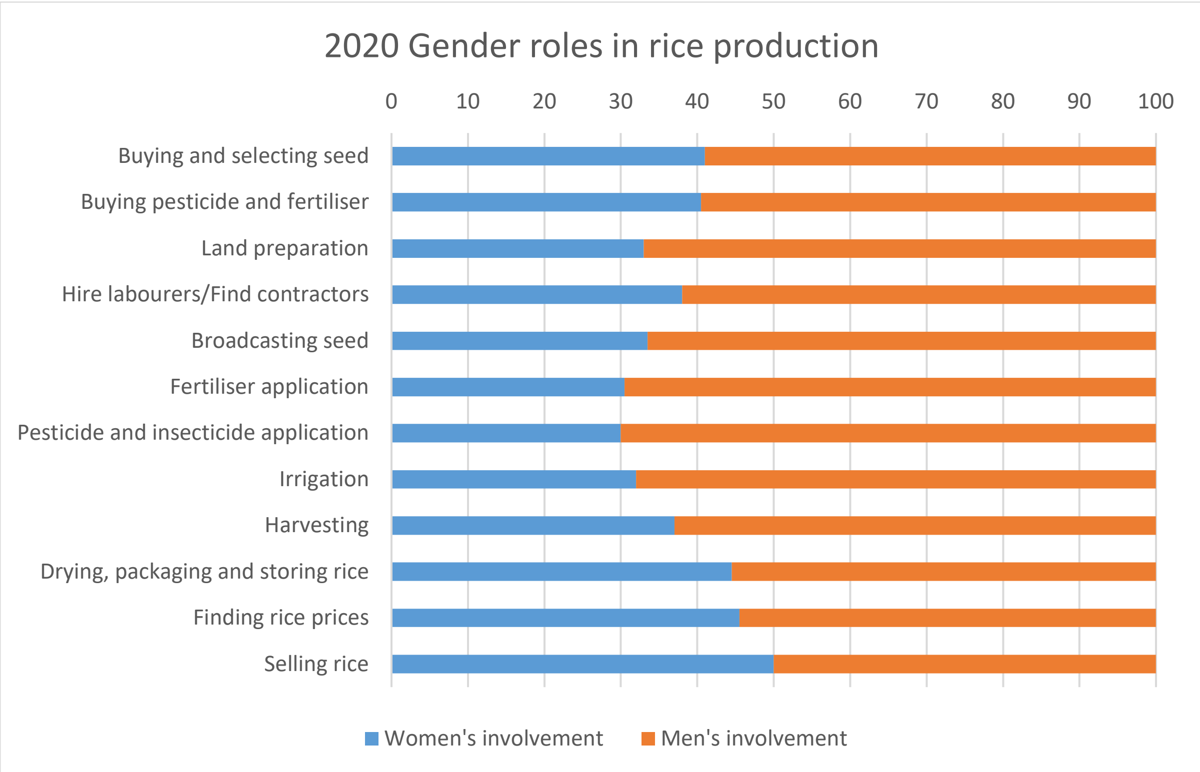


Figure 22. Mechanisation for planting crops in 2020

Gender roles in agriculture

The endline survey also enabled us to do a gender comparison of household roles in rice production. Figures 23 and 24 offer a comparison between 2018 and 2020. While most roles are quite comparable, there are some trends that can be pointed to – specifically the decreased roles of women in finding contractors (52% down to 38%) and selling rice (65% down to 50%). While reasons for this were not interrogated with households, this could be attributed to covid lockdowns which impacted women with increased loads of unpaid domestic work well as the need to perhaps travel further afield to find labourers or sell rice. In contrast, women's involvement in land preparation almost doubled from 16% involvement in 2018 to 33% involvement in 2020.





Figures 23 & 24. Gender roles in rice production in 2018 (Figure 23) and 2020 (Figure 24)

CamSID project engagement and impact

The endline survey also captured data on farmer engagement with the CamSID project specifically. Figures 25 and 26 indicate the number of events attended and level of engagement households reported with CamSID respectively. Figure 19 reveals that the majority of households contacted for the endline had no involvement in CamSID while being involved in surveys/interviews and field days (predominantly Banteay Meanchey) exhibited the highest levels of engagement. Beyond these activities, in Battambang, training, watermelon demos and mungbeans demos exhibited some of the highest levels of involvement. In Banteay Meanchey, beyond field days, involvement in training, women's groups, hub development and to a lesser extent, aquaculture demos were all revealed as key activities for engagement. Figure 20 reflects this data with better engagement in Banteay Meanchey than Battambang evidenced in this cross-section of respondents which may be due to the large CamSID field days held in this province. While both provinces exhibited good reach across target villages, no respondents reported a level of 'high engagement'. The need for more regular contact and engagement is evidenced further in the qualitative comments presented further below in the section on room for improvement.

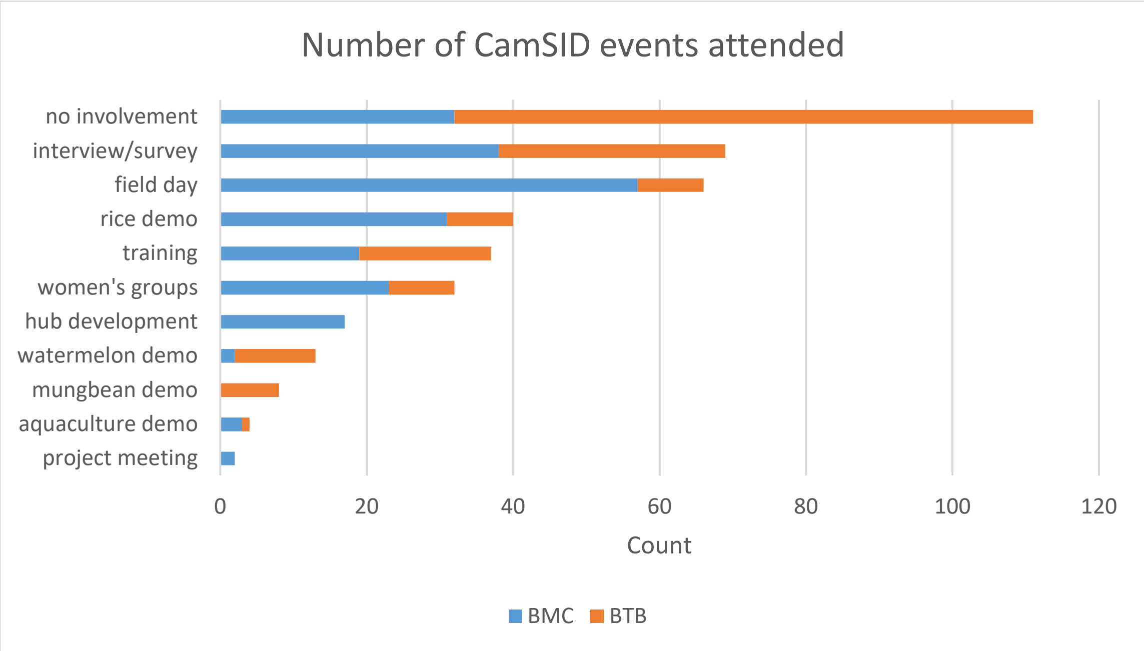


Figure 25. Number of CamSID events attended by province

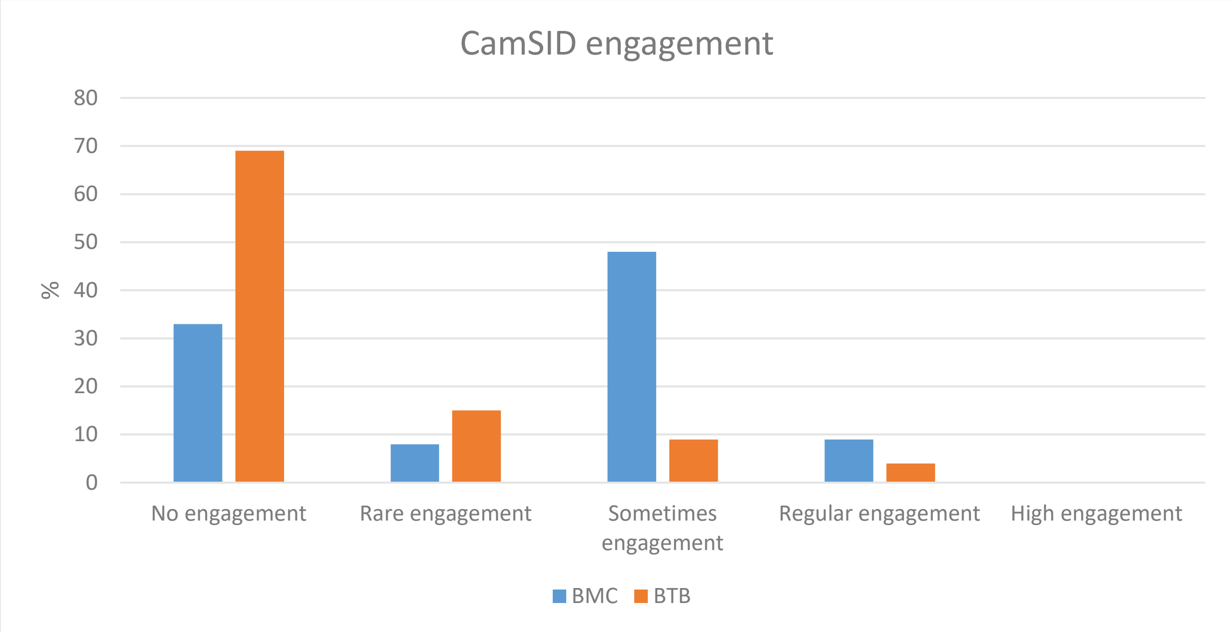


Figure 26. Reported engagement with CamSID by province

Respondents also offered qualitative comments pertaining to the knowledge, practices and experiences they gained through involvement in CamSID. When asked "what did you learn through this project", the improved production of rice, seed purification and the relationship between mechanized seeding and reduced seeding rates was a clear learning. Further learnings about variable rate application of fertilizer and more effective use of herbicides and pesticides also emerged. Learnings about diversification, specifically watermelon and fish, are also evident, as were learnings about gender in agriculture. These key learnings are reflected in the following selection of quotes (see Box 1).

Box 1. What did CamSID participants learn? (Select responses)

- Rice was grow better than hand broadcasting
- I learned a lot about rice farming by machine planting.
- using low seeding rate, fertilizer use, how to control weed and growing rice by machine like Kid seeder, drum seeder, and Eli seeder
- All this machine I think difficult to use than hand broadcasting but that point is good use low seeding rate
- Seed purity
- Thinks it's good project because project give a good seed, new seed for farmer and teach about destroy insect
- Good show about How to apply herbicide
- I know how to use kid seeder and drum seeder and join training about fish also
- I know how to use fertilizer and grow rice by machine and how to feed fish
- How to use low seeding rate fertilizer use grow rice by machine and fishing training also
- How to control rice grow and growing fish and watermelon and many training
- More knowledge about gender and seed producing
- Rice methods and gender

Respondents were further asked whether engagement with CamSID was useful for them and why. This elicited responses relating to improved rice production techniques and more effective use of inputs as well as specific mention of Integrated Pest Management (IPM), pesticide safety and seed storage. Furthermore, some respondents indicated that the project was useful and that they were part of networks of information sharing within the project, while others indicated that it was not useful as they had limited participation or were unable to recall key information delivered through extension (see Box 2).

Respondents were also asked questions about what they had adopted or planned to adopt as a result of direct engagement in CamSID. The major adoptions to occur due to

Box 2. Was your engagement in CamSID useful? (Select responses)

- This training make me know about technical to grow rice better than before
- Yes, it is about how to know a rice technical (IPM)
- Yes, teamwork show about the technical and provide about safety of how to use pesticides
- Yes, the content was useful like know about technique grow rice to get more yield, how to control pest and using fertilizer
- Yes, how to use herbicide and variety.
- Good because I follow the weed reduced 70% in my field.
- Learn more about how to store seeds
- Yes, the content was useful and my field near by Mr. Sarith so I always ask him
- Yes, it is useful. i got more knowledge and inform my son and neighborhood to follow.
- Yes, because helps me to develop myself while farming
- Not useful because just join one time
- Not useful because I did not remember any more

Box 4. What do you plan to adopt from CamSID? (select responses)

- Want to plant with Kid seeder
- Want to grow rice by Kid seeder
- I think if planting rice by kid seeder low price I want to dry it
- Want grow rice by kid seeder for seed production
- Land leveling and mungbean crop rotating
- Rice and mungbean rotation
- Fertilizer rate application

CamSID were related to mechanized sowing of crops and reduced seeding rates, the latter not always directly related to mechanization as indicated in the quotes (see Box 3). Improved applications of fertilizer, insect control and weed management were also mentioned as was improved diversification via better mungbean varieties and adoption of fish production. Others indicated that they had not adopted CamSID techniques due to a range of reasons including rainfed rice, long-season rice, subsistence rice and poor health (see Box 3). When asked what practices they planned to adopt in the future, most farmers discussed wanting to adopt the Kid Seeder for planting, but also mentioned wanting to do crop rotation with mungbean and adopting variable rate application of fertilizer (see Box 4). Participants also explained what they now needed more knowledge on and made suggestions for the focus of future projects. These suggestions focused heavily on climate resistant rice varieties that could withstand drought and flooding. Vegetable production, fish production, and control of pests and weeds, including rats and golden snails, were also suggested as areas in need of intervention. To a lesser extent, fungicide application, rice markets, rice quality seed development, machine planting, animal husbandry and soil fertility were suggested as areas of focus (see Box 5).

Box 5. What do they want to learn? (select responses)

- Variety that resistance with drought
- Want to the project find variety resistant with drought and flood
- Want to get variety that resistant with drought and flood
- Want to get variety resistant with flood
- Want to project research on climate and find some of variety that can grow got high yield
- I want the project to focus on good varieties of vegetables.
- Techniques to grow vegetable
- You should focus on farming and vegetables growing techniques
- Want to see how control golden snail
- Want to see how to control weed, disease, insect and especially golden snail
- I want to know how to control rat
- Want to learn how to feed fish
- Want to know technical feed the fish
- You should focus on the technical of using fungicide on vegetables and rice products
- Market of price rice, Rice QDS
- You should provide the machine planting again for farmers in the future
- Add techniques in animal husbandry
- How to get soil fertility technique.

Participants also offered feedback for improving CamSID with more contact with villages a key response; hosting more field days, more demos, advertising these more widely and employing YouTube to disperse information were all suggested (see Box 6).

Box 6. Feedback from improving CamSID (select responses)

- Want to video on YouTube about rice field production
- More field days, more demos - field day is good because famer can see by their eyes
- More contact– go often to the village – meeting farmers every month
- More advertising

Conclusions and Recommendations

It is evident that the impacts of drought, flooding and the global pandemic affected farming households in the study period from 2016-2020 with both 2016 and 2020 impacted more so than 2018, especially in Battambang province which produced some bumper crops and associated high incomes that year, although was not as affected by climatic variability in 2020 as Banteay Meanchey.

In terms of household capacity, two key trends emerged from the data. The first of these is the increase in land owned and land rented for agriculture with the average farm size in this dataset jumping to 5 ha. This indicates households are expanding their operation in order to stay viable. In addition to this, there has been greater uptake of loans to offset expenditure/invest in agriculture. The pandemic also generated two key trends; less migration and therefore less remittance and greater subscription of farming households to local community groups.

In general, the data indicates that rice intensification and diversification are on an upward trend. The average number of rice crops sown in each village may not take into account resowing of crops in 2020, but despite this, and considering the expansion of farms, there is a clear shift to growing more than one crop of rice per year, especially in Banteay Meanchey province. Battambang province presents a more complicated picture with some evidence of intensification, but more evidence of increasing rice yields over this period. Reliance on diversification has increased with half the households surveyed also actively growing and selling other crops. Initially, there was heavy reliance on mungbean, but this has changed with increasing diversity in the types of alternative crops grown, albeit the majority of households are still highly reliant on rice production and income. Increasing reliance on livestock to contribute to livelihoods is also evident over the last five years.

Incomes were overall worse in Banteay Meanchey province in 2020 but better in Battambang province in 2020, however 2018 produced the best incomes according to the data. While incomes were marginally better than 2016, there was a decrease in overall household expenditure, which could be Covid-19 related, resulting in household surplus of $1,500 USD. However, as noted in the report, 50% of households were accessing loans which is likely affecting income-expenditure comparisons.

Throughout the survey, particularly the midline focus groups and endline survey, it is evident that farmers were, to some extent, engaging in practice change. This is particularly in relation to adoption of mechanized sowing, including some of the technologies recommended by CamSID, albeit the vast majority of farmers still practice hand broadcasting. However, it is evident through the qualitative data that one of the key changes in practice has been seeding rates, whether or not farmers are using mechanized sowing. This is the most directly evidenced widespread impact of the CamSID project on smallholder farmers in NW Cambodia. Other impacts were also evident with key farmers who engaged with the project reporting adoption of more strategic fertilizer, pesticide and herbicide applications as well as improved diversity in mungbean, watermelon and fish improvements.

Some key recommendations for future projects include the following:

- Promoting a focus on mechanisation options like the mechanized broadcaster as a more cost effective and seed-saving step in between hand broadcasting and more expensive direct-sowing options like using the Eli and Kid seeders.
- Promoting CamSID rice technical packages through demonstration videos on Youtube and promoting these via PDAFF and other local stakeholders.
- Investigating diversification agility in livelihoods with non-rice crops and livestock temporally and spatially.
- Ensuring regular and sustained contact with farmers and households for better engagement and diffusion in target villages. This may involve hiring local farmers or people who live in villages as part time project liaisons and points of contact for communication and extension.
- Investigating climate resilience in rice farming and research on varieties that are both flooding and drought resistant.

7.1.2 Farm household typologies

Impredicative loop analysis (ILA), ILA assumes 4 critical interdependent variables along which household can be characterized in a typology (Giampietro 2003). As a basis for the typology, the research team decided on wealth ranking (assets + income) and an even distribution of 20%-20%-20%-20%-20%. Wealth was found to be most significantly correlated with land ownership, and then ownership of machinery. Therefore, the ILA originates from land ownership (top y axis in the graph). For simplicity, this analysis assumes rainfed rice farming, which is the most widespread farming system in the study area. A separate ILA on irrigation was done during the 2018 annual meeting. This analysis was done across all study villages in the target area and typologies were defined via the five wealth indices. Obviously, types could be further disaggregated according to province and irrigation systems utilized.

- Framework assumes 4 interdependent resources [land, labour, income, energy]
- Types divided according to wealth ranking (land as determinant)
- All values are per hh/yr

Energy: Mechanical energy = hand tractors + motorbikes

Land: all accessible land

Labour: Available labour = hh members – migrants

Income: Total income = Crop income + labour income + remittances

In our CamSID project, we mainly engaged with Type 4 – “Professional Farmers” who are also our lead farmers. These “Professional Farmers” provide a social service, helping us to disseminate knowledge and innovations to the Type 2 – “Subsistence Farmers” and other groups. We acknowledge the presence of Type 3 – “Migrants”. Most of the migrants work in Thailand. However, during the COVID-19 pandemic, there was reverse migration (from 2020) with migrants returning from Thailand, bringing back COVID-19 infections to the border provinces (e.g., Battambang and Banteay Meanchey).

The typologies are represented graphically in Figures 27-33.

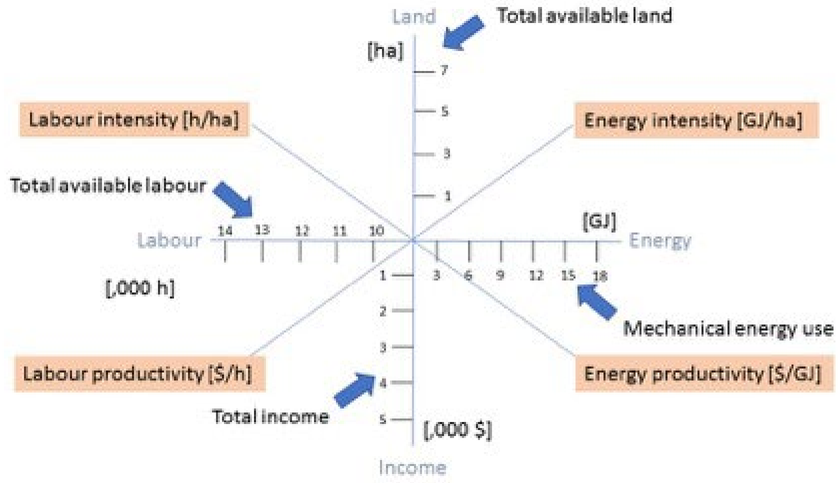


Figure 27. Graphical representation of Impredicative Loop Analysis

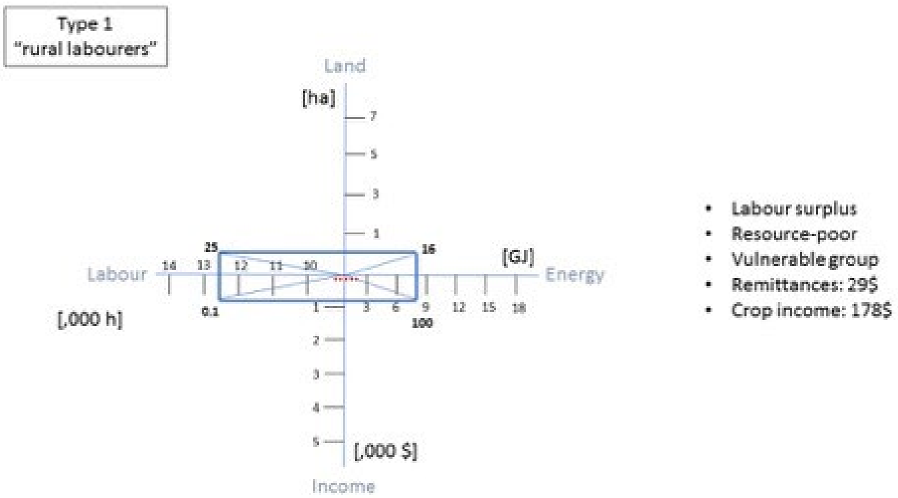


Figure 28. Type 1 'Rural labourers'

Type 1 are resource-poor in every aspect except labour. Labour availability is fairly equal (between 4-5 household members) across all types. Given the scarcity of land within this type, labour is at a surplus. Cropping is primarily conducted for food enhancement and hardly commercial. Interestingly, remittances are also low. Hence, it could be assumed that these households do not have the means for migration and must rely on local labour demand and other agricultural/non-agricultural jobs.

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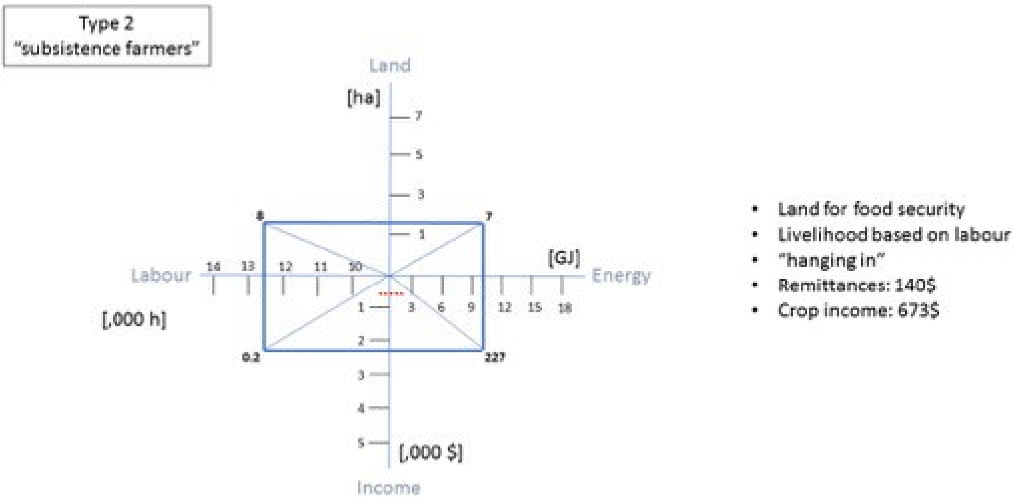


Figure 29. Type 2 'Subsistence farmers'

Type 2 are classic subsistence farmers, which do not engage in much commercial farming and focus on food security. However, land is sufficient to feed the family (in terms of rice). Household income relies on labour, usually from local demand as migration levels are low.

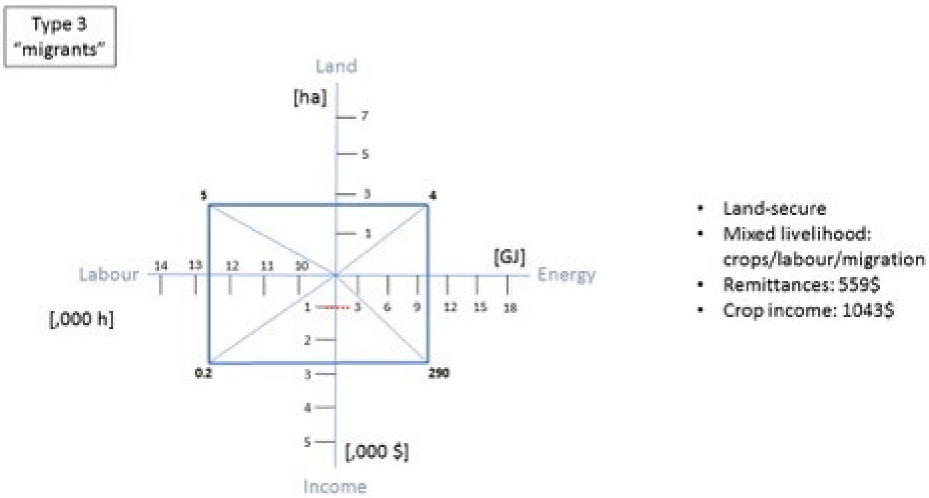


Figure 30. Type 3 'Migrants'

Type 3 relies heavily on migration (highest level of remittances among the 5 types) but income from cropping is significant, at least in terms of stabilising the farming system. It remains questionable if major investments can be made into these farming systems without access to financing.

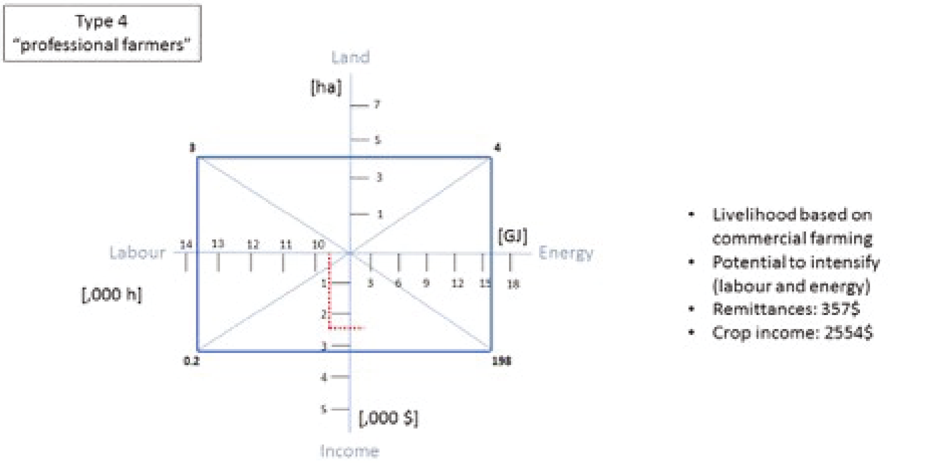


Figure 31. Type 4 'Professional farmers'

Type 4 seem to be making a living primarily off their farming (crops), which forms a major part of their income. In addition, there seems to be room for possible investments to further intensify the system. These are 'professional farmers' who base their livelihoods around cropping and thus seem to be the optimal target group for CamSID interventions

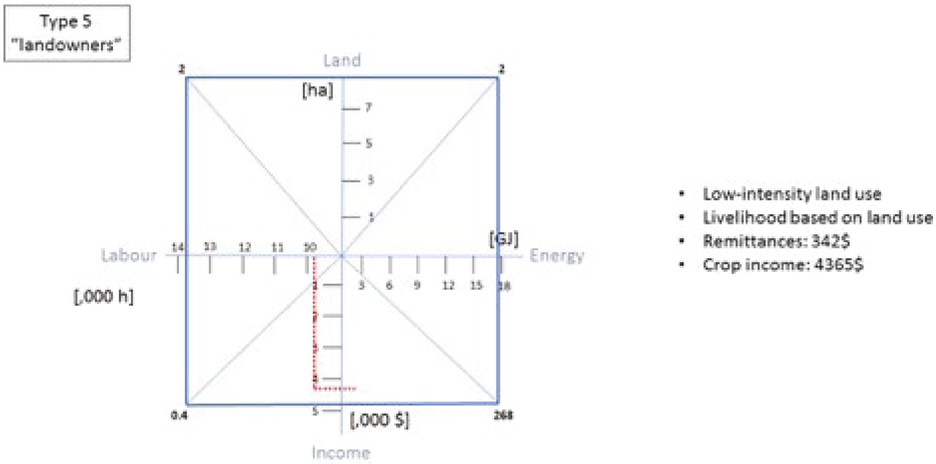


Figure 32. Type 5 'Landowners'

Type 5 own large areas of land and currently base their livelihoods around cropping. Given the demographic trends, however, they will need to intensify their systems, perhaps with a focus on mechanisation. Alternatively, they may start renting out and pursue other, non-agricultural lifestyles. This analysis merges ILA with Dorward's livelisystems approach (Dorward (2009) (Figure 12). Dorward distinguishes groups of farming households according to their current trajectories into:

- "Falling off"…vulnerable household in danger of entrenched poverty and resource scarcity with a questionable future in farming.
- "Hanging in"…subsistence farmers that focus on food security and stabilising the farming system, rather than commercialisation and mechanisation

- "Stepping up"…households that possess the resources to invest in the farming system and are willing and able to make substantial changes in terms of intensification (potentially, out target group)
- "Stepping out"…household that are eyeing an exit from agriculture, as their resource base allows transitioning up the value chain or migration into other livelihood activities.

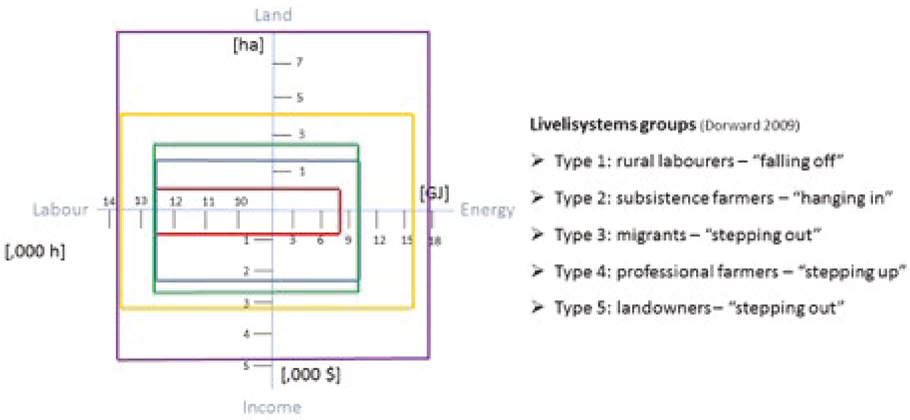


Figure 33. All types

7.1.3 Social network analysis (SNA)

From the social network analysis of Angsangsak village, the betweenness centrality of farmers is positively correlated with technology diffusion. Hence Farmer Node 71 is the central figure from which many farmers get their farming advice from (Figure 34). However, the position in social networks alone does not tell the full story. The analysis also suggested that exposure to mass media and agricultural associations was negatively correlated with adoption of new technologies. Additionally, the larger the annual net profit earned, the more likely a farmer will adopt new technologies.

Figure 34. Sociogram of Angsangsak village based on advice seeking networks

The higher betweenness centrality of a farmer, the earlier this farmer may adopt technology. Farmers with high betweenness centrality have access to diverse cliques within the local social networks and therefore have the best access to diverse sources of information.

Moreover, due to the brokerage opportunities possessed by farmers with high betweenness centrality in their networks, most agricultural technologies will go through them, giving rise to the possibility of technology adoption. **For this reason, our CamSID project focussed on training lead farmers (Type 4 "Professional Farmers") who have high betweenness centrality in their networks. These lead farmers were identified during the PRA where we asked farmers in each village which lead farmers they trust and get their information from.** Trust among farmers contributes to the significant role of word-of-mouth information from other farmers in adoption behaviour. It can be attributed to the traditional Cambodian society which is organised around kinship and family relations play a dominant role in Cambodian farmers' social lives.

However, in our CamSID project, we also found that lead farmers who are popular, are not always a successful diffusion strategy. For example, although we provided a 4W tractor and a Kid seeder to our lead farmer at Kouk Tonloap Village, he preferred to focus on land preparation (ploughing) and mechanised broadcast seeding (rather than seeding using the Kid seeder). This is because the high costs of Kid seeder operations (>$40/ha) make it less economic for poorer farmers in Banteay Meanchey Province to engage Kid seeder contracting from this lead farmer.

7.1.4 Gender analysis of the rice and vegetable value chains

Gender in the rice value chain

Where women are more involved in the activity (their involvement is at least 50%), then they play a bigger role in the decision making; they discuss with their husband and make the decision in agreement. Women are reported to be involved at 50% in the decision making related to, for example*, Transplanting in the gaps, Weeding, Making the rice levee, Drying, packaging and storing rice, Hiring Laborers and Contractors.* Exceptions are related to *Buying pesticide and fertilizer* and *Buying bags and strings* – probably due to their limited knowledge regarding inputs and harvesting needs. They are the best negotiators within the family but in this case their action is informed and influenced by the husband's opinion. On the other hand, it is worthy to note that the farmers reported that the women play a bigger role than men in the decision making related to *Selling Rice* (60% vs 40%). This was the only activity in which women had control over the decision-making process. Similarly, when women are less involved in an activity *e.g., buying seed; land preparation; broadcasting* then their opinion is less likely to influence the final decision. For instance, for the decisions concerning land preparation, the farmers reported that women are involved in decision-making at 12.5%. Also interesting to note are the instances when women play less of a role in the activity but more of a role in decision-making. This is usually related to inputs; women were not very involved in applications, but when to apply inputs – fertiliser, pesticide/insecticide and herbicide, was a decision often made by checking the field as a partnership, although the man ultimately had more say in these decisions (Figure 35).

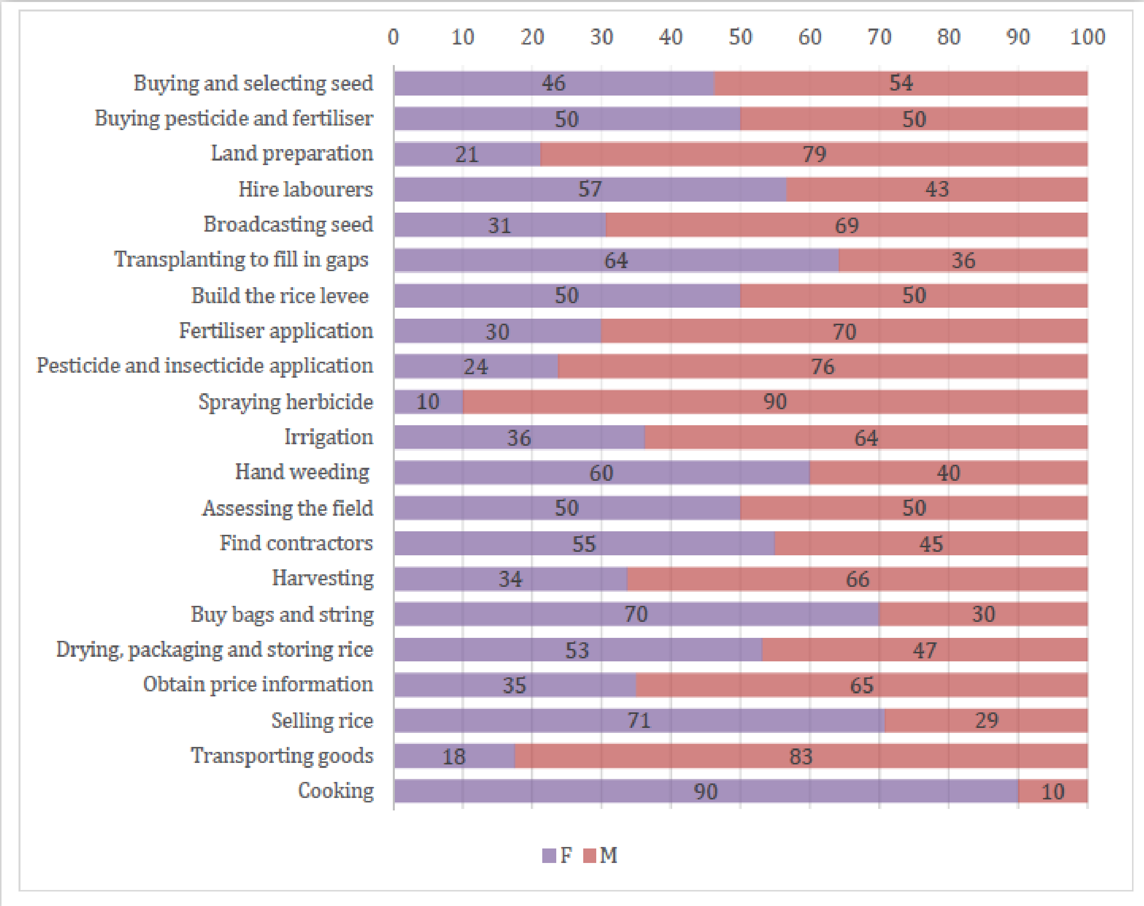


Figure 35. Male and female % of involvement in each activity listed by respondents in the rice value chain

The opportunities for women to lead the way in innovation and farm improvement are extensive. There are a number of key skills women have and roles women could fulfill which could increase their participation in the rice value chain without requiring a 'gender reversal' or a drastic shift in gender roles. These potential services include women as financial managers for households, investments, local businesses and ACs. Women as record keepers (monitoring key aspects of production) and farm planners (generating and using data to identify trends and opportunities for practice change). Women as quality control experts (to find efficiencies and potential improvements/innovations or new markets). Women as local extensionists – acting as conduits for bringing outside knowledge of innovation into villages and households. Women as entrepreneurs – exploring potential for developing businesses and generating off-farm income via collective groups of women. Women as citizen scientists – trialing and monitoring new practices or approaches on a small scale, for example Integrated Pest Management. In these positions, women could become facilitators of not only increased equity, but increased sustainability in their villages, by improving environmental, economic, socio-cultural and personal outcomes for all.

Gender roles in vegetable production

For centuries, the backbone of Cambodia's economy and agriculture sector has been the cultivation of rice. However, recent market trends have seen changing dietary patterns and a decline in the global price of rice for the foreseeable future, leaving small-scale rice farmers without a sustainable income. An option that farmers in North-west Cambodia have is to diversify into vegetable production. Vegetable demand has been on the rise in the past 10 years due to their nutritious qualities. Additionally, vegetables are a useful form of crop rotation for minimising the spread of diseases and improving the quality of soil and are suitable for growing in post-wet-season Cambodian soils.

There is a great demand for Cambodian vegetables as they are recognised to be of high quality relative to those imported from neighbouring countries. Challenges that actors in the vegetable value chain face are the lack of resource-base and technical knowledge. Once these issues have been resolved and proper post-harvest storage has been implemented, vegetables may be a positive diversification option for improved livelihoods. Women play a key role in vegetable production and integrated models that realise women's potential to capitalise on and value-add to vegetable products will advance the vegetable industry in Cambodia.

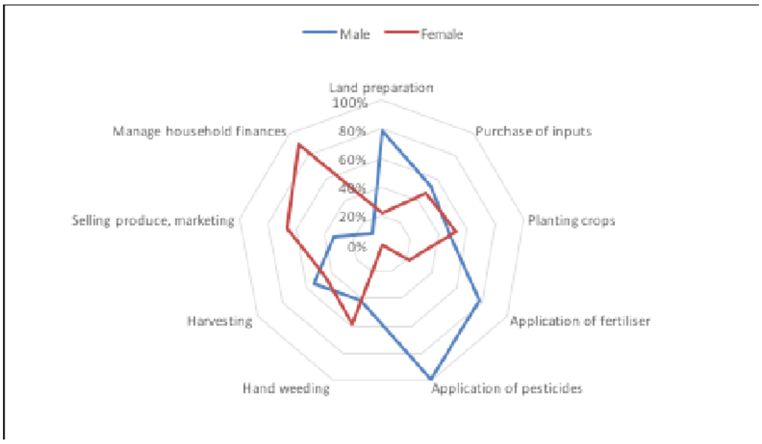


Figure 36. Distribution of gender roles in vegetable production in northwest Cambodia.

The distribution of gender roles in vegetable production was analysed via the 70 vegetable surveys conducted (Figure 36). The main difference between the genders indicates that men do most of the hard labour activities such as land preparation and application of pesticides and herbicides while women are more predominantly involved in monetary decision making such as managing the household finances and selling the produce. However, the survey revealed that an equal workload is shared among males and females in farming roles where hard labour is not required (for example, planting crops). During surveys, some women stated that they are out in the field for only a few hours a day while the children are at school. Women are seen to participate in crop planting, harvesting and hand weeding as these were tasks, which were not as time sensitive nor perceived to be as 'unsafe' as pesticide and herbicide application.

Directions for future research

Women were identified as the primary manager of household finances, selling of produce and equally involved in purchase of inputs. Proposed activities include:

- Training for women in household financial management, farm investments, local businesses and leadership of Agricultural Cooperatives.
- Sustainable intensification and diversification require significant changes in the types of inputs required (seed, fertiliser, pesticide) and engagement of women as well as input sellers will be sought.

7.1.5 Changes in weed management practices in rice from 2017 to 2020

The average exploitable yield gap increased from 1.3 t/ha in 2016-17 to 1.4 t/ha in 2018-19 and this was related to a drought in 2019. The major yield constraints cited by farmers were lack of water, inability to manage water and competition by weeds. With the restoration of irrigation schemes, there has been a significant transition from medium and long duration rice varieties to a double-crop system with short duration varieties. Improved water security provided by wet season irrigation has encouraged farmers to plant two short-duration rice crops with the first planting in May.

However, irrigation water does not arrive until July on average. Water shortages between sowing and when irrigation water arrives result in reduced crop establishment, sub-optimal herbicide and fertiliser application timing and poor weed control. Reduced tillage, drill planting and use of pre-emergence herbicides can improve weed management for crops sown in May. Adoption of drill planting could improve crop establishment and enable use of pre-emergence herbicides.

One of the objectives of this study was to identify emerging weed problems and management issues that have arisen since the survey in 2017. Historically, the main method of weed control in direct-seeded rice in the study area was mid-season tillage where medium and long-duration crops are ploughed or harrowed 30-80 days after crop emergence, depending on water accumulation in the field. Mid-season tillage was practised by 70% of farmers in the 1990s whilst only 15% of farmers used herbicides, mainly 2,4-D at that time. Farmers were still using mid-season tillage in 2008-09 and this varied between years (18-62%) depending on need and the only herbicide used was still 2,4-D which gave rise to concerns about control of grass weeds such as *Echinochloa* spp.

By 2016-17, 76% of farmers were using 2,4-D with 18% still using 2,4-D as the sole herbicide. By this time, farmers had begun to diversify herbicide active ingredients with 32% of farmers using bispyribac-sodium, pyribenzoxim (27%), fenoxaprop + pyrazosulfuron + quinclorac (26%) and propanil + clomazone (9%). In 2018-19, 100% of farmers still used herbicides but the herbicides used continued to change with use of 2,4-D decreasing by 13% (Figure 37). Use of bispyribac-sodium increased dramatically by 32% and use of fenoxaprop + pyrazosulfuron + quinclorac increased by 17%. This is consistent with the increasing problems with grass weeds, especially *Echinochloa* spp. Use of propanil + clomazone remained the same at 9%.

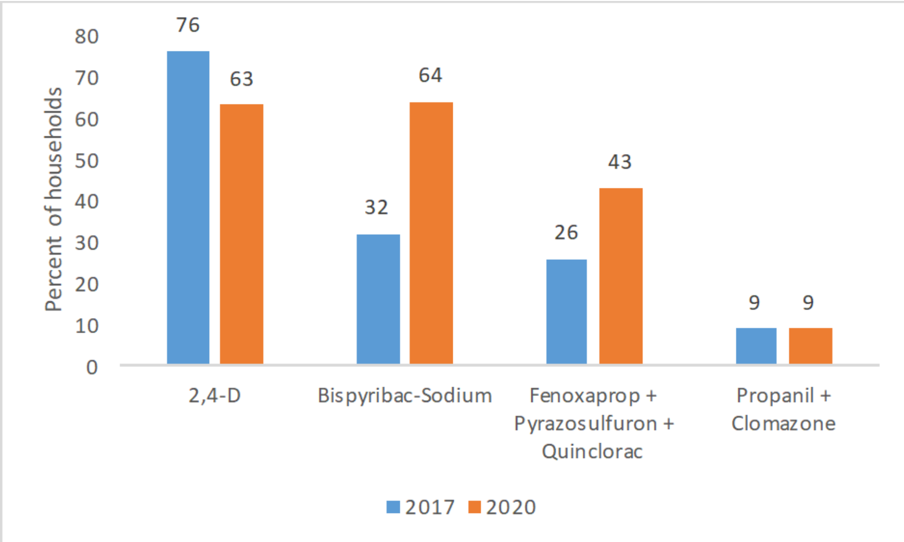


Figure 37. Changes in post-emergence herbicide use in Boeng Reang, Kampov, Ou Ta Nhea and Rohal Soung villages between 2016-17 and 2019-20.

Pre-emergence herbicide options for dry direct seeded rice in North-West Cambodia include butachlor, oxadiazon and pendimethalin. However, pendimethalin can be phytotoxic to rice in poorly prepared seedbeds and at higher rates of application. It has been confirmed that butachlor and oxadiazon can improve weed control in dry direct-seeded rice in the surveyed region. However, further research is required to determine the crop safety of pendimethalin. On-farm demonstrations of pre-emergence herbicides in dry direct-seeded rice are warranted in the study area.

Mid-season tillage was being used by 23% of households up until 2017 but declined to 13% in 2020. With 18% of households using mid-season tillage because of post-emergence herbicide failure, it is expected that some farmers might return to the use of mid-season tillage if weed problems continue to worsen. Moreover, in the face of catastrophic herbicide failure, mid-season tillage is an important integrated weed management option to reduce massive recharge of the weed seedbank in the soil.

There were minor changes in composition of problem weed species between 2017 and 2020. Possible reasons for changes in weed problems could include the change to the two-crop rice system in the wet season and spread of seeds by harvesting machines. The main weed seed contaminants of rice seed kept for sowing were *Echinochloa crus galli*, *E. colona*, *Fimbristylis miliacea*, *Ischaemum rugosum* and *Melochia corchorifolia. F. miliacea* was the only species effectively removed by village cleaning methods. Although prevalent in rice fields, *Cyperus. iria* with < 0.2 seeds per 500 g and *Leptochloa chinensis* with nil contamination were insignificant contaminants of seed samples.

Integrated weed management options are put forward to improve weed management and to increase rice yields without significant additional investments by farmers. The majority of farmers in the study area are relying on repeated use of a narrow range of post-emergence herbicides, thus increasing the selection pressure for the evolution of herbicide resistance. There is a need to establish the current status of herbicide resistance, particularly in key grass weeds such as *E. crus galli*. and *L. chinensis* and possibly the sedge, *C. iria*. The threat of the evolution of herbicide resistance places priority on validation of a sustainable integrated weed management strategy.

Farmer focus group meetings were held in each of the eight target villages in October-November 2020 to obtain farmer feed-back on the survey findings. All groups have expressed interest in adopting pre-emergence herbicides in rice and Telegram Smartphone networks have been established in the eight focus villages to link farmers with CamSID and private sector technical experts to accelerate adoption of pre-emergence herbicides in rice.

1f. Survey of vegetable production in northwest Cambodia

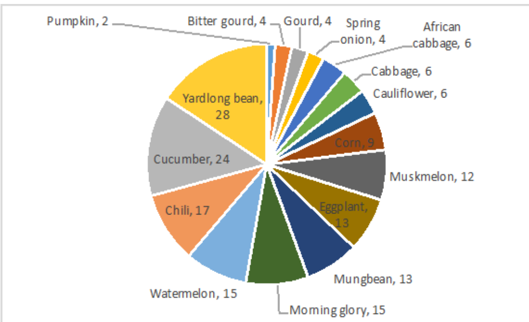


Figure 38. The main vegetable crops grown.

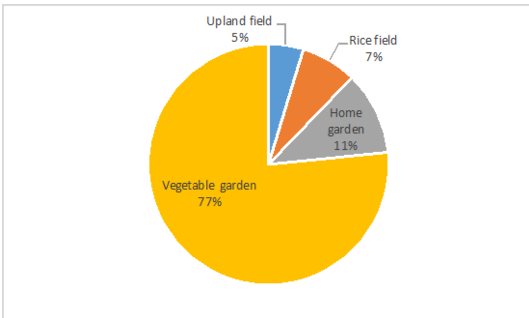


Figure 39. Locations where vegetables are grown.

Of the 112 farmers surveyed, seven farmers had not grown vegetable crops during 2019. The most common vegetables grown in 2019 were yardlong bean, cucumber and chili (Figure 38). In total, 25 different crops were reported to be grown in 2019.

Seventy-seven percent of farmers had separate vegetable gardens (Figure 39). Of the 7.5% who reported growing diversification crops in rice fields, the main crops were watermelon, mungbean and muskmelon (also known locally as rice cucumber). 'Home garden' and 'vegetable garden' are distinguished by their size and location on the property with the 'home garden' typically closer to the house and smaller in size.

There were varying levels of adoption of sustainable practices (Figure 40). The most widely adopted practice was the use of animal manure with 84 farmers reporting the use. This was followed by crop rotation which 63 farmers reported they practiced. The least commonly undertaken practice was using self-kept seeds to which there were only 14 farmers who responded.

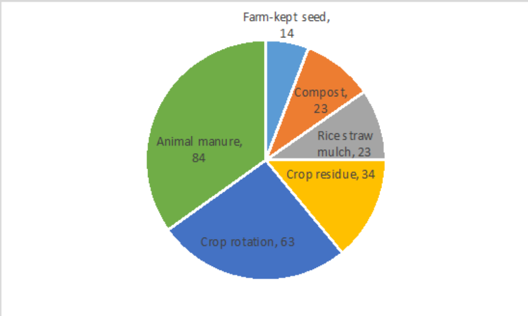


Figure 40. Number of farmers who implemented a sustainable practice.

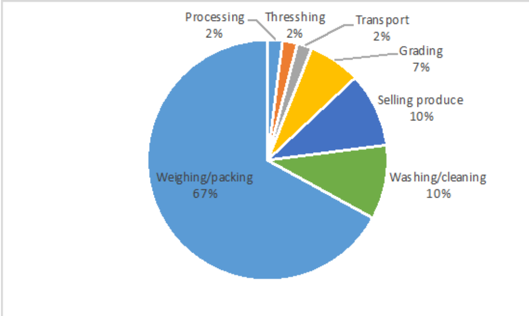


Figure 41. Processing and preparation.

The most common sale preparation activity was ‘weighing/packaging’ with two thirds of the respondents indicating they weighed and/or packaged their produce prior to sale (Figure 41). The three least undertaken tasks were ‘processing’, ‘threshing’ and ‘transporting’ of produce. Ninety-seven percent of produce is sold.

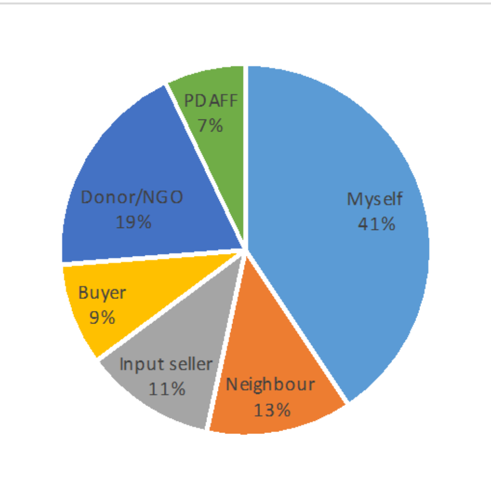


Figure 42. Sources of information average.

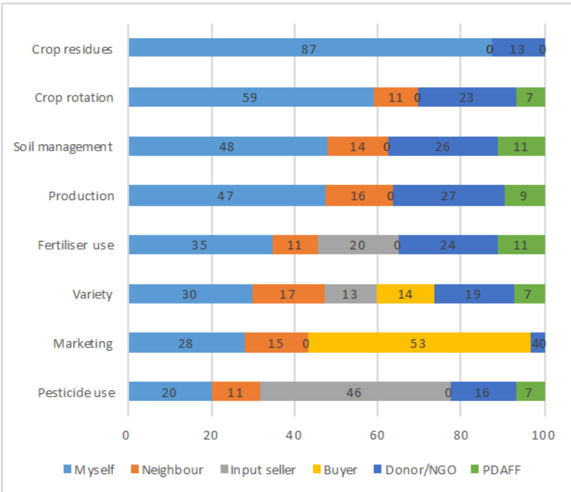


Figure 43. Sources of information for different categories.

On average, farmers relied on themselves, neighbours, input sellers and buyers for 74% of their information and on NGO/donors and PDAFF for 26% of their information (Figure 42). Farmers relied heavily on input sellers for information on pesticides, fertilisers and variety and on buyers for marketing and variety advice (Figure 43).

7.1.6 Value chain studies

Rice value chain

The current rice value chain is characterised by low productivity, low income, inconsistent supply, numerous actors including collectors, brokers and millers between farmers and markets and limited access to domestic and international markets. Smallholder farmers are usually price-takers and sell their rice directly to collectors or brokers. Vietnamese brokers compete with Cambodian brokers in buying the rice from the farmers. Vietnamese brokers offer higher prices than Cambodian brokers. In terms of millers, there are small-scale millers (less than 10 tonnes per day) who mill and sell locally within the village, medium-scale millers (less than 50 tons per day) who sell to the capital, Phnom Penh and large-scale millers (e.g. AMRU and Baitang) who have the ability to export mainly to Europe and China. Figure 44 Illustrates the rice value chain. Exports to Vietnam and Thailand are informal and rice is exported as paddy. Official exports are exported polished rice.

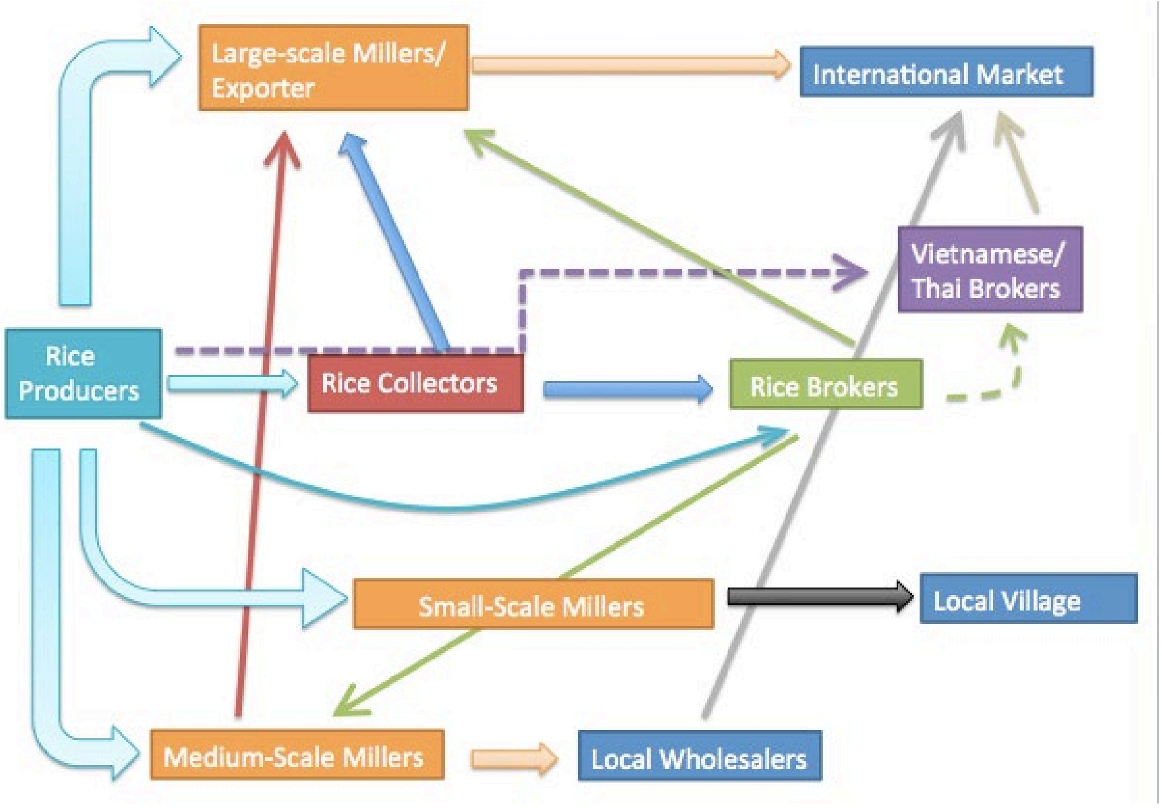


Figure 44. Rice value chain in north-west Cambodia
(arrows show flow of rice, dashed arrows show flow of information)

Mungbean value chain

The mungbean value chain consisted of producers, brokers, wholesalers and exporters. Each actor in the value chain recognised that there was a strong demand for mungbean produced in Cambodia. Cambodian grown mungbean was perceived to be of a higher quality compared with imported mungbean from Thailand (especially for sprouting). For brokers and wholesalers, opportunities for storage and value-adding may boost their enterprises. High quality mungbeans (an estimated 90% of production) were predominantly sold to large buyers based in Phnom Penh and the moderately low quality mungbeans were sold either to local village markets or to Thailand. Some high quality mungbean are purchased by Phnom Penh based large exporters who export to Vietnam/Thailand. Some are used locally for sprouting.

Vegetable value chain

Cambodian smallholder farmers are starting to cultivate higher value vegetable crops with traditional pulse and grain commodities. Vegetables are a major component in Cambodian diets, but production capacity is restricted to yearly availability of rainfall. The inconsistency and inadequate supply are compensated by imports of up to 70% of total domestic consumption from Vietnam and Thailand. However, there is a preference for high quality locally grown vegetables by retailers and consumers. This study investigated challenges through a value chain analysis on the market linkage between chain entities in the traditional and modern cooperative market networks. The issues in capturing profits by all market chain actors are interlinked from production to marketing stages which progressively siphons the value associated with specialised vegetables. The informal traditional marketing arrangements resulted in complications when the relationship between market actors deteriorated by financial mistrust and quality impairment. Yet, the lack of production knowledge and postharvest management such as packaging and cool chain management by smallholders in Cambodia contributed to deteriorating produce quality as it moved along the supply chain. This domino effect has resulted in adverse trade consequences, such as wastage being shared among the supply chain entities. The cooperative market chain had fewer market linkage issues due to the adoption of formal contracts but was challenged by similar wastage due to strict produce grading criteria. Ultimately the differences in trading volume and price between traditional and cooperative market chains were small, but the cooperative farmers benefited from an incentive to invest due to the mutual trust with buyers.

7.2 Evaluation of rice intensification options

2a. Rice cropping calendar

For short duration rice, the most preferred sowing dates across all timeframes are in July, followed by June and August (Figure 45). There was some possibility of getting good yield when sowing crop in April and May; but it also brings some risk of getting poor yield and crop failure. Yield variations were generally high for the sowing windows in April, May and June (Figure 46). **Without supplementary water irrigation, it is not recommended to plant rice from September to March because there is a fairly high probability of getting very low yield and crop failure.**

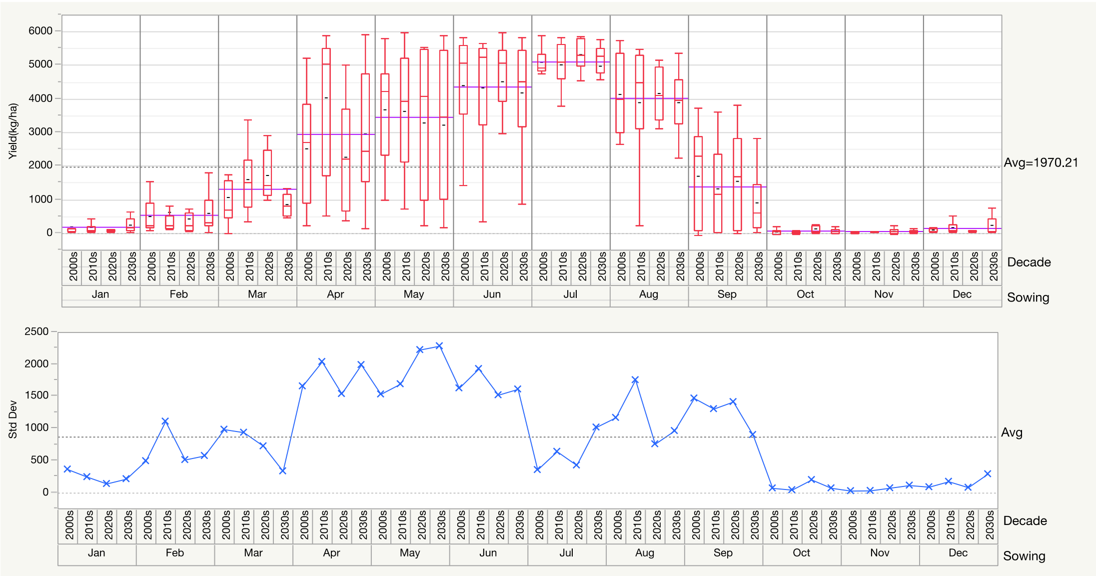


Figure 45. Yield variabilities of short duration rice (~115 days after sowing) across given timeframes and sowing months using boxplot, with black dash in the boxplot denotes average yield and purple line denotes average month yield; while the below one presents a range of yield variability in standard deviation from the mean yield.

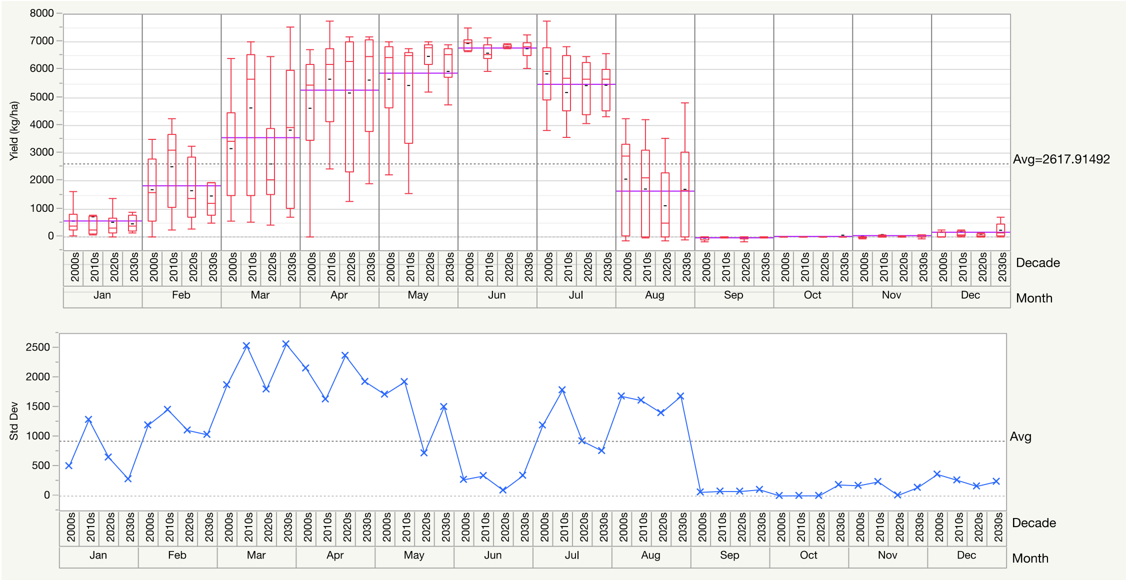


Figure 46. Yield variabilities of medium duration rice (~160 days after sowing) across given timeframes and sowing months using boxplot, with black dash in the boxplot denotes average yield and purple line denotes average month yield; while the below one presents a range of yield variability in standard deviation from the mean yield.

The outcomes from the climate analysis and APSIM-Oryza modelling, together with farmer focus group consultations enabled us to construct practical suggestions for safer cropping calendars (Figure 47).

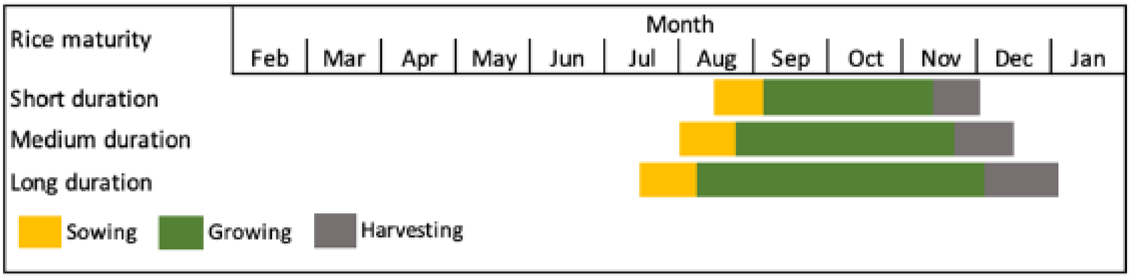


Figure 47. Proposed new cropping calendar for a one-rice crop per year rain-fed cropping system

A new cropping calendar was proposed for a one-rice cropping production per year, as shown in Figure 47(for rain-fed systems). This new cropping calendar was proposed on the basis of avoiding the possibility of drought damage in the early wet season, the possibility of flood damage in October and flooded fields during the harvesting period.

Long term historical daily climate data (1984-2019) for Pursat (PST), Battambang (BTB) and Banteay Meanchey (BMC) were generated and analysed. Long term climate projections (1984-2100) for PST, BTB and BMC were downscaled from 25 GCMs of the sixth phase of the Climate Model Intercomparison Project (CMIP6) and analysed. APSIM-Oryza model was built and run for each month of the year using the historical climate and future climate projections for PST, BTB and BMC. Eight village workshops were organised to present results of meteorological climate analysis and crop simulation outputs; aiming to obtain their inputs to evaluate and generate new cropping calendars.

2b. Evaluation of rice planting machinery and seeding rates

Short history of planting machinery

In 2005, ASEM/2000/109 led by Dr Bob Martin imported a container load of chisel plough and no-till planter parts from Australia to CARDI. This led to a Crawford Fund Workshop enabled Jeff Esdaile to work with CARDI Engineers to re-make appropriate-scale chisel ploughs and planters for Cambodian conditions but for 4-wheel tractors. In CSE/2007/027, ACIAR funded Jeff Esdaile for "Development of conservation farming implements for two-wheel tractors (power tillers) in Cambodia, Lao PDR and Bangladesh". This project produced a no-till planter for 2-wheel tractor. This met with some success in Bangladesh but not Cambodia where there is less interest in 2-wheel tractor planters. A following project CSE/2009/037 "Improved rice establishment and productivity in Cambodia and Australia (Mekong - South Asia Food Security Research program: component 2) CSE/2009/037" carried out adaptive research to develop dry sowing machinery suitable for Cambodia, following evaluation of a variety of imported machines. The project resulted in the commercial manufacture of tyne and disc versions of an improved planting machine. In the upland, 4-wheel tractor planters have been used for more than 20 years to plant maize, mungbean, peanut and soybean and in many cases these planters are fabricated locally at village level. This planter was seen in Kampong Cham in 2007. A prototype CIRAD planter was developed in 2007. CIRAD now focus on 4-wheel tractor planters. CAVAC II also looked at small-scale rice planters including Eli and Lonheng planter. Both of these can plant wet or dry. Generally, many smallholder Cambodians are more interested in engaging service providers with 4-wheel tractor planters. In 2011, Dr Bob Martin demonstrated the ROGROW planter for maize in Samlout district and the farmers asked "have you got a 4-wheel tractor version of this".

Sowing methods

Below is a summary of the advantages and disadvantages of the different rice sowing methods (Table 18).

Table 18. Advantages and disadvantages of rice sowing methods

Hand broadcasting	
Advantages	Disadvantages
• Suitable for small fields • Can be achieved with household labour • Both dry and wet seeding possible	• Time consuming • High seeding rate • High cost of seed • Poor crop ventilation • Seed on surface exposed to granivores • Requires harrowing after sowing

Kubota broadcasting machine (4-wheel tractor)	
Advantages	Disadvantages
• Suitable for large fields • Fast operation • Mainly dry seeding • Low cost to engage service provider ($7.50/ha)	• High seeding rate • High cost of seed • Poor crop ventilation • Seed on surface exposed to granivores • Requires harrowing after sowing

Mechanised drum seeder (2-wheel tractor)	
Advantages	Disadvantages
• Can work at scale in large fields • Row spacing provides airflow between rice plants • Good for wet seeding • Can adjust seeding rate • Can reduce seeding rate • Can apply pre-emergence herbicide in the sowing operation • Commercially available	• Requires clean seed • Slow operation speed • Not commercially available • Requires skilled operator • Expensive ($2,000 per unit) • Only for wet seeding • High cost of service provision ($15-20/ha) • Inconvenient to transport • Seed on surface exposed to granivores although being embedded in muddy seedbed gives it some protection

BB2C Eli / Angkor air seeder (2-wheel & 2-wheel tractor)	
Advantages	Disadvantages
• Can work at scale in large fields • Fast operation • Row spacing provides airflow between rice plants • Suitable for both wet and dry seeding • Suitable for small and medium scale • Easy to transport on Kojun trailer • Seeds are blown into the mud (not on the surface) and land levelling is not an issue	• Requires clean seed • Requires skilled operator • Eli is moderately expensive ($1,400 per unit) • Angkor retails at $1,780 per unit • High cost of service provision ($15-20/ha for 2WT version and $35/ha)

Thai Kid seed drill seeder (4-wheel tractor)	
Advantages	Disadvantages
• Multi-crop planter (rice, maize, mungbean, soybean, peanut) • Can adjust rice seeding rate (20-80 kg/ha) • Row spacing provides airflow between rice plants • Planted seed protected from granivores • Drought tolerance • Can apply fertiliser with the planting operation • Adjustable seed depth • Front and back rollers	• Cleaned seed only • For dry seeding only • Expensive ($5,500 per unit) • Not commercially available • Not suitable for uneven seed beds • Service fee can be expensive ($25-40/ha) • Cannot be used if soil is too wet

Kubota seed drill seeder (4-wheel tractor)	
Advantages	Disadvantages
• Multi-crop planter (rice, maize, mungbean, soybean, peanut) • Can adjust rice seeding rate (20-80 kg/ha) • Row spacing provides airflow between rice plants • Planted seed protected from granivores • Drought tolerance • Suitable for planting uneven seed beds • Inexpensive ($2,150 per unit) • Commercially available • Adjustable seed depth	• Cleaned seed only • For dry seeding only • No fertiliser box • Service fee can be expensive ($25-40/ha) • Cannot be used if soil is too wet

	Lunheng seeder (2 and 4-wheel tractor)	
	Advantages	Disadvantages
	• Rice planter (4-wheel tractor version shown on left) • Can adjust rice seeding rate (up to 120 kg/ha) • Row spacing provides airflow between rice plants • Planted seed protected from granivores • Drought tolerance • Suitable for planting uneven seed beds • Inexpensive ($1,200 per 4WT unit, $900 per 2WT unit) • Commercially available • Adjustable seed depth	• Cleaned seed only • For dry seeding only • No fertiliser box • Service fee can be expensive ($25-40/ha) • Cannot be used if soil is too wet

Dry seeding during early wet season

Most experiments in dry seeding with the Kid seeder provided similar (or slightly higher) yields to farmers' practice of hand or machine broadcasting. For example, in Kuok Tonlaop Village, yields of around 6.4 t/ha were achieved compared with farmer's fields using hand broadcast in 2018 (Table 19). Lower seeding rates had lower yields, mainly due to low plant establishment as the seeds were sown in the dry soil.

Table 19. Economic analysis for paddy rice production for Kuok Tonloap Village, Banteay Meanchey during the early wet season, 2018

Seeding rate (kg/ha)	Dry yield (t/ha)	Input cost ($/ha)	Labour cost ($/ha)	Income ($/ha)	Gross margin ($/ha)
20	4.1	281	247	1146	618
40	5.6	298	277	1563	988
60	5.8	316	280	1603	1007
80	6.4	334	293	1790	1163
180 (farmer practice)	6.4	383	292	1769	1093

Wet seeding during the main wet season (drum seeder, Banteay Meanchey)

During the main wet season, the mechanised drum seeder provided the highest yields (3.6 t/ha) at 20 kg/ha, much higher than farmer's practice at 2.8 t/ha, although the yields were not much different between 20 to 80 kg/ha sowing rates (Table 20).

Table 20. Economic analysis for paddy rice production for Kuok Tonloap Village, Banteay Meanchey during the main wet season, 2018

Seeding rate (kg/ha)	Dry yield (t/ha)	Input cost ($/ha)	Labour cost ($/ha)	Income ($/ha)	Gross margin ($/ha)
20	3.6	324	357	1329	648
40	3.4	342	353	1253	558
60	3.4	359	354	1228	515
80	3.3	373	351	1195	472
180 (farmer practice)	2.8	464	343	1034	227

Wet seeding during the main wet season (comparing Eli, mechanised drum and manual drum seeders, Banteay Meanchey)

Seeder comparison showed that the manual drum seeder was capable of ultra-low seeding rates of 18 kg/ha with a yield of 8 t/ha (Table 21). However, this is not always possible under Cambodian conditions due to uneven fields. The data showed that both the Eli and Mechanised drum seeders can plant effectively at around 50 kg/ha, achieving yields of over 6.6 t/ha. In Battambang, our CamSID team was able to better calibrate the Eli seeder, achieving yields exceeding that of the drum seeder in similar Cambodian field conditions.

Table 21. Economic analysis for paddy rice production sown using the Eli seeder, mechanised drum seeder and manual drum seeder for Kuok Tonloap Village, Banteay Meanchey during the early wet season, 2017

Seeding method	Seeding rate (kg/ha)	Dry yield (t/ha)	Income ($/ha)	Production cost ($/ha)	Gross margin ($/ha)	Return on investment ($/ha)
Eli seeder	50	6.6	1,980	395	1,585	4.0
Mechanised drum seeder	53	6.9	2,070	399	1,671	4.2
Manual drum seeder	18	8.0	2,400	365	2,035	5.6
Farmer practice	178	5.6	1,662	509	1,153	2.3

Fertiliser rate by sowing rate experiments conducted by CamSID BMC team at Kuok Tonloap Village and by CARDI at Pursat Province

Sen Kra Ob variety was sown using a Kid seeder on 1 May 2019. Increasing rates of fertiliser application increased grain yield but also increased the incidence of blast, stem borer and leaf folder (Table 22).

Table 22. Effect of increasing rates of fertiliser application

Variable	Low	Medium	High	S.E.	P
Blast score	2.17	3.85	5.01	0.12	0.000
Stem borer score	1.51	2.13	2.27	0.10	0.000
Leaf folder score	1.98	2.76	3.11	0.11	0.000
Panicles/m^2	265	298	288	7	0.000
1,000 seed weight (g)	27.66	27.80	27.95	0.01	0.000
Yield (kg/ha)	4,858	5,271	5,738	33	0.000

The incidence of stem borer (insect pest) was significantly greater for the broadcast treatment compared to the drill-seeded treatments and for 20 kg/ha seeding rate was significantly lower compared to 60 and 80 kg/ha seeding rates (Figure 48). Similarly, the incidence of leaf folder (insect pest) increased with seeding rate and the lowest incidence was for the 20 kg/ha seeding rate treatment (Figure 49). There was a significant fertiliser * seeding rate interaction for the incidence of rice blast disease where the seeding rate effect was magnified at higher fertiliser rates (Figure 50). The lowest grain yields were from the 20 kg/ha and broadcast treatments and the highest yields were recorded from the 60 and 80 kg/ha seeding rates (Figure 51).

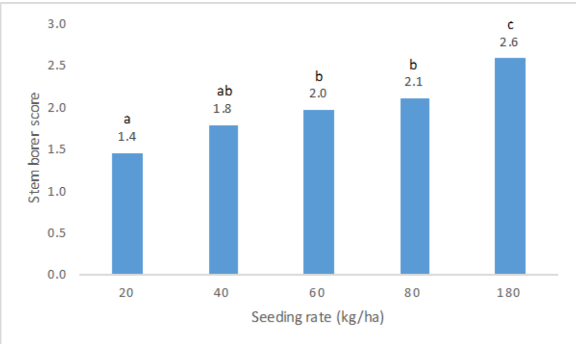


Figure 48. Effect of seeding rate on stem borer score

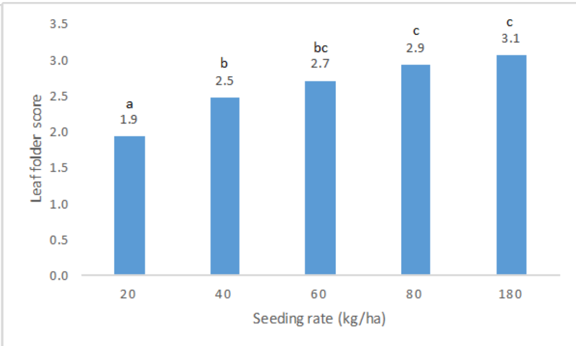


Figure 49. Effect of seeding rate on leaf folder score

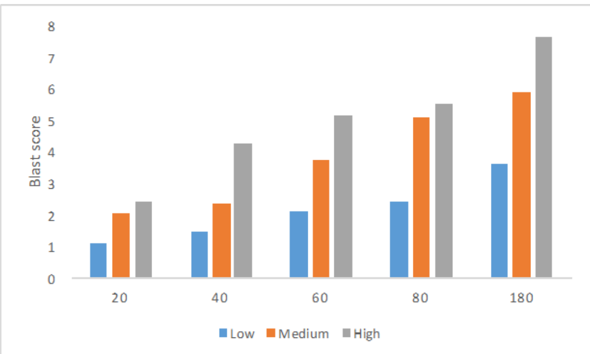


Figure 50. Interaction of fertilizer and seeding rates for rice blast score

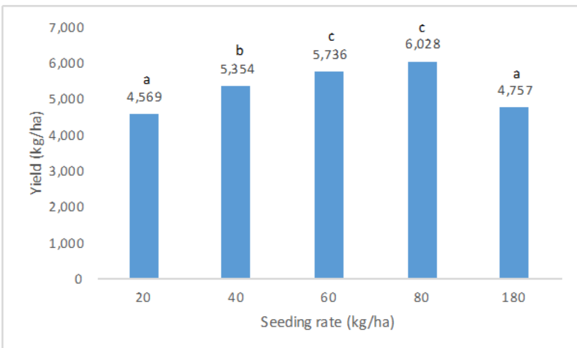


Figure 51. Effect of seeding rate on paddy yield (kg/ha)

Economic analysis

There was no significant interaction between seeding and fertiliser rates for grain yield, therefore the economic analysis is done for seeding and fertiliser rates separately. The partial budget is a useful tool that helps us evaluate the financial effect of incremental changes (e.g., seeding rate). A partial budget only includes costs that change between treatments. It does not consider input costs that are left unchanged.

Table 23. Partial budget for seeding rate

Seeding rate (kg/ha)	20	40	60	80	180
Yield (kg/ha)	4,569	5,354	5,736	6,028	4,757
Income ($/ha)	1,142	1,339	1,434	1,507	1,189
Cost of seed	13.5	27.0	40.5	54.0	121.5
Cost of planting	37.5	37.5	37.5	37.5	5.0
Cost of harrowing	0	0	0	0	17.5
Variable costs ($)	51.0	64.5	78.0	91.5	144
Net benefit ($/ha)	1,091	1,274	1,356	1,416	1,045

The first line of the partial budget is the average yield for each treatment (Table 23, Table 24). Income was calculated using the price received for Sen Kra Oub variety which was assumed to be $250/tonne. The partial budget includes only the costs that vary for seeding treatments which were: seed; planting method and harrowing to incorporate seed (broadcast treatment only).

Table 24. Partial budget for fertiliser rate

Fertiliser rate	Low	Medium	High
Yield (kg/ha)	4,858	5,271	5,738
Income ($/ha)	1,215	1,318	1,435
Cost of fertiliser ($)	81	118	155
Net benefit ($/ha)	1,134	1,200	1,280

The income for each treatment is calculated by multiplying price by yield. The final line of the partial budget is the net benefits. This is calculated by subtracting the total costs that vary from the total income for each treatment. The next step is to plot the net benefits of each treatment versus the total costs that vary.

A dominance analysis is then carried out by listing the treatments in order of increasing costs that vary. Any treatment that has net benefits that are less than or equal to those of a treatment with lower costs that vary is said to be **dominated**. The broadcast seeding treatment is dominated and can therefore be eliminated from further consideration. Further analysis is required to compare the drill seeding and fertiliser rate treatments. For that analysis, a net benefit curve is useful (Figure 52, Figure 53).

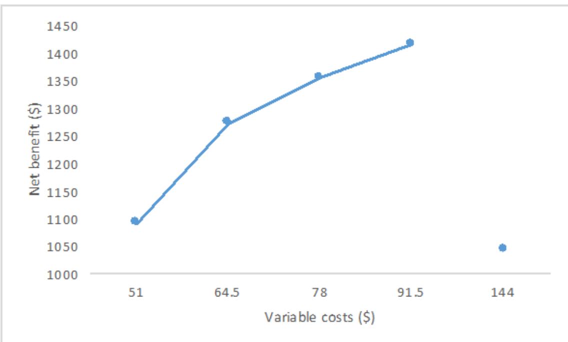


Figure 52. Net benefit curve for seeding rate

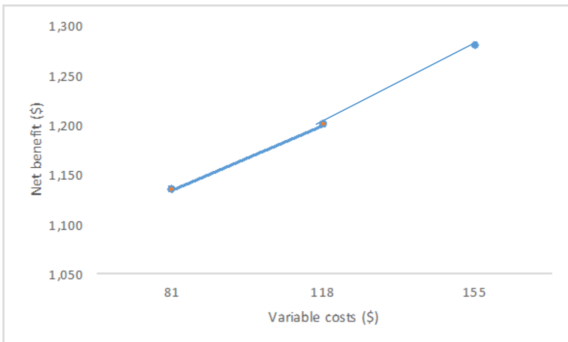


Figure 53. Net benefit curve for fertiliser rate

In a net benefit curve, each of the treatments is plotted according to its net benefits and total costs that vary. The alternatives that are not dominated are connected with lines. The dominated alternative (hand broadcasting) has been graphed as well, to show that it falls below the net benefit curve (Figure 53).

Experience and empirical evidence have shown that for most situations the minimum rate of return acceptable to farmers will be between 50 and 100%. **Therefore, for this experiment, farmers would benefit from drill seeding up to at least 80 kg/ha compared to hand broadcasting at 180 kg/ha**. The crop establishment was 63% for drill seeding at 80 kg/ha compared to 22% for hand broadcasting and this has likely contributed to the poor result for hand broadcasting.

Inclusion of an NDVI-based yield target treatment in the design might overcome this problem. **However, as the cost benefit ratios are not substantially different across the fertilizer rates for the 80 kg/ha sowing rate, risk averse smallholder farmers may choose a lower fertiliser rate to avoid high rice blast and insect incidence.**

Summary from sowing rate experiments

The key outcome of mechanised seeding rate experiments across Phnom Penh (CARDI), Pursat (CARDI), Battambang and Banteay Meanchey was the benefits (mainly stable yields and reduced disease incidence) of low seeding rates <80 kg/ha compared with farmer practice of broadcasting seeds with seeding rates >180 kg/ha. Dry seeding rates with the Thai Kid seeder and CARDI drill were optimised around 80 kg/ha (80 to 120 kg/ha) while wet seeding rates (with pre-germinated seed) with the Eli and Vietnamese mechanised drum seeder were reasonable over the range of 50 to 80 kg/ha. The wet seeding rate of 20 kg/ha was only achieved under ideal soil and irrigation conditions which was difficult to achieve under Cambodian field conditions. Machine planted low seeding rates provided conditions for reduced rice blast disease and insect pressure.

2c. Rice best management package

Site-specific nutrient management (SSNM)

Grain yield was significantly higher with the application of SSNM than the farmers' fertiliser N practice. Similarly, yield response to the N-rich plot increased significantly up to 4.6 t/ha by 37.2% and 4.3 t/ha by 34.8% with the SSNM plot compared with control, whereas farmer N fertiliser practice and the control produced similar grain yield across the rice fields (Figure 45). Compared with the farmers' N fertiliser practice, grain yield from SSNM and N-rich plots increased by 36.3 and 34.0%, respectively (Figure 54). Similarly, the mean gross margin significantly increased with N-rich treatments compared with farmers' fertiliser practices. Farmers' practice produced a similar mean gross margin to that of the control. The gross margin was US$ 379/ha with an average N application of 50 kg, while the unfertilised plot produced US$ 242/ha. There was a significant effect of the N fertiliser treatments on the total variable cost (Table 25).

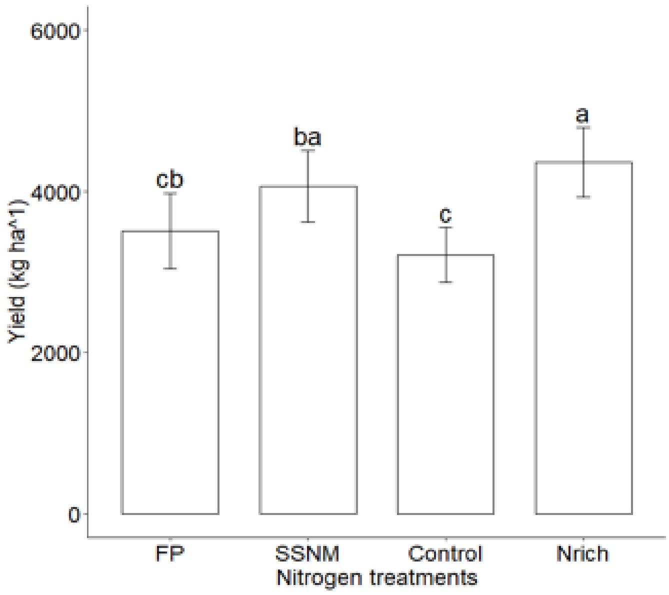


Figure 54. Yield response to different nitrogen fertiliser rates (kg/ha); FP- farmers' practice, SSNM- site-specific nutrient management, N-rich- nitrogen-rich.

Table 25: Effect of N fertiliser treatments on gross margin, total variable cost (TVC), total fertiliser nitrogen cost (TFNC), agronomic efficiency (AE) and partial productivity factor (PFP).

Fertilizer (kg/ha)	Gross margin (US$/ha)	TVC (US$/ha)	TFNC (kg/ha)	AE (kg/kg)	PFP (kg/kg)
Unfertilised Control	242c	630a	-	-	-
Farmer's Practice	379cb	571b	1055b	7.34a	43.5b
SSNM	541ba	548c	5286ba	15.66a	40.7a
N rich	633a	531c	9495a	9.56a	20.4b
P-value	0.0001	0.0001	0.001	Ns	0.0122

'ns' means not significant at P < 0.05, while means of the same letters are not significantly different at P < 0.05.

Interestingly, the total variable cost for SSNM treatment decreased significantly compared with the farmers' practice (Table 25). The lowest mean total variable costs of 548 US$ ha^{-1} and 541 US$ ha^{-1} were obtained from SSNM and N-rich plots irrespective of higher fertiliser cost compared with the farmer practice. The control (unfertilised plots) had the highest total variable cost with a mean value of 630 US$ ha^{-1}, followed by farmers' fertiliser N practice (571 US$ ha^{-1}). There was no significant effect of fertiliser treatments on agronomic N use efficiency. Agronomic N use efficiency with the farmers' fertiliser practice and N-rich were 7.3, and 9.6 kg grain yield per kg of N applied across the locations.

Pre-emergence herbicides for dry direct seeded rice in the early wet season

There were no significant differences for herbicide treatments on rice establishment but pendimethalin and pretilachlor reduced rice establishment by 21 and 19%, respectively, compared to oxadiazon and butachlor by 10 and 12%, respectively. All herbicides significantly reduced emergence of grasses except pretilachlor. Oxadiazon was the only pre-emergence herbicide to reduce broadleaf and sedge weed density. Post-emergence herbicide reduced grass weed density but not broadleaves or sedges.

Almost all of the weed biomass was grass (96.4%) with 3.3% broadleaves and 0.3% sedges. The main grass species present was *Echinochloa colona* with some *E. crus galli*. The main broadleaved species was *Eclipta prostrata* and the main sedge was *Cyperus difformis*. pendimethalin, pretilachlor and butachlor significantly reduced grass biomass but oxadiazon did not.

Oxadiazon and butachlor had significantly more panicles/m^2 than the nil treatment (Figure 55). The grain yield for butachlor and oxadiazon was significantly greater than for the nil treatment (Figure 56). There was no significant effect of pre-emergence herbicides on 100 seed weight. There was also no significant effect of post-emergence herbicide on yield components.

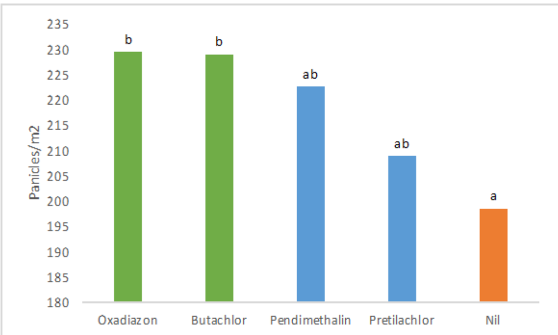


Figure 55. Effect of pre-emergence herbicides on panicles/m^2

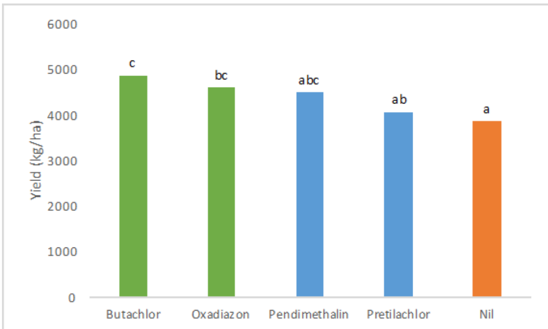


Figure 56. Effect of pre-emergence herbicides on grain yield (kg/ha)

Pre-emergence herbicides such as oxadiazon or butachlor followed by the option for post-emergence herbicide if necessary have been found to be essential to achieve effective weed control and high grain yield in dry direct-seeded rice and this was confirmed at Battambang in 2018 and 2019.

Best management practice packages for rice

Based on the research over 2017 to 2019, best management practices for rice for northwest Cambodia were summarised. Dr Try condensed this into a 6-page leaflet that was distributed to input sellers and smallholder farmers during field days. Dr Bob Martin led a monograph for a Technical Guide for Rice Production in Northwest Cambodia (in press) to be published by ACIAR. This Technical Guide was also extensively edited by Dr Ouk Makara, former Director of CARDI.

2d. Collaboration on Unmanned Aerial Vehicles (UAVs) with CAVAC

The development of the agricultural drone service provision industry in Cambodia has been primarily driven by the private sector. According to service providers, important benefits of drone application are time saving, profitability; operator health, labour saving and ease of application (Figure 57). A typical drone service provider has 80 farmer clients, services 350 ha at a rate of 15 minutes per hectare. The median service fee is $10/ha which is competitive with ground application. The most important advantages of drone over ground application are application is much quicker than ground application; drone application avoids problems getting labour for ground application; and the low water volume for drone does not reduce efficacy.

CAVAC has supported KPP Global Co., Ltd in 2019 to make agricultural drones available in Cambodia. KPP has imported and distributed a XAG drone (Chinese made) from XAG Australia. It takes 15 minutes to spray a hectare and a drone can spray 20-30 ha in a day. CAVAC supported the sale of drones by sharing service fee of 50% with farmers who access drone spraying service provided by new buyers (during the COVID-19 pandemic). By September 2021, KPP sold out 24 units (five under COVID-19 support scheme), 83% to service providers and 17% to large landholding farmers.

Figure 57. Drone application of post- sowing pre-emergence herbicide in rice

Drone purchase and ownership details

For the first drone purchased, the median cost was US$18,250 and the range was from US$9,000 to US$19,850 per unit (Table 26).

Table 26. Drone purchase and ownership details (in US$)

	Median	Minimum	Maximum
Cost of 1st drone purchased:	$18,250	$9,000	$19,850
Tank capacity:	16	10	20
Cost of 2nd drone purchased:	$18,500	$10,000	$20.000
Tank capacity:	16	16	20

Area treated and service fees (for the past 12 months)

The median number of drone service provider farmer clients is 80 and the median number of hectares treated per service provider is 350 (Table 27). The median number of applications per field is 3-4. This includes herbicide, insecticide and fungicide. Nutrients are also often applied with insecticide and fungicide. The median service fee is US$10/ha which is roughly equivalent to ground application.

Table 27. Area treated and service fees

	Median	Minimum	Maximum
Number of farmer clients:	80	4	350
Total hectares treated:	350	20	1,600
No. of applications/field:	3-4	1	4-5
Minutes per hectare:	15	9	20
Hectares per day:	17.5	4	40
Service fee/ha/application (US$):	$10.00	$5.00	$12.50
Operator wage/ha (US$):	$1.00	$0.63	$1.50

Repairs and replacement parts

The most expensive repair and maintenance costs were for batteries, propellers and motors. However, more information from service providers is required enable accurate costings and development of a business model for drone service provision.

How effective is drone application compared to ground application? 1 = very good, 2 = good, 3= neutral, 4 = poor, 5 = very poor.

There was strong agreement that drone application was more effective than ground application of pesticide and nutrients with insecticide being most effective (Table 28).

Table 28. Effectiveness of drone application compared to ground application

Ingredient	Median	Minimum	Maximum
Insecticide	1	1	2
Herbicide	1	1	3
Fungicide	1	1	3
Nutrient	2	1	3
Insecticide + Nutrient	2	1	3
Fungicide + Nutrient	2	1	3

The most important advantages of drone over ground application are: application is much quicker than ground application; drone application avoids problems getting labour for ground application; and the low water volume for drone does not reduce efficacy (Table 29).

Table 29. Advantages of drone application compared to ground application

Statement	Median	Minimum	Maximum
Drone application is much quicker than ground application	1	1	1
Avoids problems getting labour for ground application	1.5	1	3
The low water volume for drone does not reduce efficacy	1.5	1	3
Application service fee is less than for ground application	2	1	3
Gives better weed and pest control than ground application	2	1	3
Input costs are less with drone vs ground application	2	1	3
Drone application reduces operator exposure to chemicals	2	1	2
Reduces off-target human and environmental impacts	2	1	3
Rice yields are higher with drone vs ground application	3	1	3

However, not all farmers are convinced about the efficacy of low water volumes. Respondents were also neutral on yield benefits. There appears to be justification for side-by-side comparison of aerial vs ground application.

The most important disadvantages of drone application were considered to be: repair and part replacement costs (eg batteries, propellers, motors); and drone application is affected more by adverse weather compared to ground application (Table 30).

Table 30. Disadvantages of the drone

Statement	Median	Minimum	Maximum
Repair and part replacement costs (e.g. batteries, propellers)	1	1	3
Drone application is affected more by adverse weather	1	1	3
Vehicle access to some fields is difficult	2	1	4
Trees in the field make it difficult for Drone application	2	1	4
It is difficult to get clean water in some areas	2	1	4

Nine out of 12 service providers mentioned that farmers are reluctant to adopt drone application and the main reason was that farmers do not believe that drone application will work as well as ground application. Some farmers are also concerned about the efficacy of low water volumes. Farmers want to see the results first before they decide to adopt drone application technology.

The main concern for service providers (5/12) was control failure causing the drone to crash. Another concern was about the short life expectancy of parts, especially propellers.

Service providers agreed that drone operation provided a greater return on investment (ROI) compared to other machinery service provision enterprises. They also agreed that they could recover the drone purchase cost within 1-2 years (Table 31).

Table 31. Cost-benefits of service provision

Statement	Median	Minimum	Maximum
The ROI is higher than other types of machines	1	1	4
I can recover the purchase cost of the drone in 1-2 years	2	1	3
Drone allows me to spend more time with my family	3	2	4

As found with previous questions, service providers would like to see:

- Stronger and longer lasting component parts, particularly propellers;
- Batteries with longer charge time and longer life;
- Cheaper replacement parts.

Predictions of adoption ranged from 15 to 90% with a median of 70%. Most service providers were not able to estimate time to reach this level of adoption.

One service provider mentioned that some farmers say if the cost is US$5.00 to $7.50/ha they would use the drone. But if the cost is US$10.00-$12.50 they will spray by themselves. No drone service providers have stopped operating drones.

The highest priorities for training were: choosing the correct products to apply; business planning and financial management; identification of weeds, insect pests and diseases; Integrated Pest Management; drone operation (e.g., setting up waypoints); and safe operation procedures for handling toxic chemicals (Table 32).

Table 32. Priorities for training subjects

Activity or subject	Median	Minimum	Maximum
Choosing the correct products to apply	4	4	5
Business planning and financial management	4	3	5
Identification of weeds, insect pests and diseases	4	3	5
Integrated Pest Management (weeds, insects, diseases)	4	3	5
Training on Drone operation (eg setting up waypoints)	4	2	5
Safe operation procedures for handling toxic chemicals	4	2	5
Weather conditions (eg high wind)	4	3	4

Tree or land hazards	3	3	4
Application rates, water volume and timing	3	2	4

The highest priority communication and training methods are: on-farm demonstrations; field walks, field days, farmer field schools; and village workshops. Telegram groups to discuss rice production problems was seen a good idea; radio broadcasts and television programs were the lowest priorities (Table 33).

Table 33. Priorities for communication and training methods

Communication or training method	Median	Minimum	Maximum
On-farm demonstrations	4	3	5
Field walks, field days, farmer field schools	4	3	5
Village workshops	4	3	4
Social media: Facebook, Twitter, Instagram, Telegram	3.5	1	5
Focus group meetings	3.5	3	4
Single-subject leaflets	3	1	5
Smart phone apps	2.5	1	4
Links to web sites	2.5	1	4
Google Meet, Skype, Zoom (COVID-safe)	2	1	4
Radio broadcasts	2	1	3
Television programs	2	1	3

Individual comments included: I would like to see farmers be able to improve their technical knowledge; Telegram groups to discuss rice production problems is a good idea.Technical information on drone application pesticide use in rice is important to service providers because are relied upon by farmers for advice. Business management was also mentioned as a priority.

The Project Leader, Daniel Tan was also invited to give on Drones and Digital Integrated Pest Management (IPM) on 9 December 2021 which was jointly organised by the ASEAN Fall Armyworm Action Plan and Grow Asia https://www.aseanfawaction.org/drones-and-digital-ipm. This is a link to the video recording of the workshop: https://www.youtube.com/watch?v=O2XIr13T-I8

7.3 Diversification: Mungbean varietal evaluation

The Cambodian Agricultural Research and Development Institute (CARDI) released CARDI Chey mungbean (VC 1973A) in 2002. CARDI went on to evaluate 25 mungbean breeding lines and varieties between 2003 and 2005. The lines were obtained from the Asian Vegetable Research and Development Center (AVRDC), Australia and Thailand. Three

Cambodian Mungbean (CMB) varieties were released from this program: CMB-1 (VC 4152); CMB-2 (VC 3541B); and CMB-3 (HL33-6) from the Australian collection. Although officially released, none of these Cambodian mungbean varieties are commercially available, presumably because of lack of government resources. The FAO "quality declared seed" system (QDS) makes use of resources already available in seed production organizations and might make it easier to get new varieties into the hands of farmers. QDS is designed to provide quality control during seed production, which is less demanding on government resources than highly developed seed quality seed systems.

Pod-shattering is the natural process of pod dehiscence that facilitates dispersal of seeds of wild plants at physiological maturity. Pod-shattering, as an evolved seed dispersal mechanism, is an important cause of yield loss in crops still in the process of domestication such mungbean. Although mungbean germplasm is subject to various studies such as molecular diversity analysis and screening for pod shattering in mutant populations, no useful published comparisons can be found on pod-shattering in commercial mungbean varieties. However, the Australian National Mungbean Improvement Program includes resistance to pod-shattering as a selection criterion. Since all mungbean are harvested by machine in Australia, it is reasonable to expect that Australian varieties might have genetic resistance to pod-shattering and should be considered for inclusion in this study. In 2018, Cambodian government approval was obtained to import a collection of 11 public mungbean varieties from the Australian Mungbean Collection. These varieties were evaluated in comparison with the four Cambodian varieties and the locally grown DX-208 and KPS-2 varieties in 2019 and 2021. A series of experiments and demonstrations were carried out over four years from 2018 to 2021 as described below.

Experiment in 2018

There were no significant differences between varieties for plant establishment, whole pods (kg ha^{-1}) or grain yield (kg ha^{-1}). The mean plant establishment was 33 plants m^{-2}, mean whole pod yield was 1,678 kg ha^{-1} and mean grain yield was 1,023 kg ha^{-1}. DXVN-7, XANH-044, SUT-1, DX-208 and CARDI Chey had significantly more open flowers per plant than CMB-3, V-94208, CN-36 and KPS-2 at 42 DAS (Table 5). CARDI Chey had significantly more pods per plant than KPS-2 and CN-36 at 46 DAS. DXVN-7 had significantly more brown pods than CN-36 and KPS-2 at 54 DAS. CN-36 had significantly more seeds per pod than all other varieties. CN-36, the tallest variety, was significantly taller than DXVN-7, XANH-044 and DX-208, which was the shortest variety. CARDI Chey was significantly taller than DX-208. CARDI Chey had a significantly higher shelling ratio than KPS-2 and SUT-1. CMB-3 had significantly lower 100 seed weights than all varieties except DXVN-7. DX-208 had the highest 100 seed weight but not significantly higher than CARDI Chey or KPS-2 (Table 34).

Table 34. Differences between varieties for plant establishment, reproductive development, plant height and yield components at DBAS in 2018.

Variety	Open flowers per plant 42 DAS	Brown pods per plant	Seeds per pod	Plant height (cm)	Shelling ratio	100 seed weight (g)
CARDI Chey	1.2	0.6	10.9	46	0.65	7.76
CMB-3	1	0.3	10.8	44	0.63	6.98
CN-36	0.7	0	12	48	0.64	7.54
DX-208	1.2	0.1	10.1	39	0.6	7.88
DXVN-7	1.5	1.1	10.7	43	0.63	6.6
KPS-2	0.5	0	11	44	0.56	7.69
SUT-1	1.3	0.3	10.2	44	0.56	7.45
V-94208	1	0.3	10	44	0.6	8.03
XANH-044	1.4	0.5	10.3	42	0.58	7.75
S.E.	0.11	0.14	0.3	1.4	0.025	0.129

P value	<0.001	<0.001	<0.001	0.003	0.033	<0.001

Experiment in 2019

The experiment in 2019 included the Cambodian varieties (CMB-1 and CMB-2) not evaluated in 2018. There were no significant differences between varieties for plant establishment, the mean of which was 15.4 plants m^{-2}. Celera had significantly more open flowers than all other varieties at 42 DAS and Green Diamond had significantly more brown pods at 63 DAS than all other varieties and White Gold and CARDI Chey had significantly more brown pods than Putland and Delta (Table 35). The mean plant height at maturity was 71 cm (Table 35) and CMB-2 was significantly taller than DX-208. There were no significant differences for seeds per pod between varieties with a mean of 12 seeds per pod. White Gold had significantly higher 100 seed weights than DX-208, whereas Satin, Celera, Green Diamond and Putland had significantly lower 100 seed weights than KPS-2. The 100 seed weight of CMB-1 was not significantly different from KPS-2. 100 seed weights for Emerald, CARDI Chey, Yellow Sun, Berken, CMB-2, Satin, King and Delta were not significantly different from DX-208 (Table 35). The mean total yield was 1,820 kg ha^{-1} and there were no significant differences between varieties. However, there were significant differences at pick 3 where Putland showed later maturity than other varieties. White Gold appeared to be the most determinant variety (Table 35,Figure 58).

Table 35. Differences between varieties for plant establishment, reproductive development, plant height and yield components in 2019.

Variety	Open flowers 42 DAS	Brown pods 63 DAS	100 seed weight (g) 83 DAS	Height (cm) 83 DAS	Pick 3 yield (kg ha^{-1}) 83 DAS
Berken	2.3	1.2	8.17	64	136
CARDI Chey	1.6	2.9	7.97	73	132
Celera	6.1	2.2	4.35	73	205
CMB-1	1.4	2.5	7.53	60	130
CMB-2	2.1	2	8.35	78	98
CMB-3	2.4	1.6	7.71	73	203
Delta	1.6	0.8	8.58	65	296
DX-208	2.8	1.5	8.03	61	249
Emerald	2.4	1.5	7.92	73	95
Green Diamond	1.8	5.6	3.89	67	141
King	1.7	1.2	8.49	77	226
KPS-2	1.3	2	7.01	65	205
Putland	1.3	0	3.75	70	694
Satin	2.1	1.5	6.37	76	156
Shantung	1.4	1.4	8.48	74	127
White Gold	2	2.8	8.81	76	62
Yellow Sun	4.3	2.2	8.04	73	187
S.E.	0.725	0.843	0.222	4.4	63
P value	<0.001	0.004	<0.001	<0.001	0.002

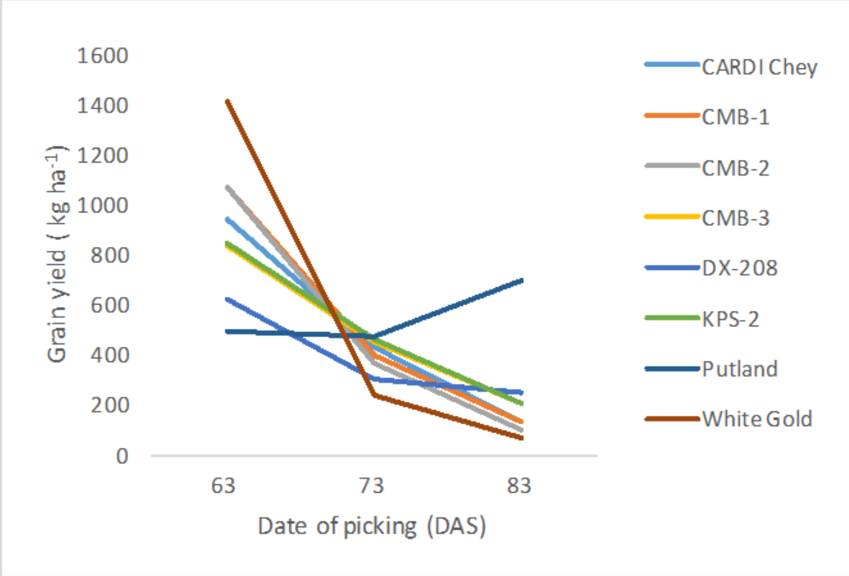


Figure 58. Grain yield (kg ha^{-1}) differences between varieties for the degree of determinant flowering and early maturity (for the first, second and third harvests or picks at 63, 73 and 83 days after sowing [DAS], respectively).

Putland, Green Diamond, Celera and Satin were rejected for further evaluation because seeds were too small to be acceptable to the Cambodian market. Berken and Emerald were retained but likely to be rejected because of small seed size. Satin was also unacceptable to the market because of dull seed coat. Yellow Sun was also rejected because of yellow seed coat colour. Six Australian varieties (Berken, Delta, Emerald, King, Shantung, White Gold) were retained for further evaluation in comparison with Cambodian varieties (CARDI Chey, CMB-2) and locally grown varieties (DX-208, KPS-2). Insufficient data were obtained to reliably determine the degree of pod-shattering and all 10 varieties require further evaluation of the extent of pod-shattering.

Demonstration for seed increase in 2020

A large-scale demonstration in 2020 included CARDI Chey, CMB-1 CMB-2, CMB-3, DX-208 and KPS-2. Plant establishment was 34.3 plants m^{-2} with no significant differences between varieties. Significant differences were found for grain yield, first pick ratio pod-shattering and seed weight (Table 36). The mean plant establishment was 34 plants m^{-2} with CMB at 43 plants m^{-2} had significantly more established plants than all other varieties. The 100 seed weight for CMB-2 and DX-208 (8.3, 8.2 g) was significantly greater than for the other varieties with CMB-1 having a 100 seed weight of 7.0 g. The mean for pod-shattering for DX-208 was 11% and was significantly greater than for all other varieties except CARDI Chey. The mean grain yield was 1,172 kg ha^{-1} and the grain yield CMB-2 (1,888 kg ha^{-1}) was significantly greater than the other varieties (Table 36). The mean grain yield harvested in the first pick at 55 DAS was 767 kg ha^{-1} and at the second pick at 88 DAS was 404 kg ha^{-1} giving a mean proportion harvested in the first pick of 63%. Farmers from Preaek Trab village inspected the demonstration at 62 DAS and ranked CMB-2 as the best variety with regard to yield, seed size and acceptable shattering.

Table 36. Differences between varieties for plant establishment, reproductive development, plant height and yield components in 2020.

Variety	Establishment (plants m^2) 48 DAS	100 seed weight (g)	Shattered pods	Whole pod yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Shelling ratio
CARDI Chey	31	7.8	5.2	666	429	0.65
CMB-1	43	7	0.5	853	563	0.64
CMB-2	34	8.3	2.5	1380	944	0.68
CMB-3	36	7.4	4.3	758	468	0.62
DX-208	33	8.2	16	95	590	0.63
KPS-2	29	7.2	0.2	804	522	0.66
S.E.	2.6	0.22	1.79	142.5	97.9	0.012
P value	0.033	0.001	<0.001	0.026	0.015	0.013

Experiment in the dry season 2021

Plant establishment, 13 plants m^{-2}, was low due to dry seedbed conditions and there were no significant differences between varieties (Table 37). At 68 DAS, there were no significant differences between varieties for open flowers. DX-208 had significantly more pods 1-5 cm than all other varieties except Emerald, CARDI Chey and KPS-2. DX-208 also had significantly more brown pods at 68 DAS than all other varieties except Delta. DX-208 had significantly more shattering than all other varieties. At 83 DAS, the total yield of whole pods and grain yield for Delta was significantly greater than for King and CARDI Chey. There were no differences for shelling ratio.

Table 37. Differences between varieties for plant establishment, reproductive development, plant height and yield components in the dry season, 2021.

Variety	Estab. 14 DAS	Pods 1-5 cm 68 DAS	Brown pods 68 DAS	Shattered pods 68 DAS	Pod yield (kg ha^{-1}) 83 DAS	Grain yield (kg ha^{-1}) 83 DAS	100 seed weight (g) 83 DAS
Berken	16	6.8	13.6	0	739	521	5.8
CARDI Chey	9	10	8.3	0.17	298	172	7
CMB-2	13	6.6	14.3	0.08	909	642	7.4
Delta	20	4	25.7	0	1401	914	7.3
DX-208	17	12.8	20	1.25	1055	687	7.8
Emerald	12	9.3	15.5	0	943	618	7.3
King	9	5.3	8.3	0	295	195	7.5
KPS-2	13	8.2	12.2	0	685	492	6.6
Shantung	14	2.8	17.2	0	636	416	7.3
White Gold	12	5.5	10.3	0	986	689	7.2
S.E.	1.92	1.69	2.85	0.13	221.46	151.14	0.23
P value	0.002	0.002	0.001	<0.001	0.037	0.042	0.001

Experiment in the wet season 2021

The mean plant establishment at 14 DAS was 46 plants m^{-2} and there were no significant differences between varieties. At 35 DAS there were significant differences for open flowers with Delta having more open flowers than KPS-2 and DX-208 (Table 38). Delta had significantly more pods 1-5 cm than all other varieties. At 50 DAS, King had significantly more open flowers and pods 1-5 than all other varieties. Delta had the most brown pods but not significantly more than KPS-2, CMB-2 or CARDI Chey. At 56 DAS, CMB-2 and CMB-3 had significantly more open flowers than White Gold and King had more pods >5 cm than all other varieties. Delta had significantly more brown pods than all other varieties. The grain yield of Emerald was significantly greater than for all other varieties at the first pick (63 DAS) and for total yield at 84 DAS. The yield in the second pick was only 33 kg ha^{-1} with no significant differences between varieties. There were no significant differences for the first pick ratio. Locally grown variety, DX-208 had the highest 100 seed weight and KPS-2, the lowest 100 seed weight. Seed weights for CMB-2, Delta and Emerald were not significantly different to DX-208 and 100 seed weights for CARDI Chey, King and Shantung were not significantly different to KPS-2 (Figure 59). In the laboratory pod shattering test, DX-208 (72%) had significantly more shattered pods than all other varieties (Figure 60). Emerald had the lowest level of pod shattering (3%) but not significantly less than for KPS-2 (6%), Delta (10%) or Shantung (12%). CARDI Chey (42%), CMB-2 (42%), CMB-3 (34%) and White Gold (27%) had significantly more pod shattering than all other varieties except (DX-208).

Table 38. Differences between varieties for plant establishment, reproductive development, plant height and yield components in the wet season, 2021.

Variety	Open flowers 35 DAS	Open flowers 56 DAS	Brown Pods 56 DAS	Shattered pods (%) 63 DAS[1]	100 seed weight (g) 63 DAS	Grain yield 63 DAS	Grain yield 84 DAS	Total grain yield (kg ha^{-1})
CARDI Chey	3.1	2	15.3	42	5.08	869	45	1266
CMB-2	3.8	2.3	16.3	42	5.50	584	55	973
CMB-3	4	2.3	17	34	5.24	680	39	1020
Delta	4.2	0.5	23.9	10	5.47	797	47	1218
DX-208	1.8	1.9	12.5	72	5.66	742	46	1119
Emerald	3.2	0.4	13.2	3	5.64	1167	32	1671
King	0.3	0.8	7.1	23	4.84	518	32	766
KPS-2	1.8	0.8	12.1	6	4.75	753	39	1134
Shantung	1.8	1	10.8	12	5.14	677	25	994
White Gold	2	0.2	8.5	27	5.43	765	27	1137
S.E.	0.67	0.57	2.04	5.9	0.142	86.9	11.3	123.3
P value	0.001	0.048	<0.001	<0.001	<0.001	0.002	NS	0.003

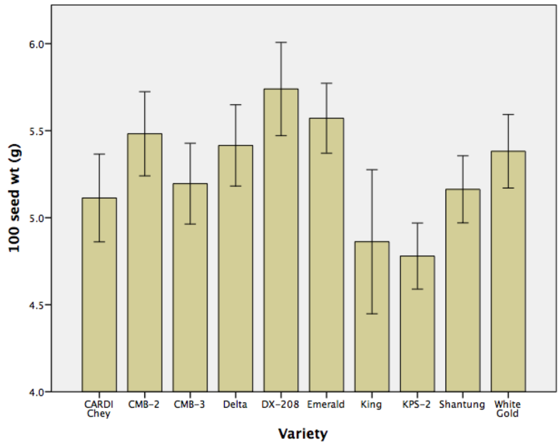


Figure 59. Differences between varieties for 100 seed weight (g). Error bars are 95% confidence intervals.

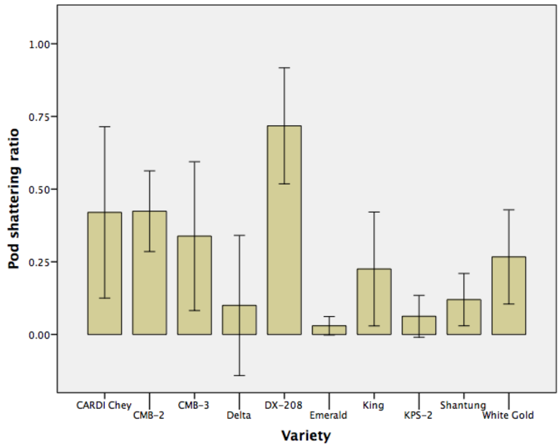


Figure 60. Differences between varieties for pod shattering ratio. Error bars are 95% confidence intervals.

Summary of mungbean evaluation (2017-2021)

This study evaluated 22 public mungbean varieties from Cambodia (4), Thailand (3), Vietnam (4) and Australia (11) for grain yield, seed size, resistance to pod-shattering, determinate flowering and suitability for machine harvesting. The Australian varieties, especially Delta and Emerald, which enable harvesting with one pick and machine harvesting, are recommended for further testing across other mungbean growing regions of Cambodia before submission for registration and

commercial release. Future research can also be focused on environmental yield constraints such as improved water-use efficiency as well as improved varieties.

Figure 61. Dissemination workshop on National variety release committee, 17th December 2021

Bob Martin was invited to attend the Dissemination Workshop on National Variety Release Committee at the Phnom Penh Hotel on 17th December 2021 (Figure 61). CAVAC has driven the process of introduction of the FAO Quality Declared Seed (QDS) system by the General Directorate of Agriculture (GDA) and this led to the formation of a new Department of Crop Seed (DCS) in GDA.

Attendance at the workshop provided Dr Bob Martin the opportunity to meet with Dr Mak Chanratana, Deputy Director of DCS on Friday 17th December to discuss commercialization of high performing mungbean varieties in CamSID trials between 2018 and 2021.

Key points:

1. Submit application for seed quality certification and variety registration in national plant variety catalogue.
2. CMB-2 for QDS.
3. Australian varieties: Need to import new pure seed of Delta and Emerald to ensure starting with pure seed. Apply for import and prepare paperwork.
4. Work with DCS and CAVAC. Possible FAO funding in 2022-23.
5. Prepare training documents for MB QDS. Draft field descriptors for mungbean were prepared by ASR.
6. Baseline mungbean farmer survey, broader VC descriptions through to end-users.

Current situation

Dr Ponh Oudam, Vice Director PDAFF Battambang, has allocated a seed increase field for mungbean varieties at the PDAFF Battambang seed production station. However, DCS has not followed through with FAO funded support.

7.4 Diversification: Watermelon

Watermelon variety trials in 2018

Svay Cheat Village, Battambang

The new technologies (full or partial) application brought higher gross margins compared to farmer practice technique. Whilst farmer practice using the same variety C29 received a very low profit of USD 433 (Table 39). The protocol (full coverage of plastic mulching) did not contribute to yield improvement compared to the partial coverage (at planting site only). A higher profit in partial coverage resulted from saving plastic (production cost) for both varieties Superman and C29. The demonstration at Svay Cheat showed advantages of new technologies for partial plastic coverage over farmer practice in both varieties, Superman and C29. The average yields are increased more than 220% and the average profit is about 10 times higher that of farmer practice.

Table 39. Economic analysis of watermelon variety trials at Svay Cheat Village, Battambang in 2018 dry season.

1	Variety Yield (t/ha)	Superman 28.30	C 29 29.3	Superman 29.30	C 29 29.3	Farmer (C 29) 12.9
2	Income (USD/ha)	9,433	9,718	9,433	9,718	4,522
3	Cost (USD/ha)	5,274	5,274	4,982	4,982	4,089
4	Gross margin (USD/ha)	4,160	4,444	4,451	4,736	433

Legend	Good	Fair	Poor

Sisophon, Banteay Meanchey

The experiment was established in the dry season on a farmer's field next to MCU. The objectives were to evaluate eight (8) watermelon varieties including two from Syngenta (Superman and Hoang Chau), two from East West (EW06, CB05), two from Agriance (Red Moon and 020 F1) compared to two Thai varieties (C28, C29) currently planted by farmers in NW Cambodia (Figure 62). The seedlings were planted into raised seedbed with plastic mulch and irrigated using drip irrigation. Pruning and pollination were manually done and kept to one fruit per plant (according to Vietnamese technique).

Figure 62. ACIAR and CamSID staff visit the watermelon trial at MCU on Feb 12, 2018 (Credit: Cuong)

Variety 020 F1 has highest marketable yield 32.5 t/ha followed by a group of 3 varieties Hoang Chau, Superman and EW 06, their yields are 28.8 t/ha, 27.8 t/ha and 26.8 t/ha respectively (Table 40). Variety C 29 was best on taste and good texture as Cambodians were used to the taste of the local variety while Superman and Hoang Chau varieties have highest sugar degree 11.9 Brix and 11.3 Brix, respectively and good flesh colour. Variety 020 F1 gave the highest gross margin: USD 6,105/ha and highest return on investment (ROI): 1.03, followed by C 29 variety with a gross margin USD 4,701/ha and ROI is 0.79.

Table 40. Economic analysis of watermelon variety trials at Sisophon, Banteay Meanchey province in the 2018 dry season.

Variety	Yield (kg/ha)	Price (USD/kg)	Income (USD/ha)	Cost (USD/ha)	Gross margin (USD/ha)	Return on investment
Superman	28,700	0.34	9,758	5,920	3,838	0.65
Hoang Chau	28,800	0.33	9,504	5,920	3,584	0.61
EW 06	26,800	0.38	10,104	5,920	4,184	0.70
CB 05	23,400	0.38	8,892	5,920	2,972	0.50
Red moon F1	23,300	0.38	8,854	5,920	2,934	0.50
020 F1	32,500	0.37	12,025	5,920	6,105	1.03
C 28	23,700	0.40	9,480	5,920	3,560	0.60
C 29	24,700	0.43	10,621	5,920	4,701	0.79
Average					3,985	0.67

Legend	Good	Fair	Poor

Watermelon agronomic experiments in the dry season at Sisophon, Banteay Meanchey in 2019

During the dry season watermelon agronomic experiments at Sisophon, Banteay Meanchey in 2019, damping-off (*Rhizoctonia* sp.) was the main disease which infected watermelon seedlings. Aphids (*Aphis gossypii*) infected the field at high populations at the seedling stage (7 DAP) whereas thrips (*Thrips tabacci*) infected the field at a later stage (28 DAP until harvest). There were no significant differences in number of fruits per hectare between all treatments but there were significant differences in fruit weight per hectare between different planting techniques. Treatment-5 had the highest yield with 41,312 kg/ha, treatment-4 had the second highest yield with 35,507 kg/ha, treatment-3 was the third highest yield with 30,839 kg/ha, followed by treatment-2 with 28,853 kg/ha, and the lowest yield was treatment-1 with 26,029 kg/ha. With economic analysis (return on investment), treatment-2 (ploughing with flat planting) was the most effective investment with return investment of 84% (spend $1 get back $0.84 of profit); treatment-3 (ploughing with raised seedbed and bare soil) and treatment-4 (ploughing with raised seedbed and straw mulching were the second effective investment with 78% of investment. Treatment-5 was not the most effective investment compared with other treatments (Table 41).

Although it produces the highest yields, plastic covering is not very environmentally friendly and has high input costs. Hence, while growing watermelon on raised seedbed with straw mulch may be an effective way to suppress weeds and conserve soil moisture, ploughing with flat planting gave the highest economic returns.

Table 41: Actual yield and economic analysis for dry season watermelon agronomic experiments at Sisophon, Banteay Meanchey in 2019.

Treatment	Number of fruits (fruit/ha)	Fruit weight (kg/ha)	Production cost (USD/ha)	Income (USD/ha)	Profit (USD/ha)	Return on investment (ROI)
T1 - Direct seeding into hole	15,133^{ns}	26,029.33^{d*}	1,285.30	2080.83	795.53	0.62
T2 - Plough, flat planting	16,000^{ns}	28,853.33^{cd}	1,301.50	2400.00	1098.50	0.84
T3 - Plough, raised seedbed - bare soil	15,267^{ns}	30,838.67^{c}	1,395.30	2480.83	1085.53	0.78
T4 - Plough, raised seedbed - straw mulch	16,067^{ns}	35,507.33^{b}	1,645.30	2928.33	1283.03	0.78
T5 - Plough, raised seedbed – plastic covering (black and silver)	17,467^{ns}	41,312.44^{a}	1,742.20	3056.67	1314.47	0.75

Based on watermelon demonstration and experiment conducted in Battambang and BMC, Drs Yorn Try and Dao Xuan Cuong have compiled Integrated Pest Management manual for watermelon. This document is used for universities curriculum, technical high schools, leading farmers, agricultural input companies and NGOs.

7.5 Diversification: Fish and fingerling production

Red tilapia production

In June 2019, CamSID project started a fish experiment at Mr. Yann Sophon's pond. Raising Red Tilapia (*Oreochromis niloticus*) at 2 fish/m^2 (50 fry/cage) was the best density with lowest mortality rate, highest average weight, rapid growth rate, less expenses, and high market price (Table 42). Compared with rice production at the same land size, fish production farmers can earn more income, since fish raising locally is uncommon, and there is good market demand.

Table 42. Economic calculation on fish experiment at Battrang village

Description	Treatment		
	T1-50 fry/cage	T2-75 fry/cage	T3-100 fry/cage
Total fish weight (kg)	59.26[a]	70.05[a]	96.23[a]
Food accumulation (kg)	153	186	320
Expenses on fingering ($)	3	4.5	6
Expenses on fish food ($)	95.70	116.21	199.80
Price per kg ($)	2.5	2	1.5
Incomes ($)	148.15	140.10	144.34
Gross Margin (Profit) ($)	49.45	19.39	-61.46

Fingerling production

As the result of CamSID project experiment, Mr. Yann Sophon was very satisfied with the proficiency and efficiency of fish raising at his pond at home. He decided to upgrade himself to be a fish raising and fingerling producing farmer (Figure 54). On May 2021, he started his business with fingerlings bought from Mr. Thann Phirun, leader of Fingerlings Production Farm of Koy Maeng commune's Fishery Community in Koy Maeng commune, Mongkol Borey district, Banteay Meanchey Province (BMC). He also learnt some production techniques from Mr. Phirun. Furthermore, Mr. Sophon got some help from CamSID staff, Hong and Seyma, such as collecting method, maintenance and promoting his business on social networks.

Mr. Yann Sophon was originally eager to produce Red-Tilapia fingerlings, but he could not find any qualified fingerling providers locally and he had difficulty in importing fingerlings from Thailand due to the COVID-19 pandemic. Instead, he decided to pivot to produce carp (Java barb-*Barbonymus gonionotus*) fingerlings, which also has good local market demand nowadays (Figure 63). **The demand for red tilapia had fallen with fewer weddings due to the COVID-19 pandemic but the demand for carp had risen.** The cycle of fingerlings production is about 65 days from breeding to harvesting period. The breeding fingerlings are introduced to nursery for 5 days, before they are released to the pond to feed for another 60 days. At the age of 65 days since breeding, fingerlings are available to be collected for customers' order. Mr Sophon can produce about 35 thousand to 40 thousand carp fingerlings per cycle (Figure 64).

There are 2 grades of price for fingerling that Mr. Sophon produced, 100 riels/fingerling (1USD = 4000 riels) for 65 day-olds (8 mm to 1 cm size), and 200 riels/fingerling for 90 day-olds (bigger than 1 cm). During the two months of his production, June & July, he sold about 50 thousand fingerlings to 6 customers; 2 are soldiers, and 4 are ordinary people, who located in Serei Soaphaon town, Malai district, Paoy Paet town, Samroang and Koub commune in Ou Chrov district, all within Banteay Meanchey Province. Moreover, Mr. Sophon has recently received orders from 2 customers in Koub commune, and another in Samroang commune. However, the orders are delayed due to the current flooding in almost every district of Banteay Meanchey Province. Province.


Figure 63. Hong (left) (CamSID) & Yann Sophon (right) **Figure 64. Carp fingerlings**

7.6 Diversification: Using a soil penetrometer to identify lowland rice soils suitable for growing non-rice crops

Soil strength decreased with depth in Kein Svay soil and increased with depth in Toul Samrong soil at Svay Cheat, Don Bosco, Os Tuk and Ta Haen Muoy (Figure 65, Appendix 2 – Soil Profiles of Battambang and Banteay Meanchey). Mungbean crops were planted at Preaek Trab, Don Bosco and Svay Cheat in December 2021 at the end of the wet season. Mungbean crops grew successfully at Preaek Trab where soil strength declined with depth (Figure 66). The soils at Os Tuk and Ta Haen Muoy showed a moderate increase in soil strength with soil depth and their suitability for mungbean needs to be confirmed. Mungbean crops failed without irrigation at Svay Cheat and Don Bosco where the soil strength increased markedly with depth.

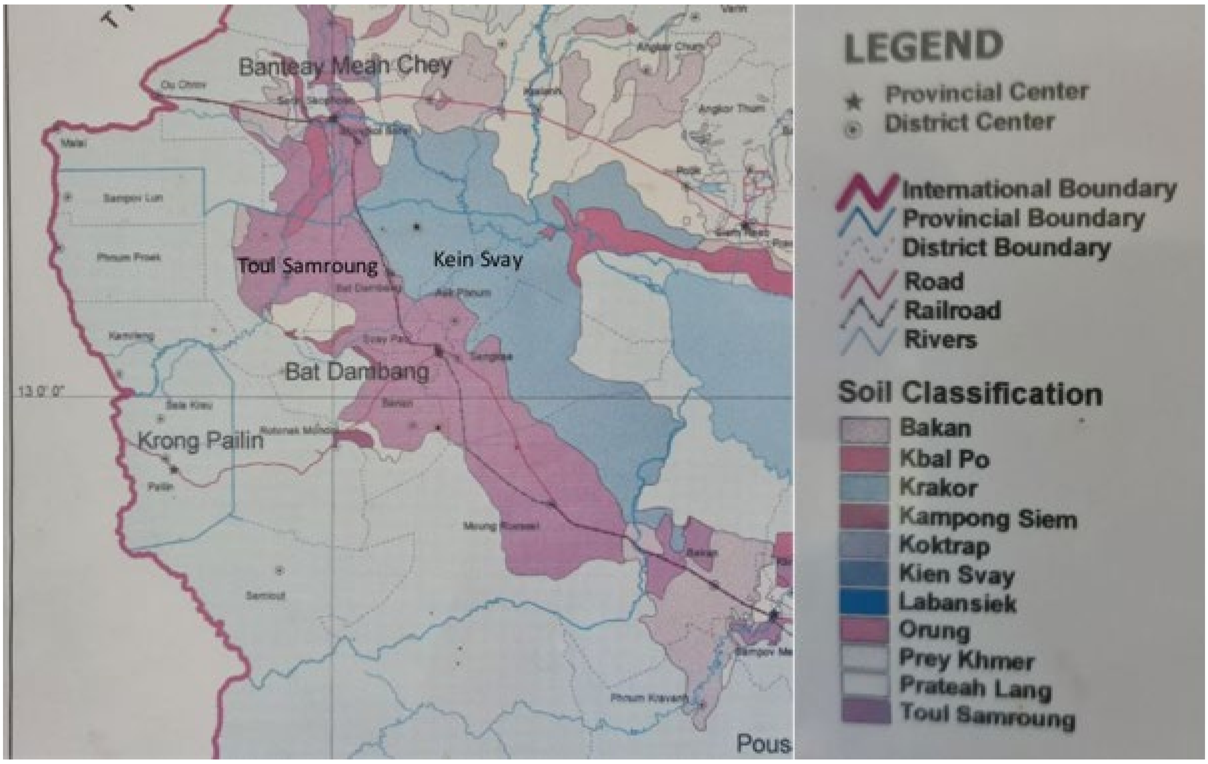


Figure 65. Soils of rice growing areas (White et al. 1997)

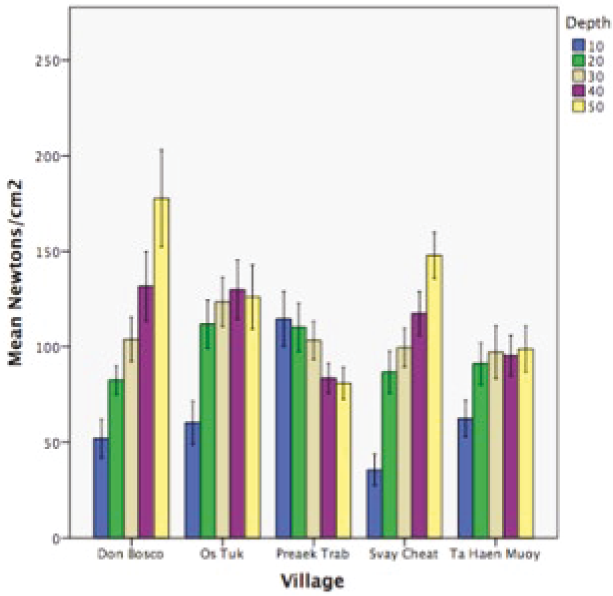


Figure 66. Changes in soil strength with depth at five CamSID demonstration sites in Battambang province

Soil penetrometer data have the potential to be used to identify soils that are suitable for growing diversification crops after rice and further testing on a wider range of soils is warranted (Figure 66). Soil penetrometer tests should be done at the end of the wet season in November-December and should be accompanied with mungbean test plots planted at the same time.

7.7 Scaling case studies

7.7.1 SFSA hub case studies at Banteay Meanchey province

The 2020 and 2021 years have been challenging. The COVID-19 global pandemic (still active in Cambodia after February 2021) and Cambodia has experienced the pandemic and very destructive extreme weather events combining first drought and then flood during the crop cycle. Despite this, the performance of the two Farmer Hubs looks rather exceptional.

The rice planting started in May-June 2020 with land preparation and dry direct seeding activities almost on track with the plan. Then, a long period of drought arrived and many farmers did not want to take the risk of replanting in Banteay Meanchey Province. They did not want to pay for land preparation and direct seeding services due to lack of cash; and fearing water shortages for forthcoming irrigation. They preferred broadcasting, which is the cheapest solution. Farmers did not invest in “truthful label” rice seeds, instead they planted their own farm saved seeds.

Later, in October and November 2020, heavy rains damaged the wet direct seeding rice crops severely at harvest time. It also destroyed roads and canals flowing towards Tonle Sap Lake. The Government and Private sectors carried out much emergency relief and support. https://www.phnompenhpost.com/national/inmates-evacuated-schools-closed-flooding-takes-toll

Consequently, the two farmer hubs have been able to achieve between 50 and 65% of their 2020 target:

- Mr Chiv Sarith achieved 65% of his business plan. He ploughed and harrowed 70 ha while planting 20 ha with the Kid Seeder (Dry direct seeding rice). He charged USD33/ha for ploughing, USD20/ha for harrowing and USD45/ha for the direct seeding.

The services generated a gross income of USD3750 and USD880, respectively; instead of USD7000 in the business plan.

- Mr Yann Sophon achieved 50% of his sales plan. He sold 30T instead of 45T in his business plan which generated a gross income of $12K instead of $25K in the plan. Knowingly he sold the seeds at $0.4/kg instead of $0.6/kg due to high variability in seed quality and non-willingness to pay from farmers. He could primarily sell Phka Rumduol, but not Sen Kra Ob for the second planting window in October (no demand). In terms of seed production for the Year 2021, he secured the planting of 10 ha of rice seed production: 7 ha Phka Rumduol, 2.5 ha Sen Kra Ob, 0.5 ha Chansensor which are going to be harvested by mid-December 2020. The challenge Yann Sophon is facing is the current rice seed inventory prior to December 2020 harvest (almost 20T). Mr Yann Sophon is looking for new storage capacity to secure the storage of the fresh upcoming harvest.
- Finally, we finalized the investment plan of a seed cleaner and power generator for Mr Yann Sophon Hub, costing $28K and $2.5K, respectively, financed by SFSA and donated to Ockenden Cambodia.

  – **Farmer Hub 1** – Mr Chiv Sarith: set-up a Customer Relation Management training to structure his current and future customer database and record all the transactions customer by customer. Review the current business case and the costing of the offers for dry and wet direct seeding areas. Screen and test new potential services (Figure 67).
  – **Farmer Hub 2**: Mr Yann Sophon: installation of rice seed cleaner delivered on site Dec. 15, 2020; organized ad-hoc training with support of Petkus: December 2020 and January 2021. Clean 2020 Dec harvest (30T expected) with seed cleaner K06 in Q1-2021 (installation in collaboration with Mr Som Bunna, CARDI) (Figure 68).
  – Conduct Farmer Hubs evaluation with ad-hoc methodology and write a PITCH for investors (while identifying potential investors)
  – CamSID conducted in -2021 research on: "*Farmers' Hubs as a vehicle to deliver solutions & services to farming communities*". The objective is to evaluate how and in which contexts Farmers' Hubs facilitate the dissemination of new products, practices, and services to smallholder farmers and the broader farming community as commercial service providers.

Figure 67. Mr Chiv Sarith: Farmer Hub owner: land preparation and direct rice seeding at Kuok Tonloap Village, Banteay Meanchey province.

Mr Yann Sophon Farmer Hub (Hub 2)

SFSA donated the power generator and the Petkus K06 rice seed cleaner hereunder which will be used by both Ockenden and the Battrang Agricultural Cooperative. A great thank you to Nharn NHOV from Ockenden who orchestrated the tax clearance and the transportation. He did it in a record time: one week compared to three weeks usually. The seed cleaner was installed at the Battrang Agricultural Cooperative building on 15 December 2020 (Figure 68, Figure 69).

Figure 68. Battrang Farmer Hub: Petkus seed cleaner installed at Battrang Agricultural Cooperative, Banteay Meanchey Province on 15 Dec 2020.

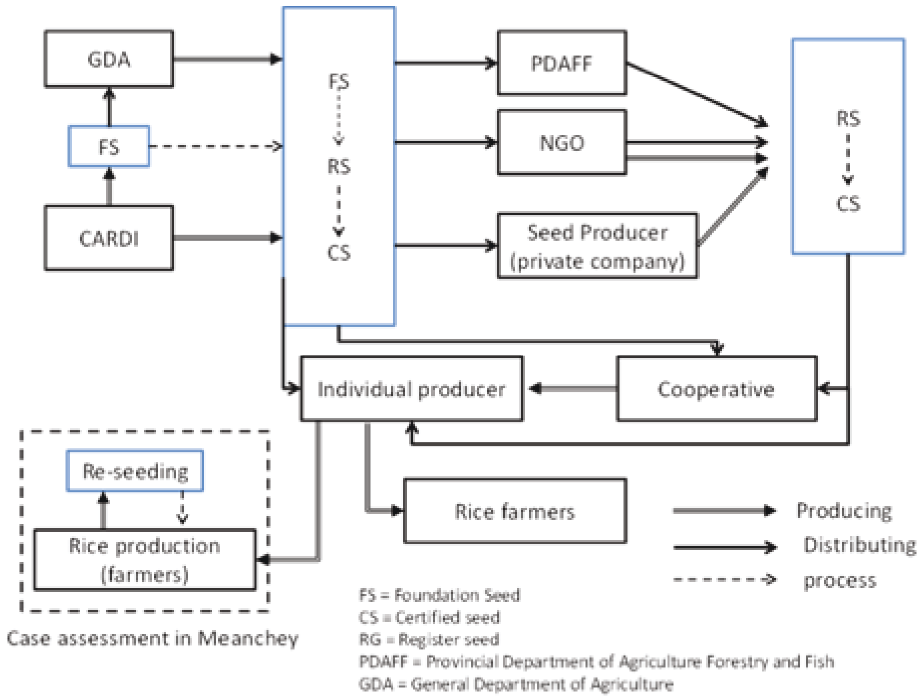


Figure 69. Seed processing system (flow chart) in Cambodia

What has been learned?

- **What went well?**

- The roll-out of the different steps from 2018 to 2021: idea generation; road map design, and implementation phases by SFSA Asia; with National Meanchey University (NMCU) support which triggered a great momentum
- Strong engagement of the farmer hub owners, with good support from MCU: visit of the farmer hubs in Bangladesh; full ownership of the business plan
- The financial investment made by SFSA to kick-off these two Farmer Hubs: $60K in three years
- Involvement of Ockenden Cambodia as an additional support. Ockenden Cambodia has been instrumental to facilitate the delivery of the seed cleaner in Cambodia: tax clearance, registration as host, reception and delivery of the machine
- The farmer's demonstrations-days organized jointly with MCU: "seeing is believing"; a key milestone to create awareness at farm level
- The feasibility study we did with IRRI in November 2019 for the rice seed production Farmer Hub
- The relatively good results in 2020 and 2021 despite massive adverse conditions: COVID-19 and weather
- The fortnightly Zoom meeting feedback provided to CamSID team: helpful to get full support and endorsement

- **What was difficult?**

- The number one difficulty is due to the lack of permanent SFSA staff in Cambodia to support all the Farmer Hubs related activities; despite permanent help from NMCU staff

- The business model was not documented clearly enough at the beginning
- The lack of visibility of the current and future customer base, the lack of consideration of the competitive space, and the absence of reliable data in the whole transactional flow (including credit)
- The decision to better assess the farmer's needs by commissioning IRRI expert delayed the investment in establishing the rice seed processing unit by six months

- **What could (should) be done?**

- Re-evaluate the business opportunity for both farmer hubs and draft a more precise "service delivery" road map for 2021
- Invest time and resources in data tracking and recording to consolidate the customer database of each farmer hub
- Recalibrate the offer in terms of scope and pricing. This is particularly true for the land preparation and direct seeding services
- Keep on upgrading the seed processing unit: small quality lab, storage capacity
- Re-assess the market opportunity and the competitive landscape: need more granular data
- Fine-tune the value proposition: clarify the differentiating points with competitors
- Seize the huge opportunity of creating and delivering an Integrated Offer matching small-holder rice farmers' demand: land leveling and direct seeded rice (DSR) mechanised services plus high quality seeds.

Finally, we have gone from nowhere in 2-3 years into strong headwinds and despite that, have a solid basis of two prototype, economically and ecologically sustainable Farmer Hubs. Handing-over to a capable existing or newly formed organization the management of these two hubs in the perspective of "mushrooming" and scaling-up this positive experience is a key objective for 2022.

7.7.2 Planting machinery scaling case studies with farmer groups at Battambang

Machine row planting and pre-emergence herbicide demonstrations for rice in Battambang (2021)

The average rice plant establishment in field 10 was 110 plants/m^2 and this is within the IRRI recommended range of 100-150 plants/m^2. Farmers are still pushing for higher plant populations but higher plant density increases the risk of crop loss from drought. There was no significant effect of pre-emergence herbicide treatment on rice crop establishment (Table 43,Figure 70). However, there was a trend for lower rice plant population density in the oxadiazon treatment.

Table 43. Effect of pre-emergence herbicides on rice establishment and weed density (log [x + 1] plants/m^2)

Treatment	Planted rice	Grass weeds	Sedges	Canopy cover (%)
Butachlor	130	0.497	0.220	9.4
Nil	103	4.057	7.026	31.3
Oxadiazon	95	3.901	3.782	24.6
Mean	110	2.818	3.676	21.8
Std. Error	11.7	0.247	0.211	5.18

Significance (P)	NS	0.000	0.000	0.031

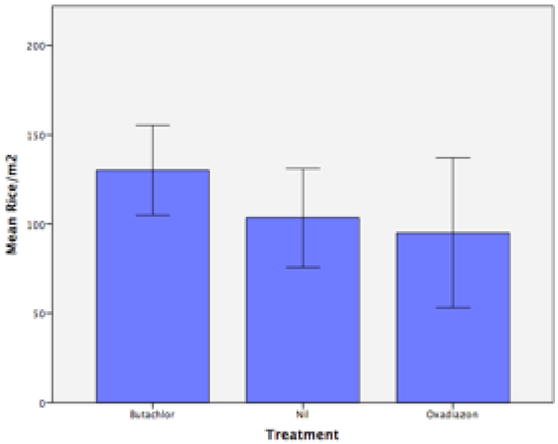


Figure 70. Effect of pre-emergence herbicide on establishment of rice (plants/m^2)

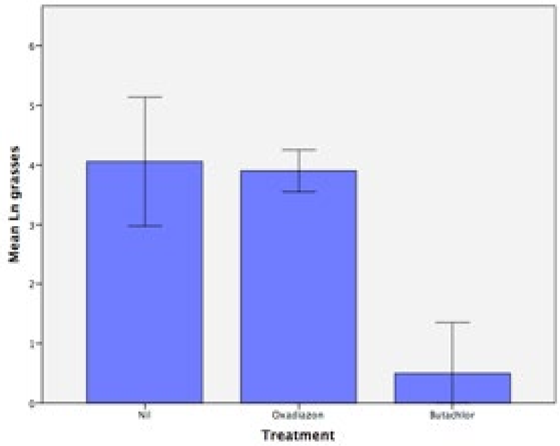


Figure 71. Effect of pre-emergence herbicide on log (x +1) grass plants/m^2

There were significant differences between treatments for control of grass weeds and sedges (Table 41, Figure 71, Figure 72, Figure 73). Butachlor gave best control of grasses and sedges. Oxadiazon did not give effective control of grasses but gave some control of sedges.

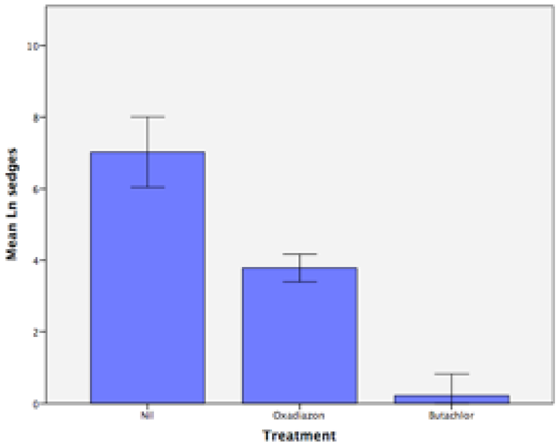


Figure 72. Effect of pre-emergence herbicide on log (x +1) sedge plants/m^2

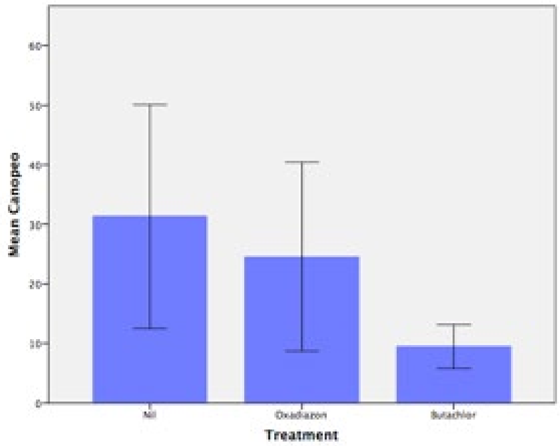


Figure 73. Effect of pre-emergence herbicide on canopy cover (%)

Canopy cover gave a similar result to weed counts but was less accurate because it combines the rice and weeds. To be an effective measure off weed canopy cover, Canopeo readings would be taken from between rows only.

Post-emergence herbicides are chosen after the weed species present can be observed. This is primarily the farmer's choice but the CamSID-EPIC team also provided advice to the farmers on which post-emergence herbicide to use. In this field, the focus will be on control of grasses and sedges for choice of post-emergence herbicide. The use of pre-emergence herbicides is a must to achieve effective weed control in direct-seeded rice, especially when dry-seeded. This demonstration clearly highlighted the importance of using pre-emergence herbicides in dry direct-seeded rice. Post-emergence herbicides should be applied at the 3-4 leaf stage of weeds or 15-20 days after sowing (DAS). The disadvantage of relying on post-emergence herbicides in dry-direct seeded rice is that they cannot be applied until after rain or irrigation. In the case of this demonstration, no rain was received by 30 DAS. By this time weeds have already had a competitive effect on the crop and cannot be effectively controlled by herbicide at this growth stage.

Survey on factors affecting the adoption of the Kid planter

Adoption of the Kid planter commenced in 2017. Willingness to adopt peaked in 2019 and adoption was completed by adopters in 2020 (Figure 74).

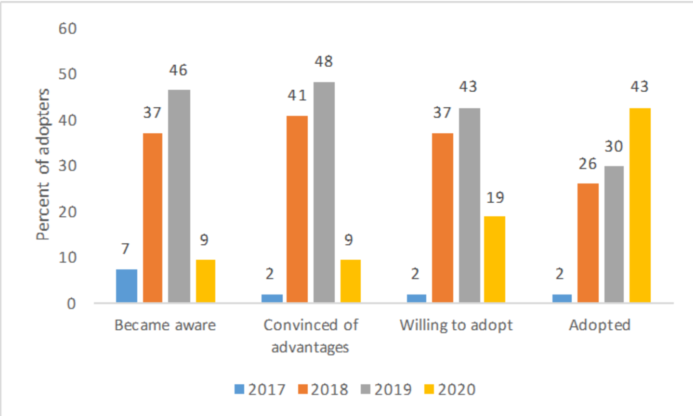


Figure 74. The adoption trends for adopters of the Kid planter

The adopters nominated a range of benefits of machine drill seeding compared to hand broadcasting and these are consistent with CamSID messaging (Figure 75). In particular, adopters readily recognised the value of reducing seeding rates, ease of weed control and improved control of diseases and insect pests.

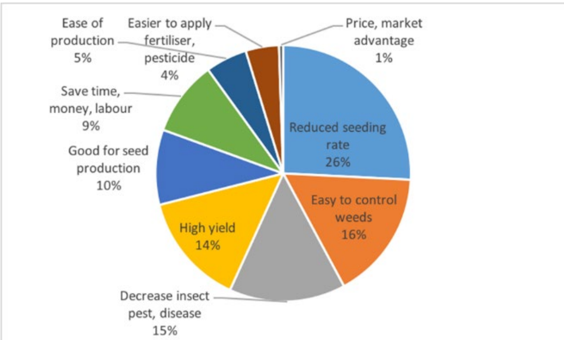


Figure 75. Benefits nominated by adopters of the Kid machine planter

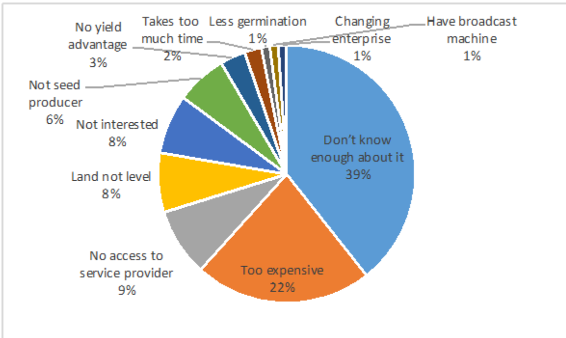


Figure 76. Reasons given for non-adoption by non-adopters

The main reasons given for non-adoption were the need for more information and the perception that machine planting is more expensive than broadcasting (Figure 76). Therefore, the priorities for further scaling out of machine planters should be to improve delivery of technical support information to agricultural cooperatives (ACs). A promising option is the formation of social media network group and CamSID Battambang is currently setting up Telegram groups with eight focus villages to test the concept.

Case study of Kid adoption in the Kampong Preang Agricultural Cooperative (AC)

Mr Phearom, Vice-President of the Kampong Preang Agricultural Cooperative (AC), provided an update for the CamSID team on use of the Kid planter for rice in October 2020. There are currently 264 farmers in the Kampong Preang AC. In 2020, 15 AC farmers are accessing the Kid seeder service provision. These farmers are all seed producers and six of them are implementing the General Directorate of Agriculture (GDA) Quality Declared Seed (QDS) protocol in 2020. Seed producers buy Sen Kra Oub paddy @ 1,300 riel/kg from farmers ($325/t) and sell “certified” seed at 2,500 riel/kg ($625/t).

According to Mr Phearom, farmers growing rice for sale as paddy for milling are not adopting the Kid seeder because of the service fee ($27.50/ha). They quote $10/ha for hand-broadcasting labour and are not using the Kid because of the perceived additional cost of machine planting. Kampong Preang farmers are apparently not accounting for the cost savings from reducing seeding rates from 200 kg/ha for broadcasting to 120 kg/ha for machine planting. At 1,300 riel/kg, the saving is 1,300 * 80 = 104,000 riel = $26/ha.

The CamSID recommended seeding rate for the Kid planter is 70-75 kg/ha and the average broadcast seeding rate for the region is 180 kg/ha. Despite the farmer perception of increased cost, if seed cost is taken into account there is actually a cost saving for machine planting of $19.25/ha compared to hand- broadcasting (Table 44).

Table 44. Comparison of machine and broadcasting planting costs for rice

Operation	Machine planter	Hand-broadcasting
Seed (@ 1,300 riel/kg)	$26.00	$58.50
Planting	$22.75	$10.00
Total	$48.75	$68.50

Farmers are also doing the same amount of land preparation for machine planting as they do for hand-broadcasting. Land preparation is typically two passes with a disc plough before broadcasting and one harrowing after broadcasting. For the Kid, farmers plough twice and harrow once before machine planting. The reason for the harrowing is to level the seedbed to improve establishment. This is an unnecessary cost as well as wasteful of soil moisture.

Figure 77. Comparison of Kid and Kubota planters for ground engagement and seed placement

Machine planting should enable reduced tillage or no-tillage to be implemented for land preparation. However, with seed boxes attached to a rigid toolbar, the Kid planter is not suited to uneven seedbeds, especially with reduced or no-tillage. A commercially available alternative is the Kubota planter which has seed boxes attached to the toolbar by parallelograms which allow seeding units to independently adjust to uneven seedbeds. (Figure 77). Further crop establishment savings can be made by adoption of reduced and no-tillage systems (Table 46). As with machine planting, reduced tillage preserves soil water and provides insurance against drought.

Scaling-out of several inter-connected CamSID outputs is primarily dependent on the adoption of machine planting. In dry direct-seeded rice, these outputs include: reduced seeding rates; use of quality seed; use of pre-emergence herbicides; reduced tillage and improved water-use efficiency.

Table 46. Comparison of land preparation systems for planting rice ($/ha)

Operation	No-tillage	Reduced tillage	Full-tillage
Pre-sowing herbicide	$17.00	$17.00	$0.00
Rotavator	$0.00	$25.00	$0.00
Disc plough (* 2)	$0.00	$0.00	$60.00
Harrow	$0.00	$0.00	$15.00
Total	$17.00	$42.00	$75.00

Seed production is an important commercial activity for the Kampong Preang AC and it is possible that their promotion of machine planting is limited or biased towards this objective. The AC might therefore not be the best vehicle for scaling-out of machine planting beyond existing seed producers.

Survey on Kid service providers (in 2021)

We were able to contact and interview 14 Kid owners, 64% of the total. The area of rice planted by owners and service providers since 2016 peaked at 726 ha in 2020 but declined to 289 ha in 2021 (Figure 78). The reasons given for the decline in planting in 2021 were: drought; too much rain; less seed production; dis-adoption and reversion to broadcasting (Figure 78).

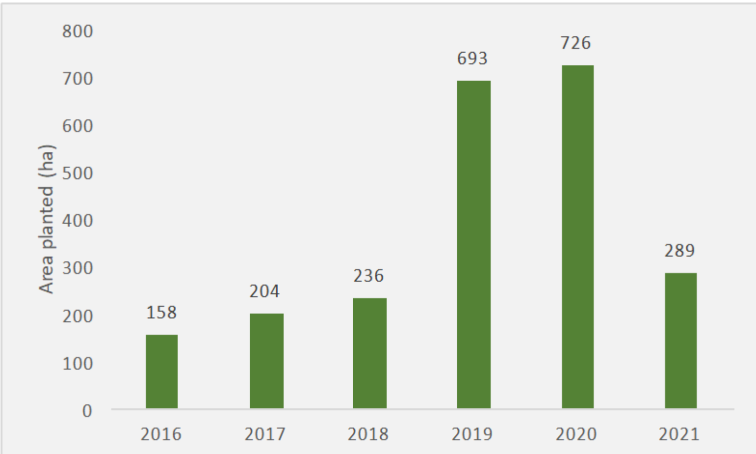


Figure 78. Area planted by the Thai Kid planter since 2016

"*My farmer clients prefer to plant with the Kid but planting opportunities are limited if there has been too much rain making fields too wet or flooded. Therefore, they broadcast seed instead to ensure timely sowing*". Comments to this effect were made by several service providers. This is an important issue and more mechanised wet seeding options are required. The Eli planter for 2-wheel tractor is designed for wet seeding is commercially available and should be promoted and demonstrated more. Currently there are no commercial options for wet seeding rice with 4-wheel tractor machines. Eli planters are being adapted for use by 4-wheel tractor and this might be the best option at this stage.

Perceived benefits influencing purchase of the Kid planter

The main sources of information received by owners and service providers about the Kid planter were CAVAC and CamSID. Perceived benefits influencing purchase included: reduced seeding rates; reduced fertiliser application costs; reduced cost of planting; reduced disease; high yield; reduced labour; and reduced land preparation. Field days and demonstrations were favoured for promotion of machine drill planting of rice.

Advantages of the Kid planter

Service providers were asked if they agreed with a set of statements about the advantages of the Kid machine row planter where 1 = strongly agree, 2 = agree, 3= neutral, 4 = disagree, 5 = strongly disagree (Table 47).

Table 47. The median response to statements regarding advantages of machine drill planting

Statement	Response
Weed control is easier with machine planting compared to broadcasting	Strongly agree
Seeding rates can be reduced with machine planting	Strongly agree
Reduced seeding rate enables me to use better quality seed	Strongly agree
Machine planting reduces the cost of fertiliser application	Strongly agree
Machine planted rice has a more open canopy and reduces blast disease	Agree
Machine planting increases crop establishment compared to broadcasting	Agree
My input costs are reduced with machine planting compared to broadcasting	Agree
Rice yields are higher with machine planting compared to broadcasting	Agree
With machine planting I can reduce the number of land preparations	Neutral

The “sales pitch” to promote adoption of machine drill planting could include the following:

1. Seeding rates can be reduced;
2. Better quality seed can be used;
3. Weed control is easier;
4. Reduced cost of fertiliser application;
5. Reduced impact of blast disease;
6. Better crop establishment;
7. Reduced input costs.

Service providers were neutral on machine planting for enabling reduced tillage. CamSID experience with machine drill planting is that machine planting allows a reduction in the amount of land preparation compared with broadcasting. Over-preparation of land can reduce the performance of drill planters, especially if the seedbed becomes “fluffy”. The response to this statement was neutral and this indicates that further demonstration of reduced tillage is an important priority. It was pleasing to see that the median responses to the remaining statements were “agree” or “strongly agree”.

Disadvantages of the Kid

Respondents were asked if they agreed with a set of statements about the disadvantages of the Kid machine row planter where 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree (Table 48). The service providers strongly agreed that machines should be able to plant at higher seeding rates. However, the median response was that they disagreed that 30 cm row spacing is too wide (Table 48).

Table 48. The median response to statements regarding disadvantages of machine drill planting

Statement	Response
The machine cannot be adjusted to allow planting rice at higher seeding rates	Strongly agree
The Kid planting machine does not work well in uneven fields	Agree
Farmers say machine planting is too expensive compared to broadcasting	Neutral
There is no yield advantage over broadcasting	Neutral
The rollers should be removed	Neutral
The row-spacing is too wide	Neutral

Seeding rates and row-spacing

Options to increase seeding rates for the Kid planter

The standard Kid planter can plant at seeding rates up to 75 kg/ha at 30 cm row-spacing and 80 kg/ha at 25 cm row-spacing (Figure 79). The median seeding rate suggested by service providers was 80-100 kg/ha in 25 cm rows.

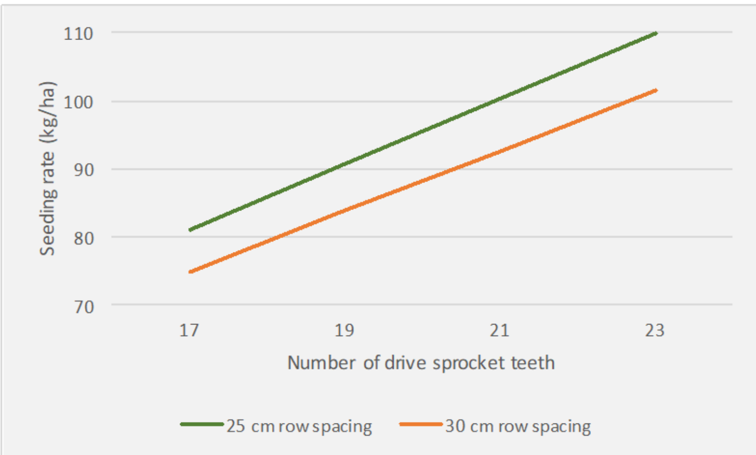


Figure 79. Options for increasing seeding rates for the Kid planter

There are three options for increasing seeding rates with the Kid planter:

1. Reducing the row-spacing from 30 to 25 cm increases the Kid seeding rate from 75 to 80 kg/ha with the 17-tooth drive sprocket. Reducing row-spacing to 25 cm also allows the number of seed boxes to be increased from 7 to 9. One service provider has done this already. However, this is an expensive option if the extra seed boxes are imported because there is an import tax on agricultural machinery spare parts of up to 35%.
2. The largest drive sprocket supplied with the Kid has 17 teeth. However, drive sprockets with more teeth can be fabricated locally. A 21-tooth drive sprocket would give a seeding rate of 100 kg/ha at 25 cm row-spacing.

3. The third option is to use seed plates with larger holes. The Kid planter is supplied with seed plates for maize and peanut as well as for rice and these can be used to increase seeding rate for rice. One service provider has used this method to increase the seeding rate of rice up to 120 kg/ha.

Service providers as well as farmers are aware that seeding rates need to be adjusted according to variety. The following seeding rates were quoted by one service provider:

- Phka Rumduol (70 kg/ha) is a medium duration photosensitive variety which allows more time for production of tillers;
- Srangae (100 kg/ha) is a short duration variety with good tillering capacity;
- Sen Kra-ob (110-120 kg/ha) is a short duration with poor tillering capacity.

There is no advantage of increasing the seeding rate if there is adequate water and nutrition. If there is inadequate water, high seeding rates will result in water stress and reduced yield. A common misconception among farmers as well as agronomists is that increased seeding rate is an economically effective way to suppress weeds. This is not correct. Increasing seeding rate can suppress weeds and increase yields compared to lower seeding rates in presence of weeds. However, these yield increases never reach weed-free yields. Furthermore, increasing seeding rate is less cost-effective compared to herbicide.

Seed and planting cost comparisons

Service providers agreed that seeding rates can be reduced with machine planting and that reduced seeding rate enables them to use better quality seed. The median service fee recommended by service providers is $30/ha and the cost of broadcasting is $10/ha. Farmers often only consider the cost of sowing. However, when the saving in seed costs is included, machine planting is usually cheaper than broadcasting (Figure 80). The cost of seed was assumed to be 1,300 riel/kg ($0.325/kg) and the broadcast seeding rate was assumed to be 150 kg/ha.

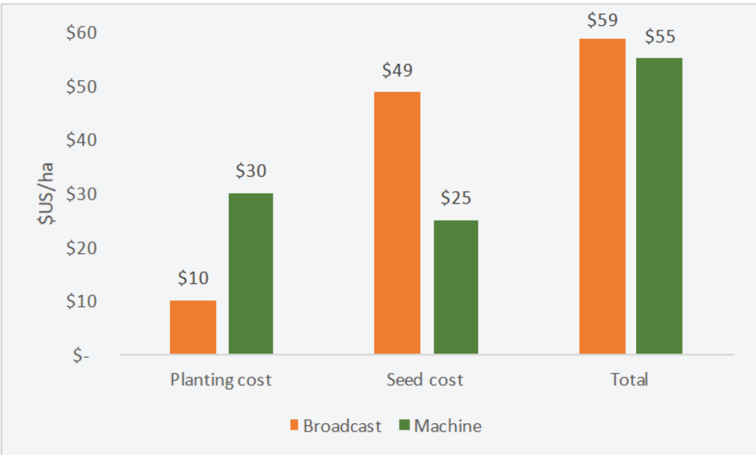


Figure 80. Comparison of planting costs for broadcasting vs machine drill planting

Machine planter options for uneven fields

The inability of the Kid planter to work well in uneven fields has become a common observation by service providers and leading farmers. The problem is that the Kid seed boxes are mounted on a rigid tool bar frame. If the soil surface is uneven, some seeds are planted too deep and some seeds are not planted at all and remain on the surface. The Kubota planter seed boxes are connected to the tool bar by parallelogram units that enable seed boxes to move up or down independently with changes in the level of the soil surface. The problem with the Kubota planter is it is not factory-fitted with a fertiliser box. However, fertiliser boxes are being fabricated locally for the Kubota maize planter and the same can be done for the Kubota rice planter.

Contract rates

The median contract planting rate suggested by service providers was in the range US$27.50 to US$30.00/ha compared to US$25.00 to US$27.50/ha suggested by farmers. If ownership and operating costs of the tractor and planter are taken into account, these contract rates are marginal to inadequate to cover costs. The chart below (Figure 81) is for a 60 hp Kubota tractor operating a $5,500 planter (Kid) and a $2,750 planter (Kubota planter with fertiliser box). The costings include a 20% profit margin.

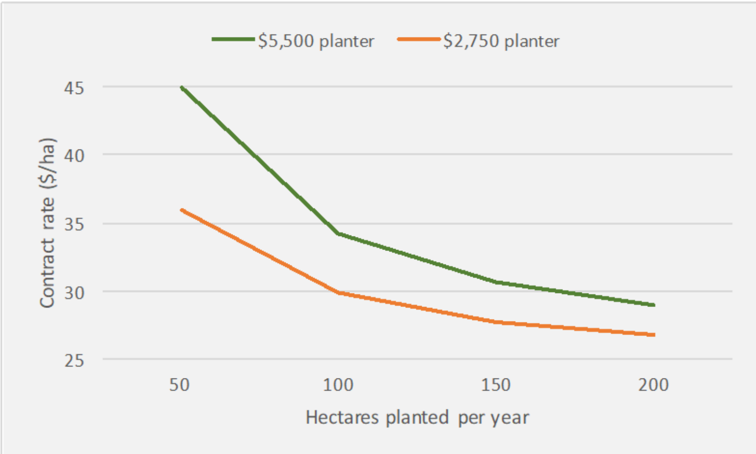


Figure 81. The effect of planter cost on contract rates for two machine drill planters mounted on a 60 hp (45 kW) tractor

The break-even contract rate decreases as the number of hectares planted per year increases. According to the costings, a service provider will not make a profit charging US$25/ha even if they plant 200 hectares per year (Figure 81). For a US$2,750 planter, the area planted would need to be 100 ha per year and 175 ha per year for a US$5,500 planter. With a contract rate of US$35/ha, a US$2,750 planter would need to cover 75 ha/year and a US$5,500 planter would need to cover 100 ha/year. The Kid planter appears to be over-priced in comparison with other Thai planters.

This group comprises large-scale farmers and service providers who source information more independently than small-scale farmers. Mr Chea Sarann is a large-scale farmer in Ta Kream commune who began using the Kid planter in 2016 and plants 100-200 ha every year. He was using the Kid planter before the CAVAC purchase subsidy began. There are four Kid users that could be seen as large-scale farm owners. We know a lot about the service provision to small-scale farmers but little about large-scale farmers. Case studies of these might uncover some useful information.

Dis-adoption of the Kid planter

Some service providers have stopped using the Kid machine planter and one service provider used the machine on 6 hectares only in 2017 and has not used the Kid planter since. He now uses a Kubota broadcasting machine. He acknowledged that the Kid is good for seed production in level fields. However, he stopped using the Kid because it is not suitable for use in uneven fields. The Kubota parallelogram planter is an option for this situation which represents the majority of rice fields in Cambodia.

Case study for Kid Seeder scaling by service provider (Banteay Meanchey province) in 2022

Mr Chao Bunthoeun, 47 years old, is a leading farmer in Thmor Pouk district. He joined the field day organized by CamSID and met with Dr Yorn Try. He was introduced to CamSID rice production technical packages, mechanised drum seeder, Eli seeder and the Thai Kid seeder. CamSID staff provided him with details on the rice agronomic package. Then he decided to buy one secondhand Thai Kid seeder from Battambang (with contact provided by Bob Martin). This machine was already purchased and used for two years (CAVAC subsidized) and he used this machine for planting service in his area. He learned to use the machine through Mr Peng Vuthea who was the previous owner of the Kid seeder in Battambang and from Mr Chiv Sarith (leading farmer in Mungkul Borei) and Mr Nheb Khim (project staff). He has 15 ha of land with 10 ha for cassava and 5 ha for rice. At this time Mr Chao Bunthoeun is a leading farmer (for cassava) and also a service provider of planting machines. Currently, he is the only farmer who has the Kid seeder for providing dry seeding service for the whole district for two planting periods a year (during early wet season in April and June). Since he bought the machine in February 2022, he has provided more benefits from the planting service and helped the community to change from machine and hand broadcast to Kid seeder planting. **He has committed to provide his planting service for 500 ha of rice every year.** Mr Chao Bun Thouen is not only a service provider for planting rice but also a leading farmer who is equipped with rice agronomic packages produced by CamSID outcomes to serve the community from now on. During April 2022, **he planted 5 ha per day for the whole month and received benefits (services charges) for USD30/ha**; he earned USD50/day and USD1500 for the early wet season (dry seeding). Then he did the second planting service provision in the middle of May due to heavy rain between end of April and early May. He planted 5 ha every day for one month and a half. With this promising machine service, he will buy another Kid seeder for next year and extend the area of service. After the first two season of providing planting service to the community, he suggested to some improvements to the Kid seeder as follows: (1) the space between row and row needs to be flexible (easy to calibrate), and (2) the space between plant and plant; and the depth of seed in the soil needs to be adjustable (the planning period during April is deeper and the planting during June is not too deep).

Table 48 shows the area planted with planting machines in Banteay Meanchey Province during April to June 2022:

Table 48. Area planted with planting machines in Banteay Meanchey Province during April to June 2022.

No	Service providers	District	Planting machine	Planting Area (ha)		
				April	May	June
1	Mr Chao Bunthoeun	Thmor Pouk	Kid Seeder	90	50	100
		Svay Chek	Machine broadcast	30	50	50
2	Mr Van Vin	Phnom Srok	Machine broadcast	25	30	50
3	Mr Chiv Sarith	Mungkul Borei	Mechanize drum seeder	5	10	10
		Mungkul Borei	Kid Seeder	20	5	30
		Mungkul Borei	Broadcasting machine	25	10	30
4	Mr Yann Sophon	Ochrov	Eli seeder	3	4	3
			Broadcasting machine	15	7	9
Sub-Total				**213**	**166**	**282**
Grand Total				**661**		

Conclusions and future directions

Rather than following a generic scale-out strategy, we propose a market-focussed strategy to address the key drivers of adoption and dis-adoption of machine planting of rice. The priority methods of delivery for service providers are: on-farm demonstrations; field walk and talks; and field days.

The priority subjects of interest to service providers are:

1. Seed cleaning, seed quality, seed treatment. CamSID, in collaboration with CAVAC, will organize visits to seed cleaning facilities, demonstrations of on-farm seed cleaning and seed storage options; demonstration of seed treatment options.
2. Mechanised planting options for rice production: field demonstration of row-spacing and seeding rate options; field demonstration of machine planting machine options for uneven fields.
3. Weed, insect and disease management. CamSID, in collaboration with CAVAC, will conduct on-farm demonstrations; field walk and talks and field days related to integrated pest management (IPM)
4. Crop production economics and business management. Face-to-face training on: calculating contract rates; calculation of cost savings with machine planting compared with broadcasting

Survey on Eli and Kubota service providers (in 2022)

The average number of established rice plants in the Eli fields was 789 plants/m^2 compared to 972 plants/m^2 for the broadcast fields. A partial budget was done to compare BB2C Eli air seeder with farmer practice hand-broadcasting at 300 kg/ha. Only costs that vary between the treatments are required for the analysis (Table 49). Although the cost of planting with the Eli (US$15/ha) is greater than for broadcasting (US$10/ha). The value of sowing seed was $0.18/kg (based on the paddy price of OM 5451 in August 2021, Cambodian Rice Federation). The total seeding cost for the Eli air seeder was US$34.80 per ha compared to US$64.00 per ha for hand-broadcasting, a saving of US$29.20 per ha for the Eli air seeder.

The paddy yield was 4,500 kg/ha in the Eli field compared with 3,400 kg/ha hand broadcast. At a paddy price of US$0.18/kg, the gross benefit for Eli seeder was US$810/ha compared with US$612/ha for hand-broadcasting and the net benefit for Eli seeder was US$775.20/ha compared with US$548/ha for hand-broadcast. Therefore, the Eli seeder provided an additional net benefit of US$227.20/ha compared with hand-broadcast.

Table 49. Partial budget for comparison of the BB2C Eli air seeder with hand-broadcasting at Ou Ta Nhea (in US$)

1. Eli air seeder

Variable costs	Unit	No. of Units	Unit value ($US)*	Total ($US)
Seed for sowing	kg/ha	110	$0.18	$19.80
Cost of planting	$/ha	1	$15.00	$15.00
Total costs that vary				$34.80
Gross benefits[2]	kg/ha	4,500	$0.18	$810.00
Net benefit				$775.20

2. Hand-broadcast

Variable costs	Unit	No. of Units	Unit value ($US)	Total ($US)
Seed for sowing	Kg/ha	300	$0.18	$54.00
Cost of planting	$/ha	1	$10.00	$10.00
Total costs that vary				$64.00
Gross benefits	kg/ha	3,400	$0.18	$612.00
Net benefit				$548.00

* Paddy price of OM 5451 in Banan district Battambang in August 2021.

The harvest field day was attended by 29 participants (Figure 82). The average age of participants was 44 with the youngest being 20 and the oldest, 68 years old. Only four participants were female which is typical for machinery field days. Since female household members are involved in significant financial decisions such as purchase of machines, more effort to engage with females is required to improve acceptance of mechanisation options.

Figure 82. Ms Sao Reaksa supervised the Eli demonstrations at Ou Ta Nhea

Advantages of Eli according to field day participants

- Save on sowing seed
- Reduced need for labour
- Reduced cost of seeding
- Higher yield
- Save time for planting
- Easy to use
- Good plant spacing

In 2022, lack of labour for broadcasting rice has become an issue. This has increased interest in Eli but also in broadcasting machines. **In addition, Bob Martin helped BB2C develop an Operating Manual for the next generation BB2C Eli seeder 3.0 and Dr Try and Khim translated it into Khmer for BB2C.**

Survey of AgriSmart Eli seeders donated in 2020 by Prime Minister Hun Sen (survey in 2022)

Fifty and fifty-one AgriSmart Eli seeders were donated by Prime Minister Hun Sen for distribution in each of Battambang and Banteay Meanchey provinces, respectively. In Battambang province, distribution was made to Agricultural Cooperatives (23), Rice Producer Groups (13) and NGO groups. Four units were retained by PDAFF. By June 2022, only one unit had been used. No training, demonstration or technical support was provided and the lack of use of these machines is not surprising.

In Banteay Meanchey province, the 51 Eli seeders were delivered to individual farmers, agricultural cooperatives (17), the private sector, NGOs and the public sector with 10 still in the PDAFF shed but with no or little training. Over the last 5 years, training was done by PDAFF, CAVAC, GIZ, Tonle Sap project and CamSID, but no training was done since these 51 Eli seeders were delivered. Only one unit had been used (see case study below

AgriSmart Eli seeder adoption case study in Banteay Meanchey (in 2022)

Mr Yann Sophon, 47 years old, is a leading farmer and head of farmer hub in Ouchrove district; he has joined CamSID project from beginning during 2016. At that time, he was a head of Samroung Meanchey agricultural cooperative (now known as Battrang Agricultural Cooperative). After five years working with CamSID, he became a hub manager with support of CamSID and SFSA; his cooperative plays both roles as agricultural cooperative and farmer hub with focus on rice seed production, seed seller, technical agronomic supporter, plant protection trainer, and service provider for planting. He received a machine broadcaster from BMC PDAFF five years ago, then he received a new Eli seeder from PDAFF for free (funded by Cambodian Prime Minister-CAVAC). Mr Yann Sophon has learned how to use the machine from Mr Nheb Khim (CamSID staff). According to Mr Yann Sophon, the function of the machine is not much different from old version which was first introduced by BB2C. The Eli seeder can plant better for wet seeding with good land preparation, and it was not useful for dry seeding. The demonstration was done many times but farmers are not attracted by this machine even though the price of planting did not exceed US$20/ha. Mr Yann Sophon has tested the Eli seeder for dry seeding; he said that the machine cannot put the rice seeds into the soil (not different from broadcast). The seed remains on the surface which is risky due to many issues including bird and rat predation, too hot surface, and the seed will die if there is no rain one month after planting. He expected that the Eli seeder can reduce seed rate by about 15 to 20% because it is hard to calibrate seed rate before or during planting operation, and the farmers have a low possibility of accessing seed quality. Since he got the Eli seeder, he has planted for 5 ha of seed production (wet seeding) and 15 ha dry seeding during early wet season. Since the Eli seeder needs more improvement, most of the machines delivered to community were not in used. Mr Yann Sophon said that Eli seeder needs to be improved in some points including seed rate calibration, reducing operating people from two people to one person, ability to put rice seed into the soil at a depth of about 3 cm, working for both dry and wet seeding method, and adding fertilizer and herbicide spraying function. When all these functions are improved, more farmers will adopt this machine. However, Mr Yann Sophon sometimes uses the Eli seeder and mechanized drum seeder for his seed production field. He is an outstanding leading farmer who provides all agronomic technical support to the community around his village. During two seasons of providing planting service to community, he suggested to improve some functions of the machine as follows: (1) the space between row and row need to be flexible (easy to calibrate), (2) the space between plant and plant; and the deep of seed in the soil need to be adjustable (the planning period during April is deeper and the planting during June is not too deep). A lot of these improvements have already been made in the new Eli seeder 3.0. However, ‘bad news travels faster than good news’ (Brown et al. 2021).

Status of the Kubota planter

There are no service providers for the Kubota planter, so a survey was not possible. The main barrier to scaling of the Kubota planter is that Kubota dealers, at least in Battambang, seem unwilling to display or promote it whereas broadcasting machines are being promoted. Neither the Kid nor the Kubota completely satisfy the needs of Cambodian rice planting conditions.

Microfinance and bank facilitation (for machinery purchase and farming)

There are several microfinance institutions and banks operating in Banteay Meanchey and Battambang province including Acleda, Hathakasekor, ABA, ARDB, Canadia, YLP and Prassac. Most of them provide loans on real estate, home loans and loans to small and medium enterprises (SME). There were only a small number of microfinance and banks such as ARDB, Canadia, Acleda, that provide small loans for agricultural investments; ARDB is a public bank providing funds for agriculture and they provide loans with mortgage; YLP is a new microfinance based in Thmor Pouk district which provide loans to smallholder farmers; they provide around US$250 without collateral and interest. CamSID has facilitated farmers to engage with this microfinance to get some loans for agriculture activity. As a result, several farmers received loans from microfinance and technical support from CamSID staff; Mr Chao Bunthoeun is a farmer in Thmor Pouk who received a loan from ARDB to buy a used Thai Kid seeder from Battambang for dry seeding service provision. He has planted for 240 ha during the four months operating between March and June 2022. With the effectiveness of Kid seeder, he committed to buy another Kid seeder machine next year. For equipment purchase such as solar pumps, AgroSolar has a financing arrangement with Chamroeun Microfinance – monthly interest rate is 1.35%. AgroSolar equipment requires loans up to US$5000 and term of the loan is 6-8 months. AgroSolar is interested in being an agent for the Eli seeder 3.0.

Financing options for the Kubota planter

Finance for Kubota tractors, combine harvesters and implements in Cambodia is provided by Kubota Leasing (Cambodia) Plc. (KLC). The tractor most commonly purchased in Battambang is the M-6040 (60 hp) and the most popular tractor less than 60 hp is the L-5018 (50 hp). The most common type of purchase is a set including the tractor, front blade, disc plough and rotavator. For the M-6040 tractor the cost of the set is US$33,000 and for the L-5018, the cost of the set is US$25,000. This can vary according to the THB-USD exchange rate. The minimum loan deposit is 30%, the term of the loan is up to four years and interest rates range from 0.90% to 1.25% per month depending on the terms. Interest payments are monthly with the first six months being interest-free (currently). Principal repayments can be monthly, quarterly or half-yearly. Most commonly, principal repayments are made half-yearly. Most loans are taken out over four years but most loans are repaid in two years or less for tractors and one year or less for combine harvesters. The purchase price for the M-6040 tractor without a front blade is US$29,300. The purchase price for the disc plough without the tractor is US$1,600 and US$2,100 for the rotavator. The loan collateral conditions do not include land title but require a scan of the Family Book, ID Card and a Guarantor who is usually another family member or neighbour. The success rate of KLC loans is 70% and the default rate is 1-2%. The purchase price for the Kubota planter in Battambang was $2,150 in 2020. The decision about what implements are included in the purchase set is made at Kubota headquarters in Thailand. The Kubota planter is designed for the L-series tractors but is not advertised in Cambodia.

7.7.3 Engagement with PDAFF and input sellers

PDAFF survey of input suppliers in BMC and BTB

The average number of staff was two with a maximum of six and 43% were female. Sixty percent of employees had attended training courses or had agriculture technical skills. However, 79% of males received training and only 36% of females had received training.

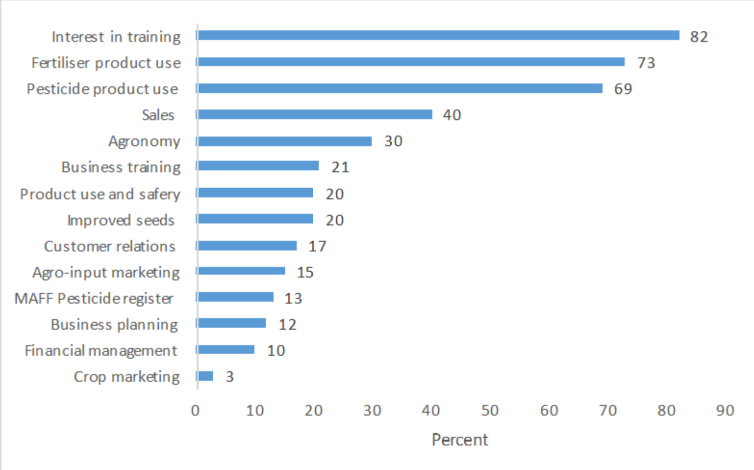


Figure 83. Training needs of agri-businesses

Eighty-two percent of businesses indicated an interest in training (Figure 83). The predominant training needs of agri-businesses were fertiliser product use (73%) and crop protection product use (69%). Input sellers receive some support from suppliers for field days and farmer meetings but lack technical materials and technical visits. The technical resources preferred by agri-businesses were in the order of posters > banners > leaflets. Videos and phone apps were not seen as useful.

Fertilisers

A wider range of fertilisers were on sale in Battambang compared to Banteay Meanchey (Table 50). Urea and DAP were by far the most commonly sold fertilisers in both provinces.

Table 50. Fertiliser prices and tonnes sold in Banteay Meanchey (BMC) and Battambang (BAT)

	Price (USD/t)			Tonnes sold in 2018		
Fertiliser	BMC	BAT	Average	BMC	BAT	Total
Urea	422	418	420	2,994	1,983	4,977
DAP	558	520	539	1,034	867	1,901
15.15.15	501	499	500	121	485	606
20.20.15	516	642	579	345	248	592
Kali	467	429	448	325	181	506
27.12.06	533	534	533	20	313	333
16.20.00	468	460	464	2	186	188
21.07.16		552	552		133	133
20.08.20	563	536	549	5	113	118

N P K (unspecified)		516	516		31	31
14.07.35		515	515		30	30
Natural		413	413		29	29
15-5-25	558		558	10		10
21.04.21		560	560		10	10

Constraints to selling agri-inputs

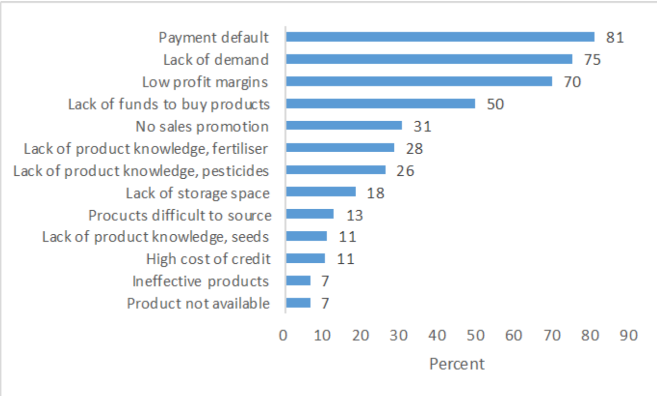


Figure 84. Constraints to the selling of agri-inputs.

The main constraints in agri-businesses are financial with farmer defaults on payment being the biggest problem (Figure 84). Lack of demand, low profit margins and lack of funds to buy products also important.

Advice sought by farmers and given by input sellers

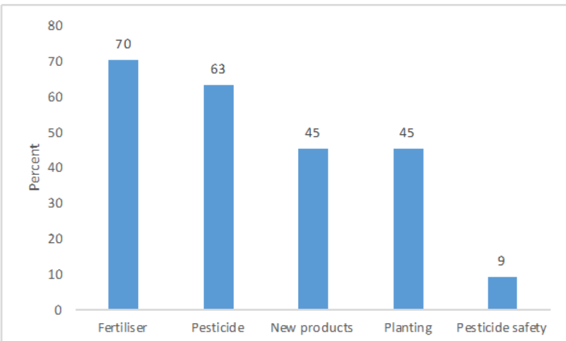


Figure 85. Advice sought by farmers from input sellers

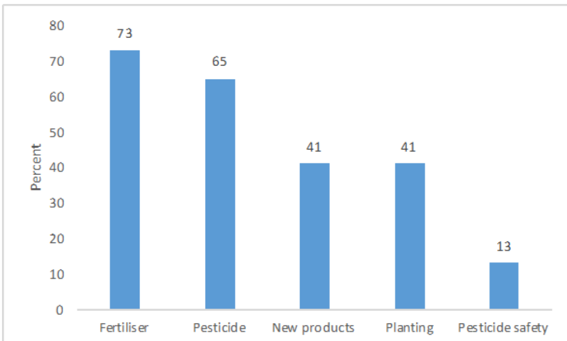


Figure 86. Advice provided to farmers by input sellers

Farmers are most likely to seek advice from input sellers on the use of fertilisers and pesticides (Figure 85). They were interested in advice on planting techniques and new products. Few farmers were interested in pesticide use safety and none were interested in financial management advice. The advice provided by input sellers was in the same proportion (Figure 86).

Eighty-two percent of businesses indicated an interest in training. The predominant training needs of agri-businesses were fertiliser product use (73%) and crop protection product use (69%). Previously, 79% of males received training and only 36% of females had received training. Therefore, future training should seek to improve the gender balance.

These results are consistent with a survey in Myanmar where a major constraint for agri-input sellers is the lack of product knowledge and capacity to provide advice to farmers.

Dealers in Myanmar recognised their lack of product knowledge, and 80-100% of all medium and large dealers requested training for use of fertilizers and pesticides.

Unlike Myanmar, there was not a strong desire to receive training in agro-input marketing and business management in NW Cambodia. This was despite the main constraints in agri-businesses claimed to be financial with farmer defaults on payment being the biggest problem. Lack of demand, low profit margins and lack of funds to buy products were also important.

CamSID project concentrated on the large- and medium-sized agri-input sellers in the target provinces. The focus can be narrowed by selecting dealers with the largest number of sub-dealers. There are four businesses with 10 or more sub-dealers in both Banteay Meanchey and Battambang. The survey sample of 179 dealers can be used to assess the capacity of agro-dealers to provide factual technical and economic information to their farmer customers and develop and test technical training program for fertiliser and pesticide input sellers.

Potential for delivery of CamSID outputs through the input supply chain

The distribution channels for fertilisers and pesticides in Cambodia are relatively simple in the absence of manufacture of fertilisers or pesticides in Cambodia (Figure 87). Future work should include case studies of one key importer for pesticides (Jebsen & Jessen (Cambodia) Co Ltd) and one key importer for fertilisers (Ye Tak Group Ltd) to map their distribution networks; facilitate the import of IPM/SSNM products; and identify opportunities to introduce CamSID technologies to their technical staff.

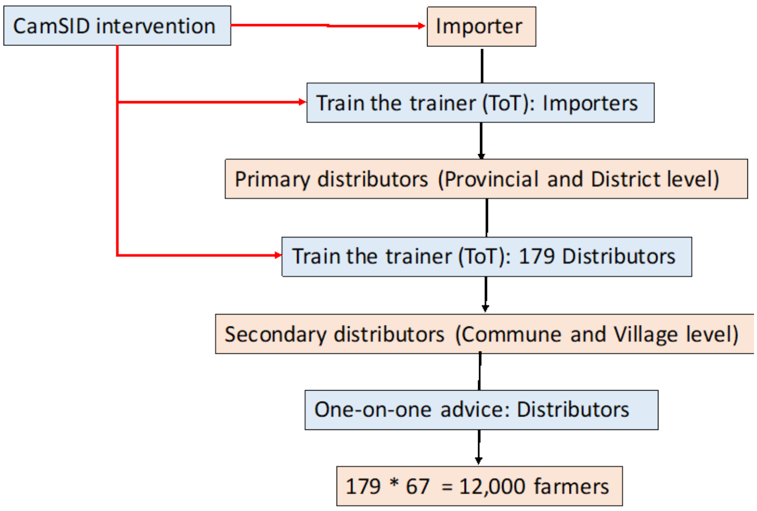


Figure 87. Generalised distribution chain for fertilisers and pesticides in Cambodia.

Training and training resources

Areas of training recommended include product knowledge, especially for fertilizers and pesticides, and agro-input marketing and business management. Where possible training should start with dealers and then follow up with both dealers and farmers in joint training sessions.

Development of training resources for input sellers is complicated by the large choice of fertilisers, herbicides, insecticides and fungicides on offer with 1,376 products from at least 80 companies are listed in the 2016 Cambodian national pesticide register. Most pesticides are imported from Vietnam (50%), China (25%) and Thailand (16%) (Figure 88).

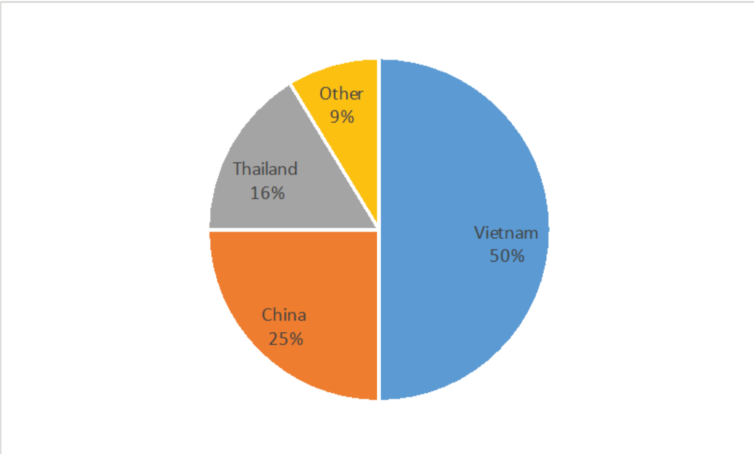


Figure 88. Sources of pesticide imports into Cambodia.

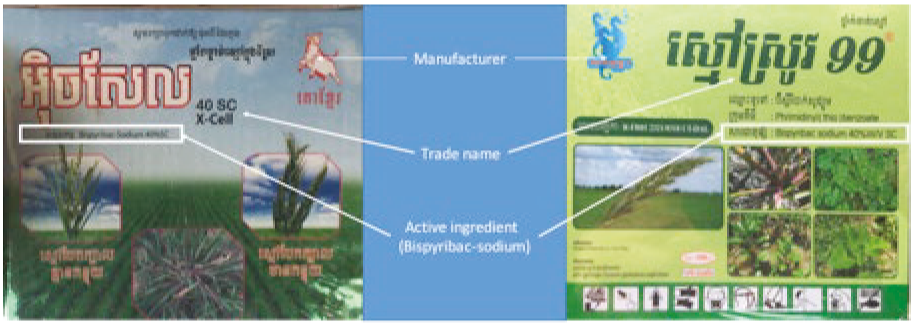


Figure 89. Extension providers, input sellers and farmers need to clearly understand pesticide labels

It is a requirement of Cambodian pesticide legislation that all pesticide labels are printed in Khmer language. However, most input sellers and farmers do not understand how to read the pesticide label, even in Khmer. The products pictured in Figure 89both contain the active ingredient bispyribac-sodium 40% w/v SC which is only printed in English. Input sellers and farmers are not likely to be able to read this and generally refer to the trade name or manufacturer's name and this does not convey details of the active ingredient. It is also important to know the concentration of active ingredient (e.g., 40% w/v) as this determines the rate of application.

Another problem is that the biochemical mode of action (MoA) group is not printed on the label and this makes it difficult for farmers to implement rotation of pesticides to avoid development of pesticide resistance. Proposed training on pesticides include:

- Safe and effective use of pesticides;
- IPM options for rice, field crops and vegetables;
- SSNM, appropriate fertilisers, rates and timing.

Engagement with PDAFF to include CamSID outputs into existing 5-day Input Seller Certificate Course

A technical meeting on selecting CamSID findings for adding into input seller training was conducted on 19th June 2020. The meeting was attended by the MCU team and Bob Martin plus two representatives from PDAFF-BTB Mr Chim Dararoth and PDAFF-BMC Mr Ngoeun Ratannak. The meeting started with a discussion on the result of input seller survey which was completed by PDAFF BTB and BMC. Based on input seller survey, the meeting defined the suitable CamSID findings for including into input seller training materials. Both BMC and BTB teams agreed to share responsibilities for preparing teaching material as tools for input seller training. CamSID provided training to Banteay Meanchey and Battambang PDAFF staff to include relevant project outputs into training for agricultural input sellers. Presentations were made on management of wet-seeded rice; site-specific nutrient management (SSNM); and integrated pest management (IPM) in rice and mungbean (Figure 90). For SSNM, the key message is rice farmers are under-applying fertiliser N and K. NPK fertilisers are strongly promoted by input sellers but are not recommended by Government. Both P and K should be applied at or near sowing and NPK fertilisers should not be used for topdressing. N-topdressing rates at panicle initiation can be adjusted up or down to match crop needs using SSNM (Leaf Colour Chart or GreenSeeker NDVI).

Figure90. **CamSID training of Banteay and Battambang PDAFF staff at Battambang on 22 December 2020**

Application of post-emergence herbicides is risky for rice crops dry-sown in May because application can be delayed if there is no rain after sowing before irrigation water arrives in July. Application of post-sowing pre-emergence herbicides such as pretilachlor for wet seeding and butachlor or oxadiazon for dry seeding can improve weed control and reduce the risk of herbicide failure. This should be accompanied by Integrated Weed Management to reduce over-reliance on herbicides.

Despite 20 years of effort, Integrated Pest Management (IPM) has not been adopted in Cambodia and farmers have become increasingly over-reliant on calendar-based application of broad-spectrum non-selective pesticides, especially for control of insect pests. Overuse of insecticides is less of a problem in rice compared to mungbean where mis-use has led to uncontrollable outbreaks of secondary pests such as thrips and aphids. Appropriate alternative bio-pesticides are registered and sticky traps are commercially available. There are emerging business opportunities for these products if the input sector does not respond to the demand. The PDAFF staff completed feedback questionnaires on the CamSID presentations and this information will be used to improve the presentation format for the input sellers.

CamSID direct engagement with input suppliers

Training agricultural companies is key for scaling out the CamSID results. The three companies interested in adopting CamSID results are: Five Star Co.ltd (selling fertilizer), Dong Xanh Co.Ltd (Chemicals plant protection) and Agreebee Cambodia plc (selling agricultural inputs) (Figure 91). Six pages of rice production technical packages were used for private company training. An early approach was to introduce our CamSID findings to the respective directors of each company, explain to them about the effectiveness of technical packages and the benefit to their business. These three companies have adopted the technical packages produced by CamSID for train their technical staffs who work directly with input sellers, leading farmers, small holder farmers, and agricultural extension staff. **The three agricultural companies have trained their staff in using CamSID technical packages and produced 20,000 leaflets for sharing to leading farmers and input sellers.** The companies still keep in touch with our project staff when they need support.

Figure 91. Lunch meeting with Directors of agricultural input companies

7.8 Capacity building

8a. Farmer training field school

Integrated farmer innovation platform activity including large scale farmer school field demonstrations (5 ha) in collaboration with PDAFF with more than 200 smallholder farmers invited, training of input sellers, lead farmers, BMC PDAFF agricultural extension centre, with a pilot village radio communication system (Figure 92). Training materials were based on CamSID technologies developed. Village radio communications system was piloted to villages (e.g., Battrang and Kuok Tonloap) where large scale farmer school field demonstrations (with PDAFF) are conducted and evaluated by recording number of farmers who have called agricultural advisors for assistance. The pilot set of the trilogy (set of three consecutive) field demonstrations at planting, maximum tillering and harvest in four villages in Banteay Meanchey Province (Batrong, Spean Sraeng, Boslouk and Kouk Tonloap villages). For example, at Battang Village, Mr Yann Sophon, who is a leading farmer and the hub owner for seed production at Battrang, was selected as key adoption farmer for CamSID findings (Figure 93). Sen Kra Oub Variety was used for demonstration. The rice production demonstration was held on 29th May 2019; the second field day was held on 17 August 2019 and the third demonstration was organized on 5th November 2019. A set of questionnaires was used for farmer interviewing after presentation on CamSID techniques ended. The number of farmers participated the three field days was 150, 160 and 200, respectively. The proportion of farmer who intend to adopt seed treatment was 42% at the first field day; then increased up to 60% during the second field day and increased further during the third field day to 81% (Figure 94). Other CamSID findings including reduced seed rate, basal fertilizer application, pre-emergence herbicide application, checking disease symptoms before spraying fungicides, and checking insect pest before insecticide spraying increased when they joined the following two field days. When farmers joined the field days from sowing to harvesting, they can see all agronomic techniques in practical implementation and feel more confident in all techniques we did in the field.

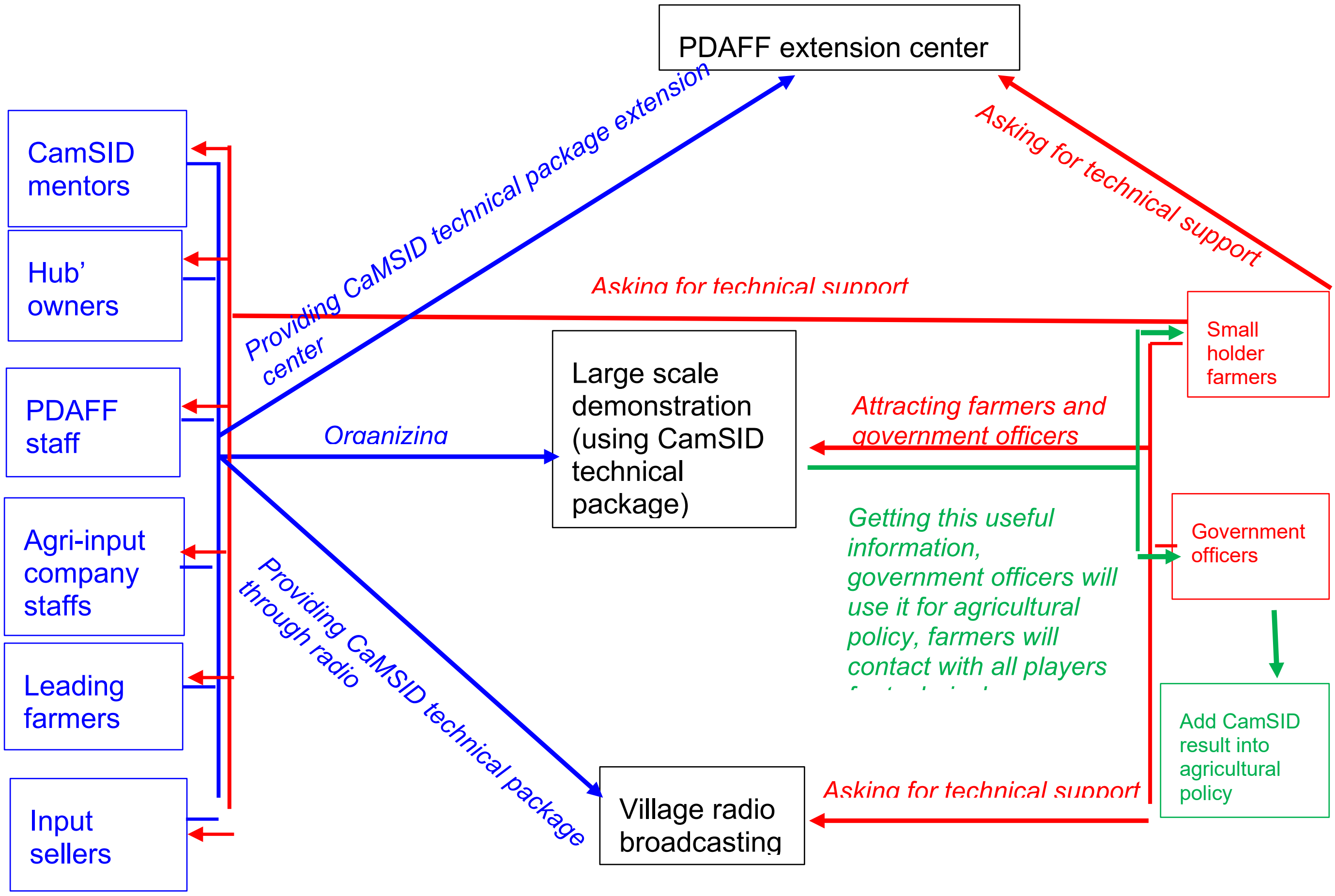


Figure 92. Farmer training school through innovation platform (Credit: Y. Try)

Figure 93. Field day activity at Bottrang Village

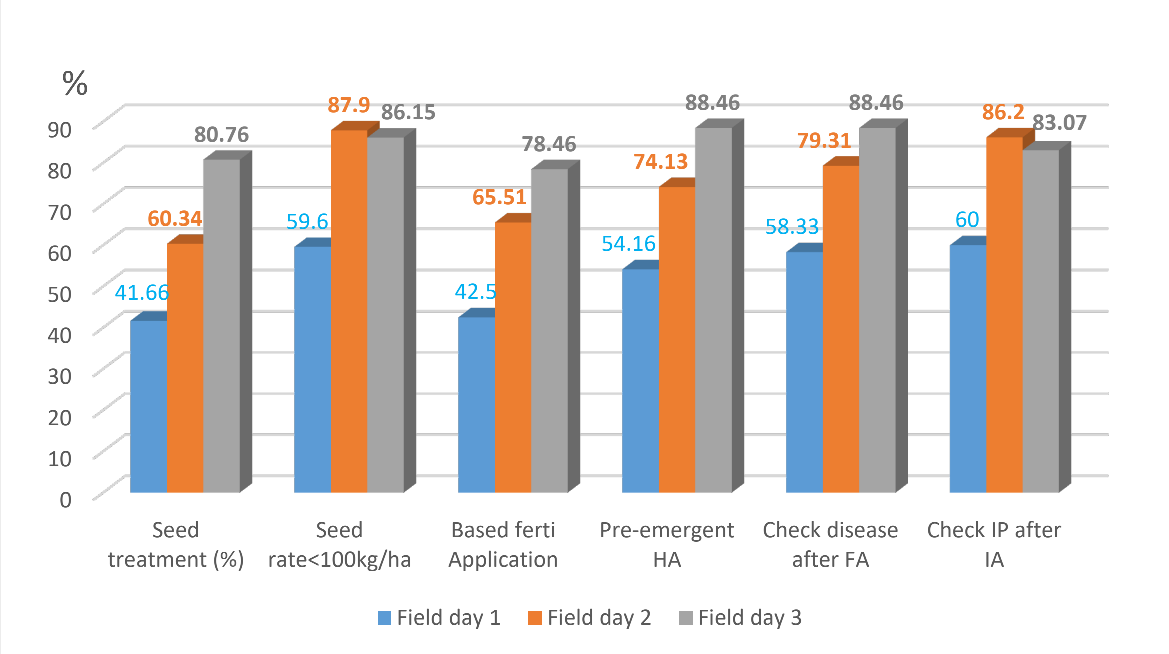


Figure 94. Proportion of attendees to the three consecutive field days who we surveyed (out of 150, 160, 200 numbers surveyed, respectively) who intend to adopt CamSID findings. The field days were held at Battrang Village in 2019.

Post-COVID-19 (2020) farmer training

Leading farmer training

Leading farmer training on dry seeding was conducted during early wet season from April to the end of June 2020. The project staff played a role as trainers for rice production techniques by coordinating with the chief of commune in collaborating with the village head in target villages (Boslouk-Mungkul Borei district, Kouk Tonlaop- Mungkul Borei district, Botrong-Ochrouv ditrict, and Spean Sraeng-Phnom Srok district). Besides these three target villages, the project also did the leading farmer training in other non-target villages including Preah Ang village-Sisophon city, Koh Pongsat village-Sisophon city, Tapeang Thmar village-Phnom Srok district, Pro Huot village-Sisophon city, Kampong Reap village Ochrouv district, Ta In Muoy village-Mungkul Borei district, Po Pir Deum village-Mungkul Borei district (Figure 95).

Figure 95. Farmer training activity at Kouk Tonlaop Village (post-COVID-19) in 2020

Teaching material were prepared by project staff from CamSID findings including planting methods (dry seeding and wet seeding), pre-emergent herbicides and post-emergent herbicide application, insect and disease management methods, seeding rate application, and seed treatment. Due to government regulations on COVID-19, the training groups were organised in small groups with 5 to 10 leading farmers. All participants sat with social distancing and wearing masks to in accordance with the government regulation. Altogether, 77 leading farmers, of which 57 are male and 20 are female, in BMC were trained in CamSID results (rice production technical packages) (Table 51). In 2021, there was also limited farmer training provided at Kouk Tonlaop and Battrang villages.

Table 51. Summary table of leading farmer training by village, commune, district, and participating farmers

No.	Village	Commune	District	Farmer	M	F	Date
1	Battrang	Samroang	Ou Chrov	4	4	0	20/4/2020
2	Spean	Spean Sraeng	Phnum Srok	8	1	7	22/4/2020
3	Kouk Tonloap	Banteay Neang	Mongkol Borei	5	5	0	30/4/2020
4	Bosloak	Soeu	Mongkol Borei	5	4	2	4/5/2020
5	Bat Trang	Samroang	Ou Chrov	5	4	1	8/5/2020
6	Preah Ang	Koh Pongsatv	Serei Soaphaon	5	5	0	20/5/2020
7	Kouk Tonloap	Banteay Neang	Mongkol Borei	6	6	0	25/5/2020
8	Bosloak	Soeu	Mongkol Borei	7	5	2	26/5/2020
9	Koh Pongsatv	Koh Pongsatv	Serei Soaphaon	4	3	1	2/6/2020
10	Cham Noam Lech	Cham Noam	Mongkoln Borei	7	6	1	4/6/2020
11	Trapean Thmar Kandal	Paoy Char	Phnum Srok	4	2	2	8/6/2020
12	Pro Hout	Ou Ambel	Serei Soaphaon	4	3	2	11/6/2020
13	Kompong Reab	Samroang	Ou Chrov	4	2	2	15/6/2020
14	Ta In Mouy	Sras Reang	Mongkol Borei	4	2	1	17/6/2020
15	Por Pi Deum	Rohat Teok	Mongkol Borei	4	4	0	22/6/2020
16	Banteay Neng	Banteay Neng	Mongkol Borei	6	4	2	01/08/2021
17	Roung Kou Kandal	Chamnaong	Mongkol Borei	5	2	3	20/01/2021
18	Thumei	Samroang	Ou Chrov	7	4	3	04/02/2021
19	Thumen Trei	Samroang	Ou Chrov	6	3	3	24/02/2021
20	Kandal	Samroang	Ou Chrov	5	4	1	03/05/2021
21	Svay Dangkot	Koah Pong Satv	Serie Saophoan	6	4	2	17/03/2021
22	Srah Chik	Srah Chik	Phnum Srok	8	4	4	30/03/2021
23	Pongro	Spean Sraeng	Phnum Srok	7	3	4	04/05/2021
24	Rohat Tuek	Rohat Tuek	Mongkol Borei	10	8	2	20/04/2021

25	Bour	Soea	Mongkol Borei	9	5	4	29/04/2021
Total				***146***	***98***	***48***	

Leading farmer training in Pursat Province with CARDI Dry seed drill

The average rice grain yield for seeding rate was 3,530 kg/ha and 4,060 kg/ha for seeding rate 60-80 kg/ha at Pursat, however the demonstration on 2 ha in Battambang province was destroyed by flooding from 15-30 October 2020.

8b Curriculum development

University curriculum development

UNICAM is an abbreviation of project title on “Implementing quality of education & training of the Young UNIversities in rural area of CAMbodia”. UNICAM is co-funded by the European Union under the Erasmus+ Program for the action Capacity-Building in Higher Education (CBHE). The main objective of the project is to enhance higher-education quality and develop human resources and build university capacity through implementing comprehensive curriculum for a Master´s program in Sustainable Agriculture (MSA), and advanced training courses at young universities in the rural areas of Cambodia.

In the latter part of 2019, Drs Yorn Try and Bob Martin were invited prepare course materials and deliver the MSA unit on Integrated Pest Management (MSA207). There were 15 Masters students in the 2019-2020 class including CamSID project staff Ms Seyma Ngan, Mr Chhan Tekhong and Mr Khim Nheb and Mr Oung Bora (Don Bosco). Ratha Rien, Sophea Yous and Sokunroth Chhun completed the MSA course work in 2018. Bob and Try also supervised the thesis component of their MSA. Ratha has based his thesis on the CamSID project activity on weed seed contamination of rice paddy and Sophea has based her thesis work on the CamSID mungbean varietal evaluation in 2018.

Both Penn State University and the University of Sydney are partners in the new World Bank funded Higher Education Improvement Project ($5 million over 5 years) to build capacity for the National University of Battambang’s horticulture and agroecology curriculum during 2021 to 2023.

High school curriculum development

On 12 December 2020, BMC team (Dr Yorn Try and Mr Nheb Khim) met with the management team of Xavier Jesuit School Cambodia to add CamSID findings into agriculture curriculum for Grades 7, 8, 9, 10, 11, and 12 (high school). The purpose of this meeting with BMC team was to incorporate CamSID results into the agriculture curriculum; this was adopted by the school management team. The agricultural subjects will include rice production techniques, vegetable growing techniques (e.g., watermelon), fish raising techniques, frog raising techniques, Agroecology (Integrated Pest Management, IPM), and beekeeping techniques. In addition, the scaling will not only focus on school students but also focus on the parents of the students. The school management team has gathered farming parents of students as a farmer group and organised a demonstration for rice growing techniques and other agricultural subjects. This work is being organised by the school. Mr Khim, Seyma, and Hong have been appointed by the school as part time agricultural mentors for students from 2022 onwards. These three mentors are responsible for preparing detailed agricultural syllabus for those subjects in collaboration with the school staff.

i. Crawford Fund training in 2016 and 2019

2016 Crawford Fund rice production systems training in Cambodia

A Crawford Fund (CF) training activity organised jointly between our project team and the Crawford Fund, was held in Banteay Meanchey and Battambang provinces from 16th October to 1st November 2016. The course was designed by SFSA's Clive Murray, working closely with Dr Yorn Try, then NMCU's Vice-Rector. Trainers came from Cambodian and Vietnamese research and education institutions, CropLife Asia (part of a global federation of agribusinesses) as well as USYD and SFSA. The trainees were mostly young graduate employees of government research institutes and extension services, NGOs and private-sector input suppliers; a few of the latter attended at their own expense. Training was conducted in English and Khmer, and copies of the presentations were distributed on USB drives. The feedback from the trainees about all the trainers was uniformly positive; almost all trainees said the course would help them in their job of transferring technology to farmers and that they would attend again if offered the chance. Many wished the course had been longer and more detailed; a few had had problems of language comprehension, including the sole trainee from Laos.

2019 Crawford fund value chain master class training in Cambodia

Crawford training 2019 was a series of 'master classes' in marketing offered by Professor Peter Batt and held in Sisophon 21st - 25th October. These master classes focused on the fresh produce mainly vegetables. There were 18 participants from educational institutions (i.e. National Meanchey University, NMCU in Sisophon, Bakong Technical College in Siem Reap, Polytechnic Institute of Preah Sihanouk Province, Battambang University, Regional Polytechnic Techno Sen BTB in BTB), the Provincial Department of Agriculture, Forestry and Fisheries (BTB), and from CAMSID's partner, Ockenden Cambodia. Topics covered in the master class included: Introduction to marketing, Business-to-business marketing, Product quality, Pricing, Distribution, Direct marketing, Collaborative marketing groups, Value chains, Mapping value chains, Analysing value chains, Marketing strategies.

At the start and at the end of the master classes, Dr Try carried out an evaluation of participants' perceived levels of understanding of the course content (Introduction to marketing, Business-to-business marketing, Product quality, Pricing, Distribution, Direct marketing, Collaborative marketing groups, Value chains, Mapping value chains, Analysing value chains, Marketing strategies) using a 1 (0%: I have not heard about this topic) - 6 (100% *I am becoming expert on this topic)* rating scale. At the start of the course the average perceived level of knowledge of participants was between 1 - 2 (~ 10%); at the end of the course, participants perceived their levels of knowledge were around 4 - 5 or ~ 70%).

The key concepts that were explored and reinforced over the 5-day series of Master classes included: customer is 'the boss'; 4Ps - product, price, promotion, people - the latter included as respectful relationships and social interactions are the core of good business practices; critical role of trust and the time investment required to build trust and the role here of having shared values; what is 'marketing'?; markets are dynamic; notion of market segments (geographic, demographic, psychographic, behavioural); notions of 'market horizon' and network theory - i.e. that each 'actor' has a different view of the supply chain with respect to their perspective and how far along value chain they see; product quality and safety, and the costs associated with quality management; notion of products having 'credence attributes' e.g. 'fair trade'; product pricing, e.g. 'floor price' is the breakeven price; the basics of market analysis.

Each day started with participants sharing the marketing knowledge that had been consolidated form the previous day's content (i.e. their 'take home messages'), the detail of these daily reflections being an indication of the level of engagement of the participants. Examples of Day 1 'take home messages' included:

- awareness of the “4Ps”: product, price, promotion, place - an addition “P”, people noting that market places are places of social interaction.
- Understanding the differences between ‘supply chains’, which focuses on the role(s) on the ‘actors’ in the chain; and ‘value chains’, which focus on the costs.
- The critical place of the customer in the process, the customer is the boss. This leads to: Who are the customers?; how are purchasing decisions made?
- Connectivity of players in the supply chain - e.g., farmers understanding(s) of what the customer wants
- The notion of business-to-business interactions and the critical role of trust in these interactions
- The distinctions between business-to-business interactions and business-to-consumer interactions
- Quality of product: the notion that product quality is contextual e.g., the best quality meat and vegetable produce is used differently to lower quality produce.

On Day 4, there was an early excursion (3 am) to the local market so that participants could observe and ask questions of those engaging in business-to-business transactions prior to the market opening to the public. Questions included what the buying/selling prices were, produce country of origin. Later that day, participants were able to interview a local farmer and a wholesaler. Participant perceptions of the farmer’s interview: the farmer is clever in that he sells to a wholesaler but also keeps 25% of his produce for the local market, there are no laws to protect against non-payment so, for him, trust is critical, the farmer has a vision for his business and wants to improve, he is an expert in growing but to mitigate risks he has a view to build a glasshouse, the farmer’s profit margins are very small, he is keen to learn more. Participant perceptions of the wholesaler interview: he works with his farmers to direct which products are in demand and to grow these; fairness is important, he is always looking to satisfy demand including looking for new producers, he has been working with some producers for 14 years (20 regulars, up to 80 in total), he operates across BMC and Siem Reap, he is also a distributer. Both the farmer and the trader are keen to learn more about marketing. Throughout the classes, participants were keen to learn and many expressed the desire to teach marketing to their students. The inclusion of a) the excursion to talk with traders and those on market stall, and b) the opportunity to sit and talk with a farmer and a wholesaler using questions targeted to improve participants understandings of how markets work, was impactful and led to participants at educational institutions thinking about how to connect their students with similar learning experiences. Devising mechanisms to support the coming together of a community of practice across educational institutions (academics and students), market traders/wholesalers, farmers would allow students and academics to get practical knowledge of their local supply chains.

ii) IAT/APSIM (CLEMS) Training in Sydney

Dr Van Touch, Sophea Yous, Rebecca Cross and other CamSID team members were trained in IAT (Integrated Analysis Tool) and APSIM Next Generation (CLEMS) in Sydney during 17th to 18th November 2019 by Cam McDonald. Dr Van Touch and Sophea Yous planned return to Cambodia to train the rest of the CamSID team on IAT/CLEMS in a workshop in 2020 (but this was postponed due to the COVID-19 pandemic).

iii) Capacity building in curriculum with infrastructure upgrade

Soil capacity building workshop

In 2014, the Yunnan Agricultural University and Agricultural Department of Yunnan Province, China donated a series of soil analysing equipment with a total investment of half million US$, set up the soil analyzing lab in National Meanchey University (NMCU), all the equipment were made in China, with manual all in Chinese. Prof. Renzhi Zhang and Prof. Lingling Li of Gansu Agricultural University visited MCU December 2017, together with Dr. Try, raised an idea to organize a workshop on soil chemical analyzing to enable NMCU to develop a soil analyzing lab, and made a start on revising curriculum for Agronomy in NMCU. The workshop was then carried out by Professors Renzhi Zhang, Lingling Li and Liqun Cai in February 2018. Over thirteen staff from MCU and UBB were trained in soil sampling and handling, analysis techniques for soil total N, P, K, available N, P, K and soil organic carbon. A soil analysis manual and curriculum for soil science is also being developed.

Capacity building on data output from weather station at NMCU

National Meanchey University has updating their strategic plan which focusses on research activity; the faculty of agriculture and food processing is developing research work on agriculture; a weather station is a very important tool to ensure the availability of climatic data for agricultural research (Figure 96). CamSID project has provided an automatic weather station for recording abiotic factors including rainfall, wind speed, humidity, temperature and maximum and minimum air temperature. This data will significantly contribute to the quality of research in the field of agriculture; and students can access to get all related weather data from this weblink (https://hobolink.com/p/6afae7a9746d6b909f05e669b9d7c05e). This equipment was set on 11th May 2019 with help from Mr An Kim Heng who is an expert from Royal University of Agriculture (RUA). Then he was invited by Dr Yorn Try to train NMCU students and NMCU staff on how to download data from the weblink to support research work.

Figure 96. Weather station installation at National Meanchey University (NMCU)

The objective of this training was to provide guidelines for downloading weather data from the website and to use that data for research purposes.

The training course was organized by Mr An Kim Heng on 08 October 2019 with coordination by Dr Yorn Try; a total of 30 trainees with 5 lecturers have joined the training courses. Mr An Kim Heng has explained all terminologies used in the climate parameters and trained the students and staff on the methods of downloading data from the website. He also taught the purpose of using all types of data. After the course was completed, the students and staff still keep communicating with Mr An Kim Heng when they needed more explanation about the climate data downloading from the Cloud.

The 30 trainees got trained from Mr An Kim Heng on climate data downloading and obtained knowledge on how to get data from the cloud. Students will download climate data from cloud and include this in their data analyses in their theses; and this climate data could give their theses more rigour. Students no longer need to pay any money to obtain this weather data (they used to pay money to obtain this data from the Department of Water Resources). Importantly, any research proposals will use this local climate data to make the result more scientific.

8c. Information tools

i. Mobile Apps

Mungbean Pest-ID app

https://apps.apple.com/au/app/pest-id/id1328731895

https://appadvice.com/app/pest-id/1328731895

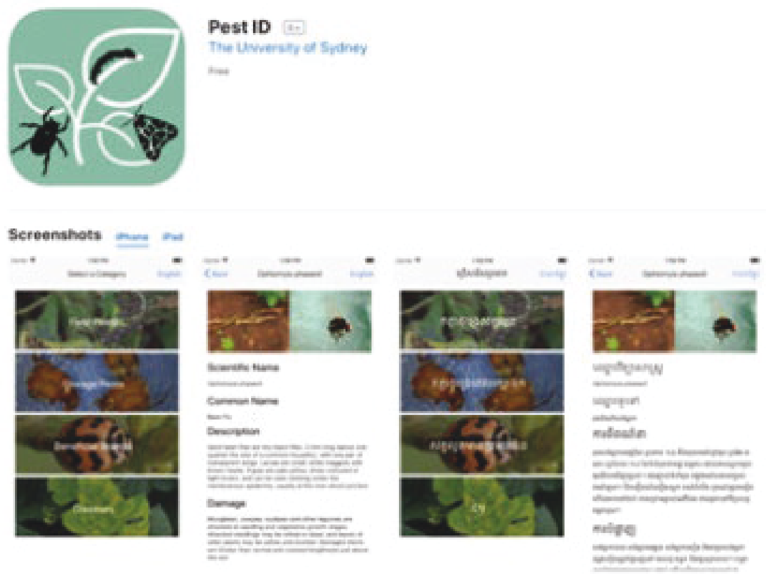


Figure 97. Mungbean insect pest identification App

This study, led by University of Sydney honours student Isabel Hinchcliffe, evaluated the feasibility of the Pest-ID App through a survey with potential users and these responses were incorporated into developing the Insect Pest ID App prototype, which was trialled with farmers and subsequently refined (Figure 97). The App also has a voice-over feature in Khmer. The Insect Pest ID App has been well received by farmers with users seeing its potential to support crop management decisions. The App has been downloaded 1,147 times on iOS and 727 times on Android.

Weed-ID app

https://apps.apple.com/us/app/weed-identifier/id1165963850

https://play.google.com/store/apps/details?id=com.usyd.weedidfree&hl=en&gl=US

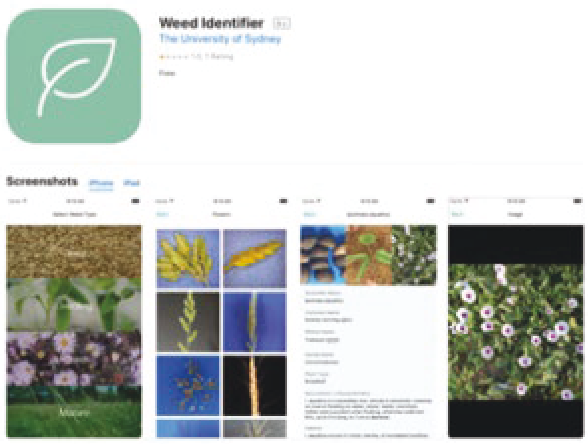


Figure 98. Rice weed identification App

A mobile phone app is helping Cambodian rice farmers manage weeds at various stages of rice production, and will ultimately improve yields, increase financial gains and build knowledge of crop management in farming communities (Figure 98). WeedID for iOS and WeedID for android, developed by Master of Agriculture and Environment student, Yehezkiel Henson and a small team of researchers, has been patented, and is already in use in Cambodia. Weed-ID contains a photo dictionary of the most common weeds in northwest Cambodian rice fields at different stages of growth. The app has images of seeds, seedlings, mature plants and flowers that will all help to identify the most important weeds in rice.

Smartphone networks (Telegram) linking farmers with technical experts for problem identification, diagnosis and advice

An FM radio talk-back program was piloted in Battambang province between October and December 2016. Almost no farmers called into the radio programs during the talk-back sessions. It was therefore decided that the programs should be discontinued until further study of communication preferences of farmers was completed. A subsequent survey of CamSID target villages revealed that only 12% of farmers relied on radio for technical information. Therefore, CamSID Battambang has explored other options to overcome barriers to the flow of information to communities beyond the project target groups. The CamSID Battambang team has been delivering training workshops and technical advice to the Catholic Mission SRDP project in Ta Haen Muoy village in Sangkae district. SRDP monitors around 60 ha of rice, upland crop, forage and fruit tree fields. SRDP staff monitor and report on crops on a weekly basis. In November 2020, SRDP set up a Telegram group to bring together SRDP field workers with CamSID technical advisers where field workers submit photos of pest damage and crop disorders to the group for diagnosis and advice. The SRDP Telegram group has been successful in providing timely advice as well as reducing the need for field visits and is not impacted by COVID precautions. CamSID Battambang has now established Telegram groups with its eight key collaborating Agricultural Cooperatives in Battambang province.

Radio broadcasting evaluation and podcast

Radio broadcasting evaluation was conducted by the appropriate method which designed by University of Sydney expert (Dr Rebecca Cross) in collaboration with BMC team (Dr Yorn Try, Mr Nheb Khim, Mr Chhan Tekhong, and Ms Ngann Seyma). After 10 months of radio broadcasting in the target villages (Battrang, Kouk Tolaop, Boslouk, and Spean Sreang), the evaluation was completed on 15th December 2020 by interviewing 40 respondents from the four target villages. For this semi-final report, we provide a preliminary report and detail information and impact will be elaborated in the final report.

Among the 40 respondents, there were 67.5% male and 30.5% female and they were head of household in the family; the age distribution of respondents ranged from 27 to 70 years old. With regards to crop diversification, 52.5% were rice farmers and 47.5% were rice and vegetable farmers. There were 92.5% farmers who owned their own land and less than 8% hired the land from someone. The land size ranges from 1 to 3 ha. 12.5% of the respondents have been listening to our radio broadcasting and they are all leading farmers in the village. The other 87.5% did not listen to our radio program with different reasons as follows:

1-Do not have radio and smart phone

2-They have smart phone but do not know how to download the app

3-The time broadcasting is too early

4-They did not know about the broadcasting program

Hence, we may need to do more promotion of the podcasts in villages with village meetings where field staff show farmers and their tech savvy kids how to access the podcasts using smartphones. Podcasts of the radio broadcasts are now available at https://anchor.fm/camsid. Analytics i.e., numbers of times each podcast has been accessed and from where, will be collected throughout 2021.

8d. Policy and extension briefs

Policy brief on adaptation to climate change

Drs Try and Van have submitted a policy brief to the Ministry of Environment on adaptation to climate change on March 2019. The policy brief is entitled, “Building adaptive capacity to warmer temperatures and fluctuations in rainfall patterns in northwest Cambodia. The recommendations are that the government should: (1) Invest more funding in farming technology and mechanisation research and provide subsidies to agricultural machinery services contractors, (2) allocate funding and necessary resources to develop and improve standardised low-cost machinery required for conservation agriculture and subsidise local manufacturers to produce low-cost equipment and machinery for expansion of conservation agriculture, (3) Assess specific local conditions and potential risks before investing in water storage capacity and irrigation – that include changes in water availability, water scarcity, water quality and other risks from extreme climate events; and (4) Invest in plant breeding programmes to develop new crops and varieties that are more resistant to biotic stressors (pests and diseases) and increase tolerance to abiotic stressors (nutrients, water, temperature) while maintaining and enhancing yield increase.

Quality Declared Seed (QDS) manual for CAVAC and GDA

Dr Bob Martin drafted a Mungbean Quality Declared Seed (QDS) document, entitled, “Commercialisation of mungbean varieties in Cambodia” for implementation by CAVAC and GDA. The document included the (1) general seed certification system for mungbean, (2) General Seed Certification Standards, (3) Mungbean characterisation data, (4) Evaluation data, (5) Reaction to pests and diseases, and (6) Grain quality. **On behalf of CamSID, Bob Martin was invited to attend the Dissemination Workshop on National Variety Release Committee at the Phnom Penh Hotel on 15th December 2021. CAVAC has driven the process of introduction of the FAO Quality Declared Seed (QDS) system by the General Directorate of Agriculture (GDA) and this led to the formation of a new Department of Crop Seed (DCS) in GDA. Attendance at the workshop provided Bob the opportunity to meet with Dr Mak Chanratana, Deputy Director of DCS on Friday 17th December to discuss commercialization of high performing mungbean varieties in CamSID trials between 2018 and 2021.**

8 Impacts

Impacts of the project outputs are apparent in the reduced sowing rates for rice, increased use of machinery for planting, adoption of best management practices such as integrated pest management and adoption of new varieties for rice (e.g., SKO-1) and mungbean (e.g., CMB-2, CMB-3 and CARDI Chey) that the project has been engaged in developing or promoting.

Impact has been achieved in four ways – (1) First, through direct interaction with farmers and farmer groups through farmer field schools, (2) Second, through training and development of training materials for PDAFF to train input suppliers in certification courses, (3) Thirdly, by engagement with service providers of Kid, Eli, drum and Kubota seeders and drones and (4) Fourthly, through information transfer and support with Telegram, Facebook, radio broadcast and podcasts.

8.1 Scientific impacts – now and in 5 years

The key scientific impacts of the project are the comprehensive body of work published on the integrated weed management of rice including a series of herbicide and sowing rate experiments. This has provided the scientific basis for a follow-on project, *Weed management in dry seeded rice in Cambodia and Laos* which is independently supported by ACIAR (CROP/2019/145) at CARDI. There is also a number of publications on mungbean varietal experiments and integrated pest management. Interestingly, in Battambang Province, only 39% of farmers recognised that there were good (beneficial) and bad (pest) insects. In the main mungbean growing areas, 100% of farmers did not consider any insects to be beneficial and pre-dominantly used chemical pesticides for pest control. The majority of farmers relied on each other (53%) and input sellers (35%) for information on insect pest management. Interestingly, information on pests and pesticides was disseminated through local networks rather than through traditional extension pathways.

8.2 Capacity impacts – now and in 5 years

At least four farmer groups; (1) Battrang Agricultural Cooperative led by Yann Sophon and (2) Kouk Tonloap farmer group led by Chiv Sareth in Banteay Meanchey Province, and (3) Kampong Preang Agricultural Cooperative and (4) Svay Cheat farmer group led by Mr Makara have been trained to continue providing services for smallholder farmers beyond the project. For example, the Kouk Tonloap farmer group led by Chiv Sareth was provided with a 4-W tractor and KID seeder, which has resulted in over 30 smallholder farmers being serviced. For example, the Battrang Agricultural Cooperative has been provided with a new Petkus seed cleaner by the Syngenta Foundation which has increased its seed cleaning capacity by more than 10-fold (see Table 52) This has resulted in interest in seed cleaners leading to another $30,000 Petkus seed cleaner being acquired by Chamroeunphal Agricultural Cooperative (donated by JICA) at Svay Cheat Village, Battambang Province. There are 10 seed providers in Svay Cheat Village, most of them using the Eli seeder for direct seeding. In addition, the Japan International Cooperation Agency (JICA) is also providing seed cleaners to agricultural cooperatives in four provinces, Prey Veng, Takeo, Kampong Chhnang and Battambang, https://www.khmertimeskh.com/50953573/jica-provides-post-harvest-facilities-and-machinery-to-prey-veng-agri-community/.

Table 52. Capacity impacts of Syngenta Foundation farmer hubs (groups)

Yann Sophon- Battrang AC Rice Seed Production	2019	2020	2021
Number of businesses in operation (Hubs) selling products and services	1	1	1
Number of famers reached and accessing products and services	Tbc	32	76
Value created at farmer level (additional NET income in USD per Ha)	100	100	100
Number of Tonnes of Seeds sold to farmers	Tbc	18	38
Total sales generated by the sales of cleaned seeds at farm gate in USD	Tbc	11500	21500
Number of jobs created	1	1	1
Number of Farmers reached during Field Days organized by Fhub	50	75	10

Chiv Sarith Land preparation and DSR	2019	2020	2021
Number of businesses in operation (Farmer Hubs) selling products and services	1	1	1
Number of famers reached and accessing products and services	0	31	27
Value created at farmer level (additional NET income in USD per Ha)	100	100	100
Number of Hectares serviced for Land preparation	demo	70	65
Number of Hectares serviced for Direct Seeding (dry and wet)	demo	20	6
Total sales generated by all Services provided at farm gate in USD	0	4600	3750
Number of jobs created	1	1	1
Number of Farmers reached during Field Days organized by FHub	50	75	10

A technical meeting on selecting CamSID findings for adding into input seller training was conducted on 19th June 2020. The meeting was attended by the CamSID team and PDAFF BTB (Mr Chim Dararoth) and PDAFF BMC (Mr Ngoeun Ratannak to prepare teaching material as a tool for input seller training. Hence, the training in rice, mungbean, fertilizer product use for rice and mungbean, weed, disease and insect pest management in rice and mungbean have been incorporated into the Input Seller Certificate Course.

CAVAC have been working with CamSID, since 2017 to introduce affordable and commercially available seed planters. There are now 18 Kid planters operating in

Battambang province. CAVAC provided a 30% subsidy for the purchase of the Kid and Eli planters (with around 18 Kid subsidised under this scheme).

- The Thai Kid seed drill was imported from Thailand by Harvest Centre Cambodia (HCC). To date, 18 Kid planters have been purchased by Cambodian machinery service providers. Twelve of these are in Battambang province. CamSID operates one Kid seeder in Banteay Meanchey province and one in Battambang province.
- The Eli air seeder, a Cambodia invention, can plant in both wet and dry soil conditions. It is manufactured by Brooklyn Bridge to Cambodia (BB2C) and BB2C has sold 433 Eli units across Cambodia from 2017 to 2020. In February 2021, Mr Bunika San of AgriSmart spin off a new company of his own and marketed the original Eli planter as the Angkor planter. BB2C upgraded their seeder in collaboration with CamSID and re-named it Eli planter 3.0 (and 3.1).
- The Angkor air seeder marketed by AgriSmart has a new feature with both disc openers and seeder coverer mounted on strong springs which allow independent movement to allow uniform coverage of seed in uneven fields. This will overcome farmer concerns about poor seed coverage by previous versions. The 2-WT Angkor seed boom can now be raised and lowered by hydraulics.
- The new Minister of Agriculture, Forestry and Fisheries has requested the Ministry to actively promote direct seeding of rice. The GDA in MAFF is working closely with Agri-Smart and other seeder distributors to respond to this directive.
- ASR was invited by AgriSmart to help present rice Agri-Smart rice planting technologies (i.e., Angkor planter) at the World Food Day event at Kampong Chhnang on 17th October 2022. Dr Ouk Rabun of MAFF chaired the event and visited the stall. In November 2022, AgriSmart signed an agreement with ASR to be the distributor for Battambang Province.

A planting machine Expo was held at Kampong Preang village in Battambang in September 2019. The purpose of this activity was to support local value chain networks and the development of self-sustaining agribusiness (e.g., input and machinery services) where appropriate to continue to support farmers through local value chain networks. The Expo was convened by CAVAC with funding support from CamSID. A total of 117 people attended the Expo and participants included the importer of the Kid planter (HCC), representatives from BB2C, CARDI, Don Bosco, GDA, GIZ (WorldVeg), IRRI, JICA, RUA and VSO also attended. The Expo was attended by 68 Agricultural Cooperative representatives, including 38 (56%) from Battambang province and 9 (13%) from Banteay Meanchey province.

Funds have been approved for a Crawford Fund workshop "accelerating the scaling of mechanized drill seeding of rice in Cambodia" led by Bob Martin. The participants are the Faculty of Agricultural Engineering, Royal University of Agriculture (RUA) but the workshop will be at Don Bosco Battambang in May 2023.

The Kid seeder is equipped to plant maize, mungbean, peanut and soybean as well as rice. CamSID is currently demonstrating the Kid seeder for planting rice and mungbean with farmers at Tahen and Praek Trab villages in Battambang province.

The project has trained three (3) PhD students and sixteen (16) honours/masters students at the University of Sydney and it has trained over ten (10) Master of Sustainable Agriculture (MSA) students enrolled at the National University of Battambang. All CamSID project staff are enrolled in the UNICAM Master in Sustainable Agriculture (MSA) program. Congratulations to our CamSID project staff Sophea Yous, Ratha Rien, Seyma Ngann and Khim Nheb who have graduated with a Masters in Sustainable Agriculture from the National University of Battambang in October 2020. The capacity building of the National University of Battambang and the Royal University of Agriculture will continue beyond 2021 through the Higher Education Improvement Project (HEIP) funded by the World Bank.

Table 53 lists the formal training received by honours and postgraduate students through the project. All project staff also enrolled in the Master of Sustainable Agriculture at the National University of Battambang (NUBB). University of Sydney students often paired up with Cambodia students in projects so that they can learn from each other. Dr Chinaza Onwuchekwa-Henry has received her PhD in 2021, Dr Lucinda (Indi) Dunn has received her PhD in 2022 (now a manager of the Hunger Project) and notable graduates are Harry Campbell-Ross who later worked as a graduate at ACIAR and has started a PhD at ANU; Rebecca Fong now working at the Commonwealth Bank of Australia (CBA), Yi Ling Ng now working at National Australia Bank (NAB), Ashley Rootsey who is now AI & Robotics Pillar Lead for the Food Agility CRC and Jamie Loveday is Program Manager of FoodLab Sydney. Ratha Rien now works for the National University of Battambang (NUBB). At the conclusion of CamSID, Dr Van Touch, Sophea Rous and Chariya Korn have been re-employed in another ACIAR-funded project, “Next generation agricultural extension: social relations for practice change (SSS/2019/138).

Table 53. Formal training received by undergraduate and postgraduate students through the project.

Name	Institution	Degree	Years	Topic	Funding source
Santik Kheav	NUBB	Bachelor	2021	Evaluation of mungbean varieties for adaptation to rice-based cropping systems and profitability in North-West Cambodia (in preparation)	Project
Sopha Yous	NUBB	Bachelor	2021	Integrated pest management for mungbean in north west Cambodia (in preparation).	Project
Pheng Samnang	NUBB	Bachelor	2021	Integrated pest management for mungbean in north west Cambodia (in preparation).	Project
Saro Ratt	NUBB	MSA	2020-2021	Evaluation of mungbean varieties for adaptation to rice-based cropping systems and profitability in North-West Cambodia (in preparation)	Project, Catholic Mission
Chariya Korn	NUBB	MSA	2020-2021	Integrated pest management for mungbean in north west Cambodia (in preparation).	Project
Khem Sokheng	NUBB	MSA	2017-2018	Composition of egg wasp parasite on rice leaf folder for best practice IPM for rice production in Cambodia	Project
Bora Oung	NUBB	MSA	2019-2020	Pre-Post Emergence Herbicide Options for Dry Direct Seeded Rice:2019	Project, Don Bosco
Sophea Yous	NUBB	MSA	2019-2020	Evaluate the growth, yield and profitability of alternative mungbean varieties in Cambodia	Project
Ratha Rien	NUBB	MSA	2019-2020	Meeting seed certification standard for weed and weedy rice contamination in rice paddy in Cambodia.	Project
Chariya Korn	NUBB	MSA	2020-2021	Integrated Pest Management on Mungbean in North West Cambodia	Project
Seyma Ngann	NUBB	MSA	2019-2020	Effectiveness of Different Planting Techniques for Watermelon After Harvesting Rice	Project

Khim Nheb	NUBB	MSA	2019-2020	The effects of fertilizer levels and seeding rates on rice yield in North-west Cambodia.	Project
Tekhong Chhan	NUBB	MSA	2020-2021	Pesticide Poisoning and Pesticide Regulation in Cambodia	Project
Sokunroth Chhun (PDAFF)	NUBB	MSA	2019-2020	Weed Management in Smallholder Rice System in Northwest Cambodia.	Project
Chinaza Onwuchekwa-Henry	USYD	PhD	2018-2021	Strategic agronomic options for a sustainable lowland rice farming system in northwest Cambodia	Tetfund, CSIRO-Data61
Lucinda Dunn	USYD	PhD	2018-2021	The sociological and ecological constraints of rice insect pest management in lowland rice farming systems of Northwest Cambodia	ACIAR Agribusiness Internship, Crawford Fund, RTP scholarship
Daniel Howell	USYD	PhD	2020-2022	Mechanisms and distribution of rice blast in Cambodia	ACIAR Agribusiness Internship, RTP scholarship
Lih Wei Wang	USYD	MAgrEnv	2021-2022	Adoption of innovations by smallholders in NW Cambodia	USYD
Kim Hour San	USYD	B. Food & Agribusiness Honours	2020	Value chain analysis of vegetable cooperatives in Cambodia	Project
Caitlin Cavanagh	USYD	BScAgr Honours	2019	Benchmarking of mungbean in Cambodia	SSEAC honours scholarship
Stella Lay	USYD	BScAgr Honours	2019	Adoption of improved practices in the vegetable production system in northwest Cambodia	SSEAC honours scholarship
Daniel Howell	USYD	BSc Honours	2018	Rice husk ash for the control of rice blast.	Project
Aaron Zhang	USYD	B Engineering Honours	2018	Social network analysis of Angsangsak village	Engineering Honours scholarship
Rebecca Fong	USYD	BScAgr Honours	2018	Feasibility of vegetable production and value chains in NW Cambodia through smallholder and value chain surveys	Project
Harry Campbell-Ross	USYD	BScAgr Honours	2018	Evaluation of mungbean varieties for northwest Cambodia	SSEAC Honours scholarship
Isabell Hinchcliffe	USYD	BScAgr Honours	2018	Mungbean pest identification App for mungbean farmers in Cambodia	SSEAC Honours scholarship
Yezekiel Henson	USYD	MAgrEnv	2017	A weed identification App for rice farmers in Cambodia	International Environmental Weeds Foundation (IEWF)
Yi Ling Ng	USYD	B. Food & Agribusiness Honours	2017	Rice value chain network analysis	Project

Sarah Condran	USYD	BScAgr Honours	2017	Identify options for sustainable intensification for smallholder rice farming households	SSEAC Honours scholarship
Ashley Rootsey	USYD	B. Food & Agribusiness Honours	2017	Mungbean value chain analysis	SSEAC Honours scholarship
Louise Capistrano	USYD	B. Food & Agribusiness Honours	2017	Opportunities for aquaculture and vegetable diversification	SSEAC Honours scholarship
Bhakti Uday Haldankar	USYD	BScAgr Honours	2017	Multi-scale assessment of land clearing of the northern floodplains of the Tonle Sap Lake	SSEAC Honours scholarship
Jamie Loveday	USYD	B. Commerce Honours	2017	Concept of 'entrepreneuring' as a practice-approach to entrepreneurship in a Cambodian context	Sydney School of Business scholarship

8.3 Community impacts – now and in 5 years

<u>Seed drills</u>

In collaboration with CAVAC, the total number of known Kid planting machines owner and service providers in Cambodia is now 22. Unfortunately, the area of rice planted by owners and service providers since 2016 has peaked at 726 ha in 2020 but declined to 289 ha in 2021. The reasons given for the decline in planting in 2021 were drought, flood, less seed production, dis-adoption and reversion to mechanised broadcasting. The Kubota planter has also been piloted as it can plant on uneven ground (unlike the Kid planter), although it needs to be fitted with a fertiliser box.

The Eli air seeder has also grown in popularity with over 10 Eli seeder seed producers around Svay Cheat Village. There have been 433 Eli seeders sold by Brooklyn Bridge to Cambodia (BB2C) in collaboration with CAVAC and with CamSID technical support over the last 4 years. The Eli seeder can plant both wet and dry seeded rice mainly on 2W tractors although it can be retrofitted for 4W tractor. The original Eli seeder was marketed by Mr Bunika San of AgriSmart. The Prime Minister of Cambodia, H.E. Hun Sen visited the CAVAC Irrigation Scheme on 21 July 2020 and he liked the Eli seeder so much that he ordered 2,000 Eli seeders for smallholder farmers using his own budget (although only 250 Eli seeders have been delivered in 2021 so far). In February 2021, Mr Bunika San set up his own company and re-named the original Eli planter, the Angkor Planter. Brooklyn Bridge to Cambodia (BB2C) upgraded their planter to Eli 3.0 (and 3.1) with field testing in collaboration with CARDI and the BTB CamSID team.

The sales figures for the Eli planter are provided below by BB2C CEO, Paula Shirk:

2016 - 16 planters

2017 - 18 planters

2018 - 57 planters

2019 - 42 planters

<u>2020 - 300 planters</u>

Total - 433 planters

However, 2020 is an anomaly, as 250 were government sales based on Prime Minister Hun Sen's donation, 20 were CAVAC sales and only 30 were sales to smallholder farmers and service providers.

There are about three Vietnamese mechanised drum seeder operators (on 2W tractors), mainly operating in Banteay Meanchey province. They mainly perform wet seeding with high precision mainly for quality rice seed production during the early wet season and dry season.

Quality seed production

Although the adoption by paddy growers for mechanised planters have not been great due to the emerging popularity of mechanised seed broadcasters, mechanised planters (Kid, Eli, Drum planters) have now been widely adopted by quality rice seed producers. Low seeding rates provided by mechanised planters have improved crop establishment (especially with dry seeding) as the rice seedlings can establish even if the monsoon rains are delayed by over a month (broadcasted rice seeds usually die and have to be replanted). The rice plants established by mechanised planters are healthier, as the row spacings provide aeration with less rice blast disease and insect damage. The plants are more resilient, producing consistent yields and making it easier to remove weeds.

Provision of the Petkus seed cleaner by Syngenta Foundation (SFSA) to Battrang Agricultural Cooperative (AC) hub installed with the help of CARDI in December 2020 has enabled this hub to produce, high quality clean seed. In fact, several seed production ACs have visited this hub and have been lobbying donors to provide this critical infrastructure. This has resulted in interest in seed cleaners leading to another $30,000 seed cleaner being acquired by Chamroeunphal Agricultural Cooperative (donated by JICA) at Svay Cheat Village, Battambang Province. Japan International Cooperation Agency (JICA) is also providing seed cleaners to agricultural cooperatives in four provinces, Prey Veng, Takeo, Kampong Chhnang and Battambang, https://www.khmertimeskh.com/50953573/jica-provides-post-harvest-facilities-and-machinery-to-prey-veng-agri-community/

Best management practices

Through the farmer field schools and planting machinery demonstrations, there has been an increased adoption (up to 50% in several target and scale out villages) in best practices and integrated pest management technologies. **For example, surveys in 2017 showed that prior to 2016, almost no farmers used any pre-emergence herbicides in dry seeding with most farmer solely depending on post-emergence herbicides. However, with field demonstrations and farmer field schools (even applying pre-emergence herbicides with drones), this is now quite common practice, especially with dry direct drill rice.** An example of the impact of this research is that the outputs of CamSID will be continued in the new ACIAR-funded project (CROP/2019/145) on "**Weed management techniques for mechanised and broadcast lowland crop production systems in Cambodia and Lao PDR**" for five years, from 2021-2025.

Future plan for scaling rice production packages

With additional funding, CamSID plans to partner with NGOs and the Cambodian government to further scale innovations to other provinces (Figure 99).

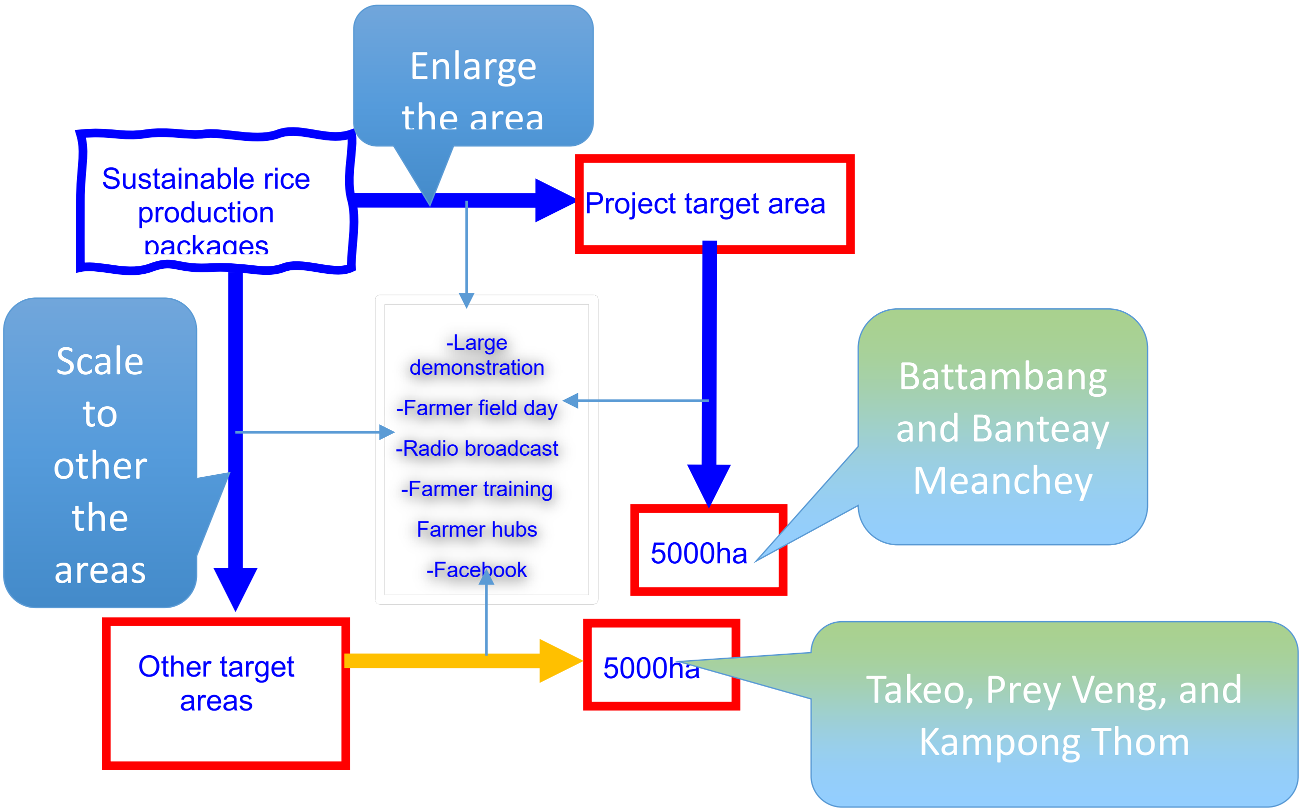


Figure 99. Future scaling for rice production packages (Credit: Yorn Try)

Mungbean varieties

The trialling of mungbean varieties with growers by CamSID has resulted in the growing popularity of the CARDI varieties, CMB-2 and CARDI Chey, which are replacing the imported KPS-2 and DX-208 in Battambang province. The advantage of the CARDI varieties are the larger seed, non-shattering characteristics which allow for once-over machine harvest, rather than multiple hand harvests. Australian varieties, Delta and Emerald, are also being considered for registration and release. Further collaboration with PDAFF (Dr Oudam) and General Directorate of Agriculture (GDA) is needed for production of quality declared seed for mungbean. Dr Ponh Oudam, Vice Director, Battambang PDAFF has made available a field for mungbean seed purification and seed increase at the PDAFF seed farm in Ou Mal village (13.072994° N; 103.088832° E).

Watermelon and fish

From the mid-term survey, it was evident that the villages around Sisophon and Battrang are starting to diversify from rice and growing watermelon, vegetables and fish as an income diversification option. One lead farmer, Mr Yann Sophan has also started to produce carp fingerlings to his neighbours (in addition to leading the Battrang Agricultural Cooperative, supplying quality rice). Diversification provides additional cash income as well as possibly better nutrition for smallholder farmers.

Engagement with farmer hubs and partnership with NGOs

CamSID's strategy of engaging with farmer hubs has produced model case studies for empowering existing business enterprises that are self-sustaining and able to flourish beyond the project. In Banteay Meanchey province, where there are few donors operating, CamSID partnered with Syngenta Foundation (SFSA) and Ockenden Cambodia to establish SFSA facilitated farmer hubs for quality seed production (Battrang) and machinery contracting (Kuok Tonloap). **Further research on the farmer hubs was also commissioned by ACIAR in CROP/2020/202 – Farmers' Hubs as a vehicle to deliver solutions to farming communities.** In Battambang province where there are more donors, CamSID partnered with CAVAC, VSO, IRRI (EPIC and EiA) to scale planting machinery (Kid, Eli, Kubota planters) and best management practices including integrated pest management and pre-emergence herbicides.

In June 2022, Herve managed to get some budget from SFSA (approximately US$10,000) to support Ockenden in ongoing work in equipping 10 Agricultural Cooperatives (ACs) involved in seed production with seed cleaner

Ockenden will provide the following services

1. Set-up the organizational structure and ensure knowledge and experience transfer from the two existing farmer hubs, engaging with the younger generation. Develop the concept of Learning Centre, starting with Yann Sophon who could teach and train new farmer hub owners on site. Deliver a High-Quality Seed Production Certificate post-training.

2. Enhance resilience to climatic challenges amongst Rice Seed Producers. Create ad-hoc crop management protocols (Disaster Proof Paddy Field): pond to secure water for irrigation, dike, canal, land levelling. Ensure high-quality standards for "Rice Seed Production": ad-hoc protocols, inspection, post-harvest management: seed cleaning, grading, packaging, and stock management. Organize field visit and share best practices regarding rice production methods to farmers.

3. Improve and enlarge farmer hubs' services: identify the needs, do a proper costing of the expected services, list potential service providers (inside and outside ACs communities), draft a precise implementation plan including the financial resources, encourage savings and lending scheme amongst members.

4. Communicate benefits of high-quality seeds and services provided by the farmer hubs to foster the adoption by the farming communities. Organize "show and tell" activities like field demonstrations, provide information on pricing of the proposed products and services, communicate on social medias and newspapers / TV.

Engagement with PDAFF in training input sellers

CamSID's engagement with PDAFF has incorporated CamSID outputs in rice and mungebean best management practices into the 5-day input seller training certification program, ensuring the input sellers are continued to be trained beyond the life of the project. CamSID also directly engaged with input sellers, resulting in CamSID outputs being incorporated into information leaflets distributed by input sellers to their farmer clients.

8.3.1 Economic impacts

One reason for farmers not adopting machine drill seeding is that the costs of contracting for drill seeder service providers are perceived to be too high. In fact, if the seed costs (e.g., for seeding rates of over 200 kg/ha) are taken into account, the total costs of drill seeding (e.g., for seeding rates of 80 kg/ha) are actually slightly lower than broadcasting. The calculation for contract rates for machine drill planters (Kid and Kubota) below by Dr Bob Martin is a good example (Tables 54 and 55).

Table 54. Ownership costs for a Kubota L-5018 (50 hp) tractor traded in after five years

Ownership costs	Calculation	Result
Average value = (purchase price + trade-in price) / 2	($23,000 + $11,500 / 2	$17,250.00
1. Depreciation cost = (new price – trade-in price) / 5 (years)	($23,000 - $11,500) / 5	$2,300.00
2. Interest cost = average value * interest rate (12%)	$17,250 * 0.12	$2,070.00
3. Insurance cost = average value * 1%	$17,250 * 0.01	$172.50
4. Shed housing cost = new price * 0.5%	$10,000 * 0.005	$50.00
5. Workshop cost = total workshop costs * % time on tractor	$250 * 0.4	$100.00
Total ownership costs per year		$4,692.50
Total ownership costs per hour = total overhead costs per year / hours worked per year (500 hours)	$4,692.50 / 500	$9.39

Table 55. Ownership costs for a Thai Kid machine drill planter tractor traded in after five years

Ownership costs	Calculation	Result
Average value = (purchase price + trade-in price) / 2	($5,500 + $2,750 / 2	$4,125.00
1. Depreciation cost = (new price – trade-in price) / 5 (years)	($5,500 - $2,750) / 5	$550.00
2. Interest cost = average value * interest rate (12%)	$4,125 * 0.12	$495.00
3. Insurance cost = average value * 1%	$4,125 * 0.01	$41.25
4. Shed housing cost = new price * 0.5%	$10,000 * 0.005	$50.00
5. Workshop cost = total workshop costs * % time on planter	$250 * 0.1	$25.00
Total ownership costs per year		$1,161.25
Total ownership costs per hour = total overhead costs per year / hours worked per year (200 hours)	$1,161.25 / 200	$5.81

Profit margin

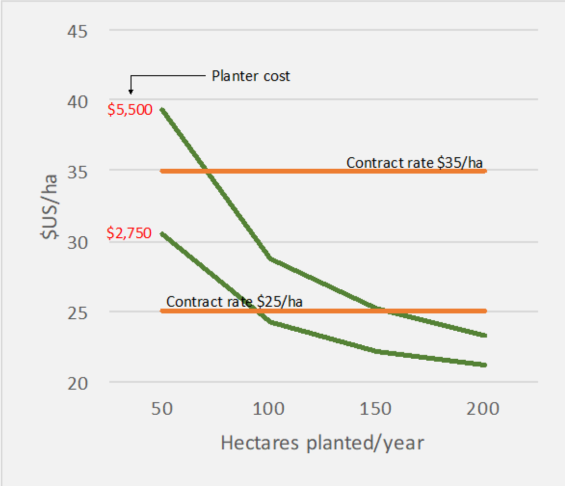
A profit margin needs to be built into your contract rate to make doing the work worthwhile. In our example, we take 20% of the machinery and labour costs as the profit margin.

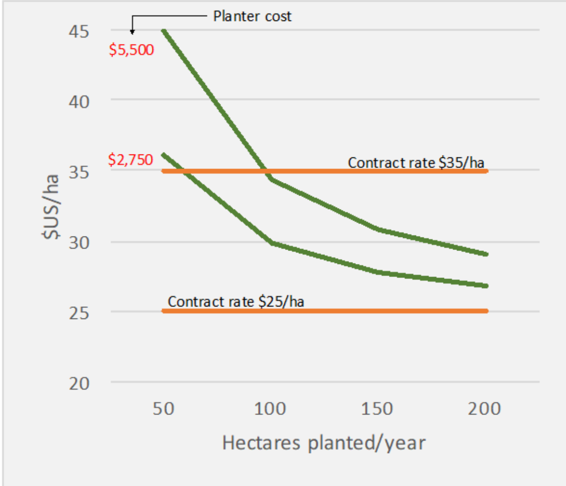
Establishing a contract rate

The most common way to decide on a machinery contract rate in Cambodia is to match other contractors in the area. However, it is important to remember that the contract rate is based on the assumption that the machine will work a certain number of hours per year. Any change in this estimate will alter the costs per hour (Table 56). It is assumed that machine drill planters can plant at 1 ha/hour.

Table 56. Estimated operating costs for a new Kid planter with either a 50 or 60 hp tractor

Cost components per hour	Hectares planted per year				
	50	100	150	200	250
Planter ownership cost per hour	$23.23	$11.61	$7.74	$5.81	$4.65
Planter operating costs per hour	$1.83	$1.83	$1.83	$1.83	$1.83
50 hp tractor ownership costs/hour (500 hours/year)	$9.39	$9.39	$9.39	$9.39	$9.39
60 hp tractor ownership costs/hour (500 hours/year)	$13.00	$13.00	$13.00	$13.00	$13.00
50 hp tractor operating costs per hour	$6.85	$6.85	$6.85	$6.85	$6.85
60 hp tractor operating costs per hour	$8.85	$8.85	$8.85	$8.85	$8.85
Total costs per hour (50 hp tractor)	$39.32	$28.69	$25.15	$23.38	$22.32
Total costs per hour (60 hp tractor)	$44.93	$34.30	$30.76	$28.99	$27.93





50 hp tractor **60 hp tractor**

Figure 100. The effect of tractor size and planter cost on contract rates for machine drill planters

To estimate what a yearly cost is on a "per hour" basis, divide the yearly cost by the number of hours per year spent operating the machine. The more hours per year you operate the machine, the lower your hourly cost of operation will be (Table 55).

Tractor size is an important consideration that affects the contract rate (Table 55). For a Kubota L-5018 (50 hp) tractor, operated for 500 hours per year, the operating cost is $18.24/hour. In contrast, for a Kubota M-6040 (60 hp) tractor, operated for 500 hours per year, the operating cost is $21.85/hour (Figure 100).

The more contracting done per year, the more the ownership costs are reduced per hour. Since the variable costs are calculated on a "per hour" basis they do not vary with the amount of work completed. In our example, the local contract rate for machine drill planting of rice is $25/ha and contractors would need to plant more than 150 hectares per year to break even with a 50 hp tractor. However, for a 60 hp tractor, the contractor would lose money at a contract rate of $25/ha (Table 55).

A contract rate of $25/ha is OK for a 50 hp tractor but $35/ha would be more appropriate for a 60 hp tractor. The purchase price of the planter also has a large effect on the cost of operation. At $5,500, the Kid planter is expensive compared to the Kubota planter at $2,150. However, the Kubota planter does not have a fertiliser box. A Kubota planter fitted with a fertiliser box ($2,750) would be an attractive option.

8.3.2 Social impacts

The outward migration of labour to Thailand from the border provinces of Battambang and Banteay Meanchey has resulted in a prolonged labour shortage. As a result, smallholder farmers relied on contracting service providers for land preparation (80% primary tillage) and rice harvesting (95% by combine) compared with only 40-80% by combine in southern Cambodia in 2018 (see CSE-2012-077). The COVID-19 pandemic has resulted in reverse migration which has resulted in reduced remittance from migrants but has also brought back the Delta variant of COVID-19 from Thailand which resulted in the border provinces being worse affected than others.

The CamSID project made a contribution into the gender roles in rice and vegetable farming activities. Women are the best negotiators within the family although their action is informed and influenced by their husband's opinion. Women played a bigger role than men in decision making related to selling rice. Similarly, women are less involved in activities such as buying seed, land preparation and seed broadcasting and their opinion is less likely to influence the final decision. The decisions in relation to inputs such as fertiliser and pesticides was a decision often made by checking the field as a partnership, although men ultimately had more say in these decisions.

The opportunities for women to lead in innovation are extensive. Women have key skills and play a key role in the Cambodian rice and vegetable value chains. It is noteworthy that although women are not keen to operate 2W tractors, they are consulted in major investment decisions such as purchase of machinery and inputs. Hence, it is important that farmer field school training create opportunities for both the training of both men and women.

8.3.3 Environmental impacts

The increased use of direct seeding may result in increased use of pre-emergence herbicides to manage weeds. The adoption of low seeding rates by small holder farmers significantly contributed to increase the effectiveness of pesticide application, the lower seeding rates application the lower blast infection and higher effectiveness of insecticide. Prior to 2017, most farmers have depended mainly on post-emergence herbicides. Our project introduced farmers to pre-emergence herbicide options for dry direct seeded rice in north-west Cambodia which include butachlor, oxadiazon and pendimethalin. In addition, collaboration with CAVAC resulted in the emergence of drone operators who supply farmers with drone spraying services for pesticides including herbicides. This resulted in the ability to apply pesticides safely and remotely at low volumes which benefits the smallholder farmers. However, the Cambodian government is recommending higher volumes of water to be applied with pesticides to reduce the concentration of pesticides applied.

8.4 Communication and dissemination activities

The project has a Wordpress website: https://aciarcambodiasidproject.wordpress.com/

A newsletter currently edited by Dr Van Touch (8 produced so far), Khmer Rumduol Meas which has been distributed to partners and stakeholders to disseminate progress and news on the project.

The Crawford Fund training group has set up a Crawford Ag Leaders Facebook site: https://www.facebook.com/groups/1728309297492681/permalink/1741938839463060/

A Facebook page for CSE-2015-044 has also been set up and moderated by postdoctoral fellows, Dr Van Touch and Dr Rebecca Cross:

https://www.facebook.com/CambodiaSID/

Daniel Tan was also interviewed by the Sydney Southeast Asian Centre (SSEAC) for a podcast featuring sustainable farming practices in Cambodia.

https://newbooksnetwork.com/from-the-archives-supporting-sustainable-farming-practices-in-cambodia-with-professor-daniel-tan

SFSA produced a video on the SFSA farmer hub in Cambodia

https://www.youtube.com/watch?v=xcEJRekIL2k

Radio broadcast and podcast

A survey of farmers' communication needs and a pilot radio show were conducted with CamSID target villages in Battambang in early 2017. The talk-back radio show attracted very little feedback from listeners and it was subsequently found that only 44% of survey respondents listened to radio compared to 78% who watched television. In addition, only 12% of respondents used radio to source technical information for agriculture.

Project team members, Dr Yorn Try, Nheb Khim, Ngann Seyma and Chhan Tekhong presented radio programs about project learnings in 2020 and 2021. The radio broadcasting evaluation has been completed with 40 respondents interviewed. **Approximately 12.5% of farmers surveyed listened to the radio program (while 87.5% did not) and most of these listeners are lead farmers who share their knowledge with other farmers. The team has now repackaged these broadcasts into a podcast series that is being promoted via social media**.

Field days

The project organised at least 10 field days every year across both Banteay Meanchey and Battambang provinces. Prior to the COVID-19 pandemic (i.e., in 2017 to 2019), very large field days and farmer field schools were held with over 100 farmers attending each time. During the COVID-19 pandemic (i.e., in 2020 and 2021), smaller groups of lead farmers were trained due to social distancing requirements. Below is a summary of the notable field days and farmer field schools organised (Table 57):

Table 57. Summary of key field days in northwest Cambodia.

Dates	Locations	Main topics	Comments
10/07/2017	Kuok Tonloap Village, Banteay Meanchey Province	Rice direct seeding versus hand broadcasting	Khmer TV8 crew filmed the rice direct seeding demonstration at Kuok Tonloap Village on 10 July 2017 and was broadcasted on Saturday 15th July and re-broadcast on Monday 17th and Tuesday 18th July 2017. https://www.youtube.com/watch?v=iAiZK6zZJcs
2019 (pre-pandemic)	Botrong, Kouk Tonlaop, Spean Sraeng and Boslouk villages, Banteay Meanchey Province	Rice direct seeding and best practice management	A series of scale-out demonstrations (farmer field schools) in four villages. This a trilogy demonstration whereby farmers were invited to visit the same field during each stage (1) Planting, (2) Maximum tillering and (3) Harvest in each village. Approximately, 150, 170 and 200 smallholder farmers participated at the planting, maximum tillering and harvest stages, respectively. The proportion of farmers who intend to adopt the innovations was 50%, 70% and 75%, during the planting, maximum and harvest stages, respectively.
10/09/2019	Kampong Preang, Battambang Province	Planting machinery Expo	This machinery expo was convened in collaboration with CAVAC. A total of 117 people attended the Expo and participants included the machinery suppliers, Harvest Centre Cambodia (HCC), Brooklyn Bridge to Cambodia (BB2C) and 68 Agricultural Cooperative representatives.
12/08/2020	Ou Ta Nhea Village, Battambang Province	Planting machinery and weed management	A joint BTB/BMC field day in Ou Ta Nhea was held on 12 August 2020 to educate farmers, machinery dealers and agribusinesses on planting machinery. This field day was also featured on Cambodian national television (CTV): https://www.facebook.com/CambodiaSID/videos/656255671907136
22/07/2021	Don Bosco Agro Technical School, Battambang	Eli seeder and drones	Visit by the Australian Ambassador to Cambodia, H.E. Pablo Kang and was attended by 26 people including drone service providers.
31/07/2021	Botrong village, Bottrong commune	Rice production packages, especially seeding rates using Kid Seeder	The field day was conducted at harvest and 20 farmers have joined this event.
22/10/2021	Kouk Tonlaop,	Rice production	This field day was conducted at Kouk Tonlaop village; 20 farmers and BMC team have joined this event; the SFSA team from

	Banteay Neang commune	packages, especially seeding rates using mechanised drum seeder	Battambang also joined the event and conducted some farmer interviewing with shooting of video activities of Mr Chiv Sarith's led farmer hub
12/02/2022, 29/04/2022	Thmor Pouk, Banteay Meanchey	Rice production packages, especially seeding rates using mechanised drum seeder	The first field day was conducted at Thmor Pouk (a new area) and trained 67 smallholder farmers on 12/02/2022 as the first wet seeding in this area (mainly a dry seeding area). The second field day was on 29/04/2022 with 54 farmers and 20 technical high school students trained. These field days resulted in 500 ha of rice planted using CamSID technology.
22/03/2022	Don Bosco Agro Technical School, Battambang	Lunheng and Eli seeder and drones	Visit by the Deputy Ambassador to Cambodia, Andreas Zurbrugg accompanied by Third Secretary, James Lawler. The Kid, Kubota and Lunheng seeders were demonstrated. The Lunheng seeder was invented by Cambodian, Mr Lunheng Hong (Siem Reap). The IRRI Excellence for Agronomy (EiA) project provided funding for the Lunheng seeder. Closing remarks were made by H.E. Sok Khorn, Rector, National University of Battambang. He commended the ACIAR CamSID and CAVAC teams for their efforts over 5 years of collaboration on innovations to achieve sustainable intensification and diversification in Cambodian lowland rice systems. https://www.cnc.com.kh/detail/news/28802

9 Conclusions and recommendations

9.1 Conclusions

This project has engaged with dynamic and innovative farmers' groups and agricultural cooperatives to determine the advantages and challenges of mechanising planting, adopting best management practices for rice and crop diversification for lowland northwest Cambodia. In addition, there has been successful scaling of innovations to the surrounding villages and, in some cases, regionally. There has been excellent communication between CamSID team and the farmer groups, the farmers have innovated in partnership with research inputs from the CamSID team. For example, in Battrang village, a farmer developed an idea of producing carp fingerlings in his pond to supply his neighbours during the COVID-19 pandemic period due to increased demand for carp. Farmer groups and agricultural cooperatives have some experience in growing rice and vegetables, and their partnership with CamSID has guided the directions of the project, in line with our project objectives.

The project has demonstrated the effectiveness of a range of planting machinery (e.g., Kid, Eli, drum planters) with benefits of crop productivity and incomes of smallholder farmers and service providers. Uptake of these planting machines is mainly influenced by socio-economic conditions. For example, there are now 14 Kid service providers and farmer operators in Battambang province for dry drill planting and only 2 Kid service providers in Banteay Meanchey (BMC) province. This is evident as BMC has lower-income farmers who consider $35/ha for Kid service providers too expensive compared to the cheaper option of mechanical seed broadcasting. For wet seeding, there has been wider adoption of the Eli seeders in Battambang and some adoption of drum seeders in Banteay Meanchey. **Overall, in both provinces, most of the mechanised planter adoption has largely been by high-value, high-quality seed producers rather than small-scale paddy farmers.** Scaling of mechanised planting and best management practices to surrounding villages has been successful with approximately 50% of villagers adopting the new practices (according to the midline survey focus groups). In Banteay Meanchey, farmer field schools linked with training of the leading farmers (and farmer hubs) by Syngenta Foundation (SFSA) and Ockenden Cambodia has led to adoption of best practices. In Battambang province, the partnership with CAVAC, IRRI and PDAFF has led to adoption of mechanical planting (Kid, Eli planters), pre-emergence herbicides as well as mungbean varieties, and other best practices. Training of PDAFF to incorporate CamSID outputs into the 5-day input supplier certification course ensured that this is engrained (upscaled) into the provincial training program after the project ends. **To answer the central question, the most effective way to encourage adoption of SID innovations is to first discover who are the key influencers [e.g., lead farmers, agricultural cooperatives (ACs) and input sellers] within farmer social networks, and then engage these key influencers to scale SID innovations to smallholder farmers. Smallholder farmers and input sellers are invited to large field days and farmer training schools organised by lead farmers, ACs and PDAFF.**

However, the benefits of intensification and diversification varied greatly, depending on infrastructure such as availability of irrigation supply, cost of planting machinery, and cost of inputs. **It is likely that SID innovations may not work for smallholders who have no access to supplementary irrigation water as they can only grow one rice crop per year.** Diversification was also limited to certain villages with leading farmers who had knowledge and experience to grow crops other than rice (e.g., mungbean, watermelon and vegetables). Due to the high costs of land levelling, the adoption of the Kid planter encountered obstacles, whereas the Kubota planter performed better on uneven fields. In Banteay Meanchey province, smallholder farmers have even innovated the use of low-cost timber (plank) levelling with 2W tractors, facilitating wet planting of rice with the drum seeder. Another limitation is the lack of market access by many smallholder farmers who can grow a good-quality crop but are not generally able to sell it at advantageous prices as they sell their rice and vegetables (e.g., watermelon) to collectors (pisteurs or middlemen) rather than directly to millers and the market, respectively.

9.2 Recommendations

Following value chain, physical and biological factors were identified as potentially important for sustainable intensification and diversification of the lowland rice area of northwest Cambodia merit further research attention.

1. Planting machinery
   a. Development and demonstration of minimum tillage planting machinery suitable for lowland rice conditions;
   b. Local testing of the Kubota planter (for 4-wheel tractor) for uneven soil surface;
   c. Trialling of subsiding the service charges for contracting drill planting services in provinces with poorer farmers;
   d. Local testing of the next generation of the 2- wheel tractor Eli 3.0 (and 3.1) air seeder for possible planting under minimum tillage conditions
   e. Survey of the adoption of the 250 Eli planters donated by Prime Minister Hun Sen (e.g., are they in operation or are they sitting in the shed and rusting away).
   f. Further local testing of other indigenous planting machine manufacturers, such as the Lunheng belt seeder

2. Mungbean varieties
   a. Incentives for seed producers to produce and supply CARDI mungbean varieties through the GDA Quality Declared Seed (QDS) system in partnership with PDAFF;
   b. Seed increase promising Australian mungbean varieties (e.g., Delta, Emerald) and apply for registration by MAFF;
   c. Promote benefits of rice-mungbean rotations in the lowland rice system;
   d. Investigate alternative legume crops, including mulch crops, for rotation with rice and for regeneration of degraded rice soils.

3. Rice varieties
   a. Develop photoperiod insensitive aromatic rice varieties like CARDI's Sen Kra Ob-1 (SKO-1) with **rice blast resistance** (SKO-1 is currently very susceptible to blast)

4. Value chain
   a. Determine if consumers value high quality, value-added produce (e.g. rice, mungbean) and vegetables;
   b. Assess the possibility for smallholder farmer groups to get together and access mills and markets directly, bypassing the collectors (e.g., with the Sustainable Rice Platform (SRP) system promoted by VSO).

Zero tillage is common in Cambodian upland cropping systems but rare in the lowland apart from a handful of contract farming trials by CIRAD. There have been several planting machines (Kid, Kubota, Eli) trialled by CamSID in the lowland but most still require some tillage due to damage by combine wheel tracks. The rice stubble is also frequently burnt after harvest with the excuse that rat catchers use fire to drive out rats. This combined with smallholder farmers' positive relationships with tillage contractors (after giving away their draught animals) has resulted in Cambodian rice soils being ploughed too many times at the expense of the smallholder farmer, who is losing moisture prior to planting rotation crops (e.g., mungbeans). A key research gap is the feasibility of minimum tillage planting and the business case for minimum tillage planting in the lowland rice system in Cambodia.

Prior to the CamSID project, CARDI had "released" several mungbean varieties such as CARDI Chey, CMB-1, CMB-2 and CMB-3. However, when smallholder farmers were asked, they were growing imported varieties such KPS-2 (Thailand) or DX-208 (Vietnam) which either had small seed or shattered early, making them unsuitable for combine harvesting. Although CamSID was successful in trialling the new CARDI varieties (e.g., CARDI Chey and CMB-2), only a limited quantity of CMB-2 seed was seed increased and made available to mungbean growers in Praek Trab, Angsangsak and Tahen villages. Organising for seed producers willing to produce Quality Declared Seed (QDS) was a challenge due to lack of a framework for mungbean seed producers and difficulties with storage due to damage by bruchids (which was solved through the importation of insect-proof Gro-Bags).

The CamSID project was the first key ACIAR-funded project to trial the photoperiod insensitive Sen Kra Ob rice variety in 2016. Eventually, Dr Makara of CARDI selected Sen Kra Ob-1 (SKO-1) which was released in 2019. Seed increase of SKO-1 was carried out in collaboration with Mr Oudam of Battambang PDAFF in the new PDAFF seed production facility in 2021 in collaboration with the Battambang CamSID team. SKO-1 was also seed increased by the CamSID-facilitated SFSA Battrang Agricultural Cooperative in 2021. Unfortunately, **SKO-1 is still very susceptible to rice blast**, similar to the original Sen Kra Ob. CARDI needs to start a breeding program to breed a SKO-1 type aromatic rice variety that is resistant to rice blast.

From the CamSID surveys, it was evident that growing rice is a poverty trap and that for most smallholder rice farmers, one route out of poverty was to diversify into high value crops such as mungbean, watermelon, vegetables, fish farming or alternative business enterprises such as machinery contracting. This was challenging as most rice farmers only know how to grow rice. They attempt to grow alternative crops like watermelon but too often, they have no market access. Hence, smallholder farmers are often exploited by collectors (pisteurs or middlemen) who even harvest and sell the watermelon on their behalf. Hence, there is no real incentive for smallholder farmers to grow a high quality, high value crop. Further research should investigate if farmer groups (hubs) can team up together and directly access higher value retail markets such supermarkets and restaurants.

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Patents

A patent (record of invention) was lodged/submitted for the Cambodian WeedID app (available both on iOS) (#CT19091) CDIP Ref. 2017-026

A patent (record of invention) was lodged/submitted for the Mungbean Pest ID app (available both on iOS and Android) CDIP Ref. 2018-080

11 Appendixes

11.1 Appendix 1: Links to reports

1. Inception workshop report
2. Baseline study report
3. Gender analysis report
4. Mid-term review report
5. CARDI final report summary
6. Rice production technical package
7. Syngenta Foundation farmer hub pitch (draft)
8. Commercialisation of mungbean varieties in Cambodia
9. Policy Brief for Ministry of Environment

11.2 Appendix 2: Soil Profile Descriptions (Battambang and Banteay Meanchey Provinces

Extracted from: Hin, S., Lim, V., Heng, H. Preliminary Notes – Soil Survey, Battambang Province, The Kingdom of Cambodia. Surveys completed in February 2020. ACIAR Cross Project SMCN/2016/237 and SMCN/2014/088. Assessment of soil pH and lime requirement in Cambodia.

11.2.1 Svay Cheat site

Province:	Battambang	District:	Sangkae
Commune:	Reang Kesey	Village:	Svay Cheat
	GPS coordinates	12.924639°N	103.247334°E

Sampling depths:	0-10, 10-20, 20-30, 30-50, 50-70, 70-100 cm
Disturbance:	Slightly disturbed vegetation

Landform

Landform pattern:	Plain
Relief/modal slope:	Plain
Landform element:	Flood plain
Micro-relief:	Even
Slope class (US):	Flat

Surface and Hydrological Properties

Rock outcrop (%):	None
Surface coarse fragments:	None
Physical properties:	50-100 cm soil

Vegetation

Crop:	Rice, flooded/paddy

Land use

Site:	Rainfed arable cultivation
Surrounds:	Wet rice cultivation

Current Classification

Local Soil Name:	Toul Samroung, no phase specified

Soil profile description

Depth (cm)	Description
0-15	Pinkish grey (7.5YR 7/2 moist) sandy clay; common fine prominent yellowish red (5YR 5/8 moist) redox mottles; slightly hard consistence, sticky, plastic; pedal, moderate, fine to coarse, platy structure; rough-ped fabric; common roots, fine; no coarse fragments; pH 5.5; very few, fine, low porosity, vughs void; Soil Strength:10 cm=27, 31, 24; 30 cm=27, 27, 26; 60 cm=27, 25, 24; 90 cm= 25, 28, 25; (+%3).
15-28	Grey (7.5YR 6/1 moist) clay; common fine distinct dark reddish brown (5YR 3/4 moist) redox mottles; hard consistence, very sticky, very plastic; few roots, fine; 2% sub-rounded fine gravel; pH 6; very few, fine, low porosity, vughs void.
28-55	Light brown (7.5YR 6/4 moist) heavy clay; common fine faint yellowish red (5YR 5/8 moist) mottles; very firm consistence, very sticky, very plastic; no roots; no coarse fragments; pH 6.
55-100	Grey (5YR 6/1 moist) heavy clay; very firm consistence, very sticky, very plastic; no roots; no coarse fragments; pH 6.5.

11.2.2 Os Tuk site

Province:	Battambang	District:	Sangkae
Commune:	Kampong Preang	Village:	Os Tuk
	GPS coordinates	12.963442°N	103.34360°E

Sampling depths:	0-10, 10-20, 20-30, 30-50, 50-70, 70-100 cm
Disturbance:	Slightly disturbed vegetation

Landform

Landform pattern:	Plain
Relief/modal slope:	Plain
Landform element:	Flood plain
Micro-relief:	Even
Slope class (US):	Flat

Surface and Hydrological Properties

Rock outcrop (%):	None
Surface coarse fragments:	None
Physical properties:	Cracking surface; 50-100 cm soil

Vegetation

Crop:	Rice, flooded/paddy

Land use

Site:	Wet rice cultivation
Surrounds:	Wet rice cultivation

Current Classification

Local Soil Name:	Toul Samroung, no phase specified

Soil profile description

Depth (cm)	Description
0-20	Light brown (7.5YR 6/4 moist) clayey silty clay; common fine faint yellowish brown (10YR 5/8 moist) mottles; very hard consistence, sticky, plastic; pedal, strong, medium and coarse, platy structure; rough-ped fabric; common roots, fine; no coarse fragments; pH 6.5 (Raupach and Tucker indicator); few, fine, low porosity, vughs void;Soil strength: 0-20cm= 26, 32, 32; 20-45cm= 25, 31, 29; 45-95= 30, 26, 26; 95-110cm= 19, 24, 19kpa
20-45	Reddish grey (5YR 5/2 moist) clayey clay; common fine distinct yellowish brown (10YR 5/6 moist) mottles; extremely hard consistence, very sticky, very plastic; few roots, fine; no coarse fragments; pH 5.5 (Raupach and Tucker indicator).
45-95	Pinkish grey (5YR 7/2 moist) clayey heavy clay; many coarse distinct red (2.5YR 5/8 moist) mottles; extremely hard consistence, very sticky, very plastic; no coarse fragments; pH 5.5 (Raupach and Tucker indicator).
95-120+	Light grey (5YR 7/1 moist) clayey heavy clay; few fine faint brownish yellow (10YR 6/8 moist) mottles; extremely hard consistence, very sticky, very plastic; no coarse fragments; pH 6.5 (Raupach and Tucker indicator).

11.2.3 Ta Haen Muoy site

Province:	Battambang	District:	Sangkae
Commune:	Roka	Village:	Ta Haen Muoy
	GPS coordinates	13.078016°N	103.287368°E

Sampling depths:	0-10, 10-20, 20-30, 30-50, 50-70, 70-100, 100-150 cm
Disturbance:	Slightly disturbed vegetation

Landform

Landform pattern:	Plain
Relief/modal slope:	Plain
Landform element:	Flood plain
Micro-relief:	Even
Slope class (US):	Flat

Surface and Hydrological Properties

Rock outcrop (%):	None
Surface coarse fragments:	None
Physical properties:	50-100 cm soil

Vegetation

Crop:	Rice, flooded/paddy

Land use

Site:	Wet rice cultivation
Surrounds:	Wet rice cultivation

Current Classification

Local Soil Name:	Toul Samroung, no phase specified

Soil profile description

Depth (cm)	Description
0-15	Pinkish grey (7.5YR 6/2 moist) clayey clay; common fine faint yellowish brown (10YR 5/8 moist) redox mottles; very hard consistence, sticky, plastic; pedal, moderate to strong, coarse and very coarse, angular blocky structure; rough-ped fabric; common roots, fine; pH 5 (Raupach and Tucker indicator); few, fine, low porosity, vughs void;Soil strength: 0-15cm= 21, 25, 29; 15-50cm= 19,22.50, 20; 50-80cm= 19.50, 16, 19.50; 80-150cm= 18, 24, 20 kpa.
15-50	Grey (5YR 5/1 moist) clayey heavy clay; common fine faint dark yellowish brown (10YR 4/6 moist) redox mottles; extremely hard consistence, very sticky, very plastic; no roots; pH 6 (Raupach and Tucker indicator); few, fine, low porosity, vughs void.
50-80	Reddish grey (5YR 5/2 moist) clayey heavy clay; common fine faint dark brown (10YR 3/3 moist) mottles; very sticky, very plastic; no roots; pH 6.5 (Raupach and Tucker indicator); few, fine, low porosity, vughs void.
80-150	Grey (5YR 6/1 moist) clayey heavy clay; common fine faint dark brown (10YR 3/3 moist) mottles; very sticky, very plastic; no roots; pH 7 (1:5 0.01M CaCl2); few, fine, low porosity, vughs void.

11.2.4 Don Bosco site

Province:	Battambang	District:	Battambang
Commune:	Ou Mal	Village:	Sala Balat
	GPS coordinates	13.076758°N	103.174606°E

Sampling depths:	0-10, 10-20, 20-30, 30-50, 50-70, 70-100 cm
Disturbance:	Slightly disturbed vegetation

Landform

Landform pattern:	Plain
Relief/modal slope:	Plain
Landform element:	Flood plain
Micro-relief:	Even
Slope class (US):	Flat

Surface and Hydrological Properties

Rock outcrop (%):	None
Surface coarse fragments:	None
Physical properties:	50-100 cm soil

Vegetation

Crop:	Rice, flooded/paddy

Land use

Site:	Wet rice cultivation
Surrounds:	Wet rice cultivation

Current Classification

Local Soil Name:	Toul Samroung, no phase specified

Soil profile description

Depth (cm)	Description
0-20	Pinkish grey (7.5YR 7/2 dry) clayey clay; common fine faint yellowish brown (10YR 5/8 moist) redox mottles; very hard consistence, sticky, plastic; pedal, strong, coarse, angular blocky structure; rough-ped fabric; few roots, fine; pH 6 (Raupach and Tucker indicator); very few, fine, low porosity, vughs void.
20-40	Grey (5YR 6/1 dry) clayey heavy clay; dark brown (10YR 3/3 moist) redox mottles; extremely hard consistence, very sticky, very plastic; no roots; pH 6 (Raupach and Tucker indicator); very few, fine, low porosity, vughs void.
40-70	Dark brown (7.5YR 3/2 moist) clayey heavy clay; common medium faint yellowish brown (10YR 5/6 moist) redox mottles; extremely hard consistence, very sticky, plastic; no roots; pH 6.5; few, fine, very low porosity, vughs void.
80-150	Reddish grey (5YR 5/2 moist) clayey heavy clay; dark brown (10YR 3/3 moist) mottles; extremely hard consistence, very sticky, very plastic; few cutans,; no roots; pH 6 (Raupach and Tucker indicator); very few, fine, low porosity, vughs void.

11.2.5 Kouk Tonloab site

Province:	Banteay Meanchey	District:	Mongkol Borei
Commune:	Banteay Neang	Village:	Kouk Tonloab
	GPS coordinates	13.494394° N	103.016711° E

Sampling depths:	0-10, 10-20, 20-30, 30-50, 50-70, 70-100, 100-150 cm
Disturbance:	Strongly disturbed vegetation

Landform

Landform pattern:	Plain
Relief/modal slope:	Plain
Landform element:	Flood plain
Micro-relief:	Even
Slope class (US):	Flat

Surface and Hydrological Properties

Rock outcrop (%):	None
Surface coarse fragments:	None
Physical properties:	50-100 cm soil

Vegetation

Crop:	Rice, flooded/paddy

Land use

Site:	Wet rice cultivation
Surrounds:	Wet rice cultivation

Current Classification

Local Soil Name:	Toul Samroung, no phase specified

Soil profile description

Depth (cm)	Description
0-20	Grey (7.5YR 5/1 moist) clayey clay; common medium faint yellowish brown (10YR 5/6 moist) redox mottles; extremely hard consistence, very sticky, plastic; pedal,; rough-ped fabric; common roots, fine; no coarse fragments; pH 5.5; few, fine, very low porosity, vughs void.
20-40	Dark brown (7.5YR 3/2 moist) clayey clay; common medium faint yellowish brown (10YR 5/6 moist) redox mottles; extremely hard consistence, very sticky, plastic; few roots, fine; pH 6.5; few, fine, very low porosity, vughs void.
40-80	Grey (5YR 5/1 moist) clayey heavy clay; dark brown (10YR 3/3 moist) mottles; extremely hard consistence, very sticky, very plastic; no roots; pH 5 (Raupach and Tucker indicator); very few, fine, low porosity, vughs void..
70-120	Grey (7.5YR 5/1 moist) clayey heavy clay; many coarse faint brownish yellow (10YR 6/8 moist) redox mottles; extremely hard consistence, very sticky, plastic; no roots; pH 7.5.
120-150	Black (10YR 2/1 moist) mixed with clayey heavy clay; common fine faint reddish brown (5YR 5/4 moist) redox mottles; extremely hard consistence, very sticky, plastic; no roots; pH 5.5

11.2.6 Preaek Trab site

Province:	Battambang	District:	Aek Phnum
Commune:	Preaek Norint	Village:	Preaek Trab
	GPS coordinates	13.220244° N	103.299433° E

Sampling depths:	0-20, 20-40, 40-60, 60-120+ cm
Disturbance:	Strongly disturbed vegetation

Landform

Landform pattern:	Plain
Relief/modal slope:	Plain
Landform element:	Flood plain
Micro-relief:	Even
Slope class (US):	Flat

Surface and Hydrological Properties

Rock outcrop (%):	None
Surface coarse fragments:	None
Physical properties:	50-100 cm soil

Vegetation

Crop:	Rice, flooded/paddy

Land use

Site:	Irrigated cultivation
Surrounds:	Irrigated cultivation

Current Classification

Local Soil Name:	Kein Svay, no phase specified

Soil profile description

Depth (cm)	Description
0-20	Brown (7.5YR 4/3 moist) clayey silty clay; extremely hard consistence, slightly sticky, plastic; pedal, moderate, medium, angular blocky structure; rough-ped fabric; few roots, fine; no coarse fragments; pH 6.5; few, fine, low porosity, vughs void.
20-40	Strong brown (7.5YR 4/6 moist) clayey silty clay; firm consistence, slightly sticky, plastic; pH 6.5; few, fine, low porosity, vughs void..
40-60	Strong brown (7.5YR 5/6 moist) clayey silty clay; firm consistence, slightly sticky, plastic; pH 6.5; few, fine, low porosity, vughs void.
60-120+	Pinkish grey (7.5YR 6/2 moist) clayey silty clay; firm consistence, slightly sticky, plastic; pH 6; few, fine, low porosity, vughs void.