Australian Government

Australian Centre for International Agricultural Research

Final report

project	**Improving market engagement, postharvest management and productivity of the Cambodian and Lao PDR vegetable industries**
project number	ASEM/2012/081
date published	24 March 2020
prepared by	Mr Jeremy Badgery-Parker
co-authors/ contributors/ collaborators	Dr Vivian Ku, Mr Gerard Kelly, Mr Tiago Wandschneider, Dr Ben Stodart, Dr Nicola Wunderlich, Mr Heng ChhunHy, Mr Som Bunna, Mr Chuong Sophal, Dr Silinthone Sacklokham, Dr Thongkhoun Sisaphaithong, Mr Bouthsakone Inthalangsee and Mr Sayvisene Boulom.
approved by	Dr Jayne Curnow
final report number	FR2020-006
ISBN	978-1-922345-13-4
published by	ACIAR GPO Box 1571 Canberra ACT 2601, Australia

Contents

1 Acknowledgments

Credit to the entire project team who applied themselves professionally and enthusiastically to a significant research, development and extension program and took on new ideas and challenges throughout and have achieved real learning for themselves and impact for smallholders in Cambodia and Lao PDR.

Thank you to Mr HENG ChhunHy (GDA) and Dr Thongkhoun SISAPHAITHONG (HRC) for their role as project country co-ordinators and team leadership, as well as Mr SOM Bunna (CARDI), Mr Bouthsakone INTHALANGSEE (CASC), Mr Somlit VILAVONG (PAFO), Dr Silinthone SACKLOKHAM (NUOL) for keeping their partnered organisations informed and engaged with the project and Mr CHUONG Sophal (RUA) for so successfully engaging students with the project team and activities.

Special thanks for enabling the project forum events to be such successes go to Dr Tamara JACKSON (Lao 2017 and Cambodia 2017), Ms HEANG Chantou (GDA, Cambodia 2017) and Dr SAMBATH Sonnthida (CARDI, Cambodia 2017, 2018, Lao 2019) and the NAFRI team (Lao 2019). Thank you to Dr OUK Makara (CARDI) for providing additional assistance and staff time to assist in facilitating forums.

I wish to also extend my appreciation to Mr Shaun WAITS (iDE) and Ms Marieke VAN SCHIE (SNV) for their additional in-country support and advice, as well as the international experts (Dr Vivian KU, Mr Gerard KELLY and Mr Tiago WANDSCHNEIDER) who provided component team leadership, as well as technical and mentoring support.

Special thanks are due to Mr PAO Sinath (CARDI), Dr SAMBATH Sonnthida (CARDI), Mr Bouthsakone INTHALANGSEE (CASC) and Dr Thongkhoun SISAPHAITHONG (HRC) for assistance in providing translations for key documents and project outputs.

I wish to acknowledge the co-funding and in-kind support from University of Adelaide, SNV, iDE and to recognise Dr Suzie NEWMAN (formerly UoA) for her vision in establishing this development opportunity.

Finally, I acknowledge the strong support given throughout this project by Mr HO Puthea (Deputy Director, GDA, Cambodia) and Dr Bounneuang DOUANGBOUPHA (Director, HRC, Lao PDR) and Professor Wendy UMBERGER, Executive Director, Centre for Global Food and Resources, University of Adelaide.

Mr Jeremy Badgery-Parker
Research Manager,

Centre for Global Food and Resources,
University of Adelaide

2 Executive summary

In both Cambodia and Lao PDR, there is strong market demand for local, high quality, safe fresh vegetables during the late dry and wet seasons, however, the vegetable industries in both countries face a few shared challenges: (1) low yields and difficulty producing in the wet season; (2) poor competitiveness with regional neighbours; (3) postharvest losses as high as 40%; and (4) product that does not conform to quality and safety demands of consumers.

ASEM/2012/081 supported the development of innovative production and supply chain systems that enable the Cambodian and Lao PDR vegetable industries to meet year-round consumer demand for vegetables. Within this context, the project conducted market and production research to analyse opportunities for better smallholder engagement, determined quality constraints and food safety risks, developed and verified a novel protected cropping design and trialled simple postharvest interventions, invested in capacity and skills of in-country partners and convened a series of regional forums to foster communication and collaboration amongst vegetable industry stakeholders.

The project developed the High Low Plastic Roof Shelter. This structure provides good growing conditions for vegetables year-round, with a payback period of less than a year in most situations and a demonstrated increase in average annual farm income of up to 220%. The real-world change for farmers is that they can increase land productivity, grow more crops per year, actively manage pest and disease risk with preventative practices and target premium price periods for some crops. The significantly higher land and labour productivity also opens opportunities for more inclusion of people with limited resources due to social factors or community expectations and provides good potential for supporting gender equality and inclusive economies.

The development and implementation of a simple market price information system was successful in Cambodia, providing real insights into price movements and generating interest from non-government organisations, the commercial sector and farmers for more pricing data. Mapping of the key components of different vegetable supply chains identified and confirmed significant economic opportunities, particularly in terms of the stable seasonal price variations, which could be exploited by local farmers using appropriate protected cropping systems. A focus on the more perishable leafy vegetables is likely to provide a more resilient and faster economic development pathway.

Farm risk assessments found multiple, potential high-level risks, predominantly related to the inappropriate use of chemicals and a lack of personal/farm hygiene practices. Risk of chemical and/or biological contamination rendering vegetables potentially unsafe for consumption is common. The absence of both cool chain and physical protection of fresh produce postharvest is contributing to significant losses. This can be improved with some simple practice changes which were trialled and proven with the benefit cost ratio of some interventions calculated at approximately 280:1. Overall, actors in the supply chain are unaware of the impacts current practices have on quality and shelf life.

A number of resources were produced and widely disseminated to address knowledge gaps and are available on the *Tropical Research and Information Share Point* (www.tarisp.group) which was developed as a concept platform for soft publishing and sharing research and extension resources across the regional development sector.

Building on this work, in view of changing climate, a resilience farming agribusiness chain approach, using the success of protected cropping and a focus on high quality

leafy vegetables, would garner smallholder security and gender inclusion and capitalise on the opportunities of these developing vegetable industries.

The High Low Plastic Roof Shelter

3 Background

In both Cambodia and Lao PDR, there is strong market demand for local, high quality, safe fresh vegetables during the late dry and wet seasons, however, the vegetable industries in both countries face several shared challenges. These include: (1) low yields and difficulty producing in the wet season; (2) poor competitiveness with regional neighbours; (3) postharvest losses as high as 40%; and (4) product that does not conform to quality and safety demands of consumers.

Although vegetable production in Cambodia and Lao PDR is expanding, the increase in production is vastly insufficient to meet current consumer demand, and safety and quality remain a constraint. Domestic demand is heavily supplemented by imports. The need for smallholders in Cambodia and Lao PDR to meet ASEAN GAP requirements is pressing.

Within this context, the overall aim of ASEM/2012/081 was to support the development of innovative production and supply chain systems that enable the Cambodian and Lao PDR vegetable industries to meet year-round consumer demand for safe, quality vegetables.

There are a number of technical challenges in wet season production, general crop management, produce handling, farm hygiene and postharvest supply chains and to support the meeting of these tasks, financial security and farm resilience are needed.

The project was focussed in Kandal and Kampot provinces in Cambodia with a small presence in Siem Reap, and the peri-urban areas of Vientiane and Champasak provinces in Lao PDR as these regions are engaged in vegetable production and poverty is still relatively high.

Recognised constraints to development of the vegetable industries in these regions include:

- Small scale production, with limited awareness of quality and a reliance on minimal input and limited connectivity to market
- Poor postharvest management, high food safety risks and lack of understanding of market opportunities with fragmented information flow along supply chains
- Adverse weather and growing conditions and minimal knowledge of protected cropping, soil condition and water management and pest and disease management.

With the significant losses known to occur postharvest, the project set out to confirm prominent causes and identify potential interventions. Embedded with this, is a strong focus on food safety and a key issue for the project was to pinpoint safety risks with the view to better managing these risks. To maintain and expand trade options, both countries need to implement ASEAN GAP food safety standards. Whilst this represents a significant challenge for both countries, it is also a catalyst for bringing about change in this area. This project was not focussing on GAP implementation, but seeking to build capacity in food safety, particularly in the area of risk assessment and developing strategies for managing these risks.

This project also conducted market and production research and sought to develop and implement production innovations (including protected cropping and postharvest interventions) as well as improved integrated crop management and food safety strategies to assist farmers to meet these challenges.

This project aimed to gain a better understanding of the market and supply chains in Cambodia and Lao PDR to identify potential opportunities and challenges for smallholder vegetable growers. The key issues were to establish the character of

markets and product flows and the influences of seasonal conditions, produce quality and imports.

Impacting across all these issues, is the capacity to produce crops year-round, and in particular, in the wet season. Crops grown in the wet season are characterised by significant yield and quality losses of around 50% to 90%. Consequently, during these months, supply and quality of local vegetables are lower and farm incomes are limited, even though market prices for some vegetables can be higher during the wet season. There is also increasing demand for fresh vegetables in regional neighbours (Thailand and Vietnam), however Cambodia and Lao PDR have poor competitiveness.

Protected cropping can offer economic opportunities, yet inappropriate protective structures can embed poor practices and chronic inefficiency resulting in diminishing productivity. Low cost protected cropping is beginning to be introduced to smallholder communities and, detrimentally, the most common promoted structures (tunnel houses/quonset) are generally unsuitable for warm humid climates.

This project sought to find a better low-cost design option for the target situation, that could meet production and climate changes and be economically feasible.

4 Objectives

The overall aim of the project is to develop innovative production and supply chain systems that enable the vegetable industry to meet year-round consumer demand for vegetables in Cambodia and Lao PDR.

1. To analyse opportunities and evaluate interventions (including cluster farming) that enable smallholders to successfully engage with and deliver high quality safe product into local and regional markets

- Build research capacity in:
    - market analysis and development including design of research approaches, selection of appropriate methods, sampling and analysis.
    - participatory action research approaches including facilitation skills and the use of clustering for building agro enterprises.
- Analyse local and regional market opportunities for 5 vegetable crops in Cambodia and Lao PDR.
- Map social, economic and biophysical components of 3 vegetable supply chains in each of Cambodia and Lao PDR (with a focus on late dry and wet season production). Determine appropriate interventions to be tested.
- Review clustering approach used in the Philippines in HORT/2006/066/4, refine, contextualise and determine appropriate methodology for implementing in Cambodia and Lao PDR.
- Implement, evaluate and refine clustering approach.

2. To determine quality constraints and food safety risks (pesticide and microbial) in current production systems and develop strategies for delivering high quality safe vegetables to market

- Build research capacity in:
    - postharvest management.
    - food safety including identification of food safety hazards associated with fresh produce, assessing the risk of contamination and developing strategies for dealing with these risks.
- Undertake a participatory risk analysis to identify, characterise and evaluate food safety risks in vegetable production systems.
- Improve disinfestation techniques and postharvest handling practices for fresh produce to minimise the risk of foodborne illnesses.
- Reduce microbiological contamination through improved on-farm practices.
- To determine and deploy appropriate postharvest technology for reducing losses and improving quality turn-out for domestic (Cambodia and Lao PDR) and regional supply chains (Lao PDR).

3. To develop integrated crop management strategies that enable farmers to produce and market vegetables during the late dry and wet seasons

- Build research and extension capacity in:
    - water management.
    - IPM.

    - protected cropping.

- Review the use of low-cost protected crop systems in similar conditions (eg. Philippines and Vietnam) and develop appropriate designs for trialling in Cambodia and Lao PDR.
- Identify optimal varieties for year-round (main season, late dry season and wet season) production of tomato, chilli and 2 leafy vegetables in Cambodia and tomato, chilli and cabbage in Lao PDR.
- Determine potential for extending crop production into the late dry season (April-May) through improved water use efficiency using appropriate water collection and delivery systems and soil moisture management.
- Identify major disease constraints for wet season production. Design and implement management strategies to control major disease issues.
- Optimise management practices for dry, late-dry and wet season production through on-farm replicated and demonstration trials.
- Develop technical recommendations for inclusion in PADEE extension materials and similar programs in Lao PDR.
- Up-scale technical recommendations utilising demonstration trials linked to large scale development projects in Cambodia and through PAFO in Lao PDR.

4. To foster communication and collaboration between government, NGO and private sector vegetable industry stakeholders

- Convene bi-annual vegetable industry forums to: showcase the latest research and development (including technology, practices and market analysis); forge networks between public, NGO and private sector vegetable professionals; provide an opportunity to learn about developments in the region; and facilitate the exchange of ideas on sector development.
- Develop an extension hub/platform hosting research and extension outputs developed by ACIAR and other projects.

5 Methodology

Objective 1. To analyse opportunities and evaluate interventions (including cluster farming) that enable smallholders to successfully engage with and deliver high quality safe product into local and regional markets

Activity 1.1 Build research capacity in market analysis and development

A training needs analysis was conducted by the project and component leader through discussion and evaluation with the component team in each country to identify priority training gaps and a method of approach. Two in-country project team members were supported to participate in a Crawford Fund Agribusiness Masterclass to better gauge learning approaches that could be of benefit in Cambodia and Lao PDR. Training was delivered by the component lead via ongoing participatory mentoring of in-country teams conducting survey and price collection activities in wholesale markets as well as mentoring the process of data analysis and reporting.

Activity 1.2 Analyse local and regional market opportunities for 5 vegetable crops

Wholesaler survey and price data collection activities were conducted in all three vegetable wholesale markets in Phnom Penh (Deum Kor, Neak Meas and Chbar Ampov) and the only vegetable wholesale market in Siem Reap City (Samaki). These locations were selected as Phnom Penh and Siem Reap are the largest[1] and second[2] largest population and commercial centres in Cambodia, respectively. Wholesalers were chosen as the focal point for data collection because of their strategic position in the value chain. The selected crops (providing a cross section of fruit and leafy vegetable) were chilli, tomato, bok choy, lettuce and Chinese kale. Supply chain analyses of the opportunities and constraints for smallholders in Lao PDR were conducted with tomato, chilli, cabbage and coriander selected as focal points.

Activity 1.3 Map social, economic and biophysical components of supply chains

In mapping vegetable supply chains, the approach was taken to integrate with the training and capacity building elements of the project to enable in-country partners to learn and gain experience in key aspects of understanding supply chains. This approach also accommodated the updated views of in-country team members as the activities got underway, market opportunities and practical considerations (logistic and seasonal impacts).

A Market Information System (price data collection) was developed and implemented in Phnom Penh (Neak Meas wholesale market) as a means to better understand the economic elements of selected supply chains. The analysis focusses on price differences between origins, short-term price volatility and seasonal price variations. Understanding of these issues can inform strategies and activities, particularly the selection of vegetables for protected cropping. Wholesale price data was collected for bok choy, fresh chilli (4 types), tomato, Chinese kale and lettuce. In Lao PDR, the price data collection system was developed but was not successfully implemented due to changing personnel and staffing challenges. The quality of data was inadequate and subsequently this activity was ceased.

Biophysical assessment of the supply chains for bok choy, chilli and cucumber (Cambodia) and cabbage, chilli, coriander and tomato (Lao PDR) were undertaken.

- Bok choy – Grown in Kandal province (Cambodia) and supplied to Samaki Market in Siem Reap.

Consignments of produce were tracked from farm to market with quality assessments (leaf yellowing, stem browning, wilting and rotting) conducted at each transfer point. Temperature and humidity loggers and an impact sensor were included in each consignment to objectively measure the physical environment around the produce.

- Cucumber – Grown Kandal province (Cambodia) and supplied to Neak Meas Market in Phnom Penh.

Consignments of produce were tracked from farm to market with quality assessments (weight loss, insect damage, scarring, shrivelling, yellowing and disease) conducted at each transfer point. Temperature and humidity loggers and an impact sensor were included in each consignment to objectively measure the physical environment around the produce.

- Chilli – Grown in Kompong Cham province, Cambodia and supplied to Pailin (Cambodia-Thai border) for export to Thailand.

Due to seasonal impacts on production during the proposed mapping period and a number of farmers choosing to grow different crops at this time, a full biophysical assessment of this crop was not able to proceed so an observation study was conducted for chilli to understand the key postharvest impacts on this produce at each transfer point.

- Cabbage (domestic) – Grown in Champasak province (Lao PDR) and supplied to Vientiane Capital.
- Cabbage (export) – Grown in Champasak province (Lao PDR) and supplied to Songmeak Market (Lao-Thai border) for export to Thailand.

Consignments of produce were tracked from farm to market with quality assessments (defects, rotting, browning, and weight loss) conducted at each transfer point. Temperature and humidity loggers were included in each consignment to objectively measure the physical environment around the produce.

- Chilli – Grown in Kasi district, Vientiane province (Lao PDR) and supplied to Vientiane Capital.

Consignments of produce were tracked from farm to market with quality assessments (deterioration, weight loss, mechanical damage, defects) conducted at each transfer point. Temperature and humidity loggers were included in each consignment to objectively measure the physical environment around the produce.

- Coriander – Grown in Hatxaphong district, Vientiane province (Lao PDR) and supplied to Ozi Wholesale Market, Vientiane.

Consignments of produce were tracked from farm to market with quality assessments (yellowing, disease, wilting, weight loss, mechanical damage) conducted at key transfer points – at harvest, after on-farm storage, arrival at collector's premises and arrive at point of sale. Temperature and humidity loggers were included in each consignment to objectively measure the physical environment around the produce.

- Tomato – Grown in Champasak province (Lao PDR) and supplied to Vientiane.

Consignments of produce were tracked from farm to market with quality assessments (ripening, disease, damage, quality) conducted at each transfer point. Temperature

and humidity loggers were included in each consignment to objectively measure the physical environment around the produce.

Activity 1.4 Review of agro-enterprise clustering for Cambodia and Lao PDR

Activity 1.5 Evaluate and refine clustering approach

In the planning of this project and in recognition of general and government support for collective approaches to building business capacity of small farmers in Cambodia and Lao PDR, it was proposed that lessons from the work undertaken by CRS in Philippines[1], would be harnessed and the 'Eight step agro-enterprise clustering approach' could be refined for the Cambodian and Lao contexts and used to implement a cluster model in each country. The process would be evaluated and involve training of coordinators who in turn could facilitate the development of further groups.

This project task was initially intended as part of PhD research and to inform an approach to in-field development of demonstration groups by the project team, including delivering workshops and training co-ordinators to action the groups. The PhD candidate did not progress. Over the intervening period before this project's research was commenced, many clusters and farmer groups were initiated by various promoters in different agro industries. Anecdotally, farmer groups instigated and promoted through government and non-government development projects were not necessarily sustainable once project or other support was withdrawn. The universal merit of agro clusters was becoming less certain, so a more targeted evaluation of farmer groups was designed, and the project method changed accordingly. In place of physically establishing groups for study, a new research approach was adopted and case study analyses in both Cambodia and Lao PDR seeking to better understand the characteristics leading to success or failure of farmer groups was undertaken.

A qualitative study was designed using a series of guided questions, with mapping and analysis of the organisations and their stakeholders selected as the approach for this research. Checklists were developed for each of the main actor groups (producers, producers' group management, traders) as well as the main supporters (government and non-government organisations) of the respective value chains.

Groups that were not receiving support from any project were selected from different agro industries (organic vegetable, coffee and rice) and studied to enable an understanding of underlying characteristics. In Lao PDR, from each of two provinces (Vientiane and Champasak), one successful (ongoing) group and one failed (closed) group were selected from the target industries, providing a total of six producer groups for the study. Parallel to this study, an overview of the available information and literature on farmer groups in Cambodia was conducted.

[1] Murray-Prior R, et al. 2011. Reducing poverty through participatory action learning and action research processes with smallholder vegetable farmers in Mindanao. Extension Farming Systems Journal 7:2:109-114.

Objective 2. To determine quality constraints and food safety risks (pesticide and microbial) in current production systems and develop strategies for delivering high quality safe vegetables to market

Activity 2.1 Build research capacity in postharvest management and food safety

For the postharvest teams in both Cambodia and Lao PDR, discussions were held with the group leaders to canvass the knowledge areas in which the project activities would involve and to identify individually and as a cohort, the knowledge base and gaps of the project team members as well as their peers. This information was collated and used to determine the content for project training workshops. A program of 4 semi-formal training workshops was compiled for each country to address both postharvest and food safety knowledge and skills gaps in preparation for developing and conducting the research trials. 'Hands-on' training of collaborators throughout field activities and supporting the project team to prepare and deliver training to others outside the project was also a key method of developing in-country skills.

Final year undergraduate students from the collaborating universities – Royal University of Agriculture (Cambodia) and the National University of Laos – were given opportunities to conduct their research thesis studies as part of the project trial activities. Students were informed of the various project activities and guided in selecting appropriate research for their studies.

Activity 2.2 Participatory risk analysis to identify, characterise and evaluate food safety

A two-step process was engaged to better understand food safety risks in the target locations. A desktop review of food safety risks across ASEAN countries was conducted of the potential threats and challenges. Complementary to this review, on-farm risk assessments for several different vegetable farming systems were undertaken.

The risk assessment process consisted of 3 stages. The first stage involved a face-to-face interview of farmers (n=≥30) from each of the selected vegetable systems. On account of the expected limited education levels of the interviewees, most questions were constructed as closed-end questions. The questions were developed from the ASEAN GAP self-assessment checklist from the Food Safety Module[2] and covered a broad range of topics - Site History and Management, Plant Materials, Fertilizers and Soil Additives, Water, Agrochemicals/Chemicals, Harvesting and Handling Produce, Animal and Pest Control, Personal Hygiene, Produce Treatment, Storage and Transport, Traceability and Recall, and Training.

The second stage involved the project team (assessors) conducting a site inspection (of each farm) to identify potential hazards that could result from farm management or farming practices.

The final stage involved the team rating the risks using a conventional consequence and likelihood matrix.

The assessment in Cambodia was conducted in Kandal Province and focussed on two types of vegetable farms – leafy vegetable (n=51) and fruiting vegetable (n=40). The leafy vegetable is used as a model for crops grown close to the soil and the fruiting vegetable (cucumber) provides a model for crops where the harvested portion is away from the soil.

[2] *Good agricultural practices for production of fresh fruit and vegetables in ASEAN countries: Food safety module, 2007*

In Laos, the assessment was conducted in Vientiane Province and focussed on four types of vegetable farms – leafy vegetable (n=60), organic leafy vegetable (n=40), GAP leafy vegetable (n=30) and fruiting vegetable (n=40) (tomato).

Activity 2.3 Improve disinfestation techniques and postharvest handling practices

Activity 2.4 Reduce microbiological contamination through improved on-farm practices

To inform an approach for minimising food safety risks, produce management practices along the supply chain were monitored to determine key practice changes that could provide simple benefits in postharvest handling and safe vegetable production. Farm risk assessment activities (interviews and site inspections) as well as observation of supply chains and training needs analysis discussions were collated to identify recommendations and methods of dissemination.

Training workshop content for postharvest and food safety as well as complementary dual language posters were prepared which focus on key recommendations.

Activity 2.5 Determine and deploy appropriate postharvest technology for reducing losses and improving quality turn-out

In conjunction with the development of recommendations and information content on improved handling practices, practical interventions to address key issues were also identified and evaluated. With the knowledge gained from activity 1.3, which mapped several different supply chains and determined the primary reasons for loss of product postharvest, prominent causes of problems were extracted from the collated data and supply chain observations. From this process, key interventions were identified. These were then tested in the supply chain and evaluated on the basis of reducing produce loss as well as economic feasibility.

Objective 3. To develop integrated crop management strategies that enable farmers to produce and market vegetables during the late dry and wet seasons

3.1 Build research and extension capacity in water management, IPM and protected cropping

A multifaceted strategy was undertaken to build research and extension capacity in focus production areas with the intent to improve the reliability of supply of fresh vegetable. Initially, a series of informal discussions were held with the production teams in both Cambodia and Lao PDR and with the group leaders to canvass the level of awareness and base knowledge on managed environment cropping, vegetable production, irrigation and pest and disease (IPM) issues. This process was aligned with the expected project activities and matched learning needs to expected activities. The outcomes informed the development of tailored training workshop content in protected cropping design and management, irrigation, designing and implementing in-field trials and IPM.

A program of semi-formal training workshops was then compiled for each country to address protected cropping, irrigation and IPM skill gaps in preparation for developing and conducting the project activities. ‘Hands-on’ training of collaborators throughout field activities and supporting the project team to prepare and deliver training to others outside the project was also a key method of developing in-country skills.

Final year undergraduate students from the collaborating universities – Royal University of Agriculture (Cambodia) and the National University of Laos – were given opportunities to conduct their research thesis studies as part of the project trial

activities. Students were informed of the various project activities and guided in selecting appropriate research for their studies.

Activity 3.2 Review the use of low-cost protected crop systems and develop appropriate designs for trialling

A desktop review of low cost protected cropping structures being used in tropical environments and an assessment of key design merits and potential problems was undertaken. This process was used to inform the development of a new design for trial in both Cambodia and Lao PDR. The primary focus was on developing a cost-effective alternative to the poor performing tunnel (Quonset/igloo) structures commonly seen in other countries. These structures are a very poor choice for hot climates and can severely stagnate development of a sustainable industry.

A trial design for a low-cost protective structure was prepared for field evaluation and the teams were guided in sourcing materials and constructing several structures across two provinces in each country with collaborating farmers.

A total of 16 sites (8/country) were used for the design and performance evaluations and these were developed in two phases. This two-step process was used to allow for learning and development of the project team and to accommodate any changes that might be required following the initial performance assessment. The sites were selected through a guided criteria process and review. Armed with key selection criteria, project teams worked with leader farmers and existing project working groups to shortlist sites. These were then jointly reviewed with the project management and technical input to choose final locations.

Ambient and internal growing conditions were then monitored over several seasons to assess performance. Crop trials were conducted and included assessment of the structure impact. The structures were also reviewed in terms of cost, ease of construction, maintenance and durability.

The financial performance of the crops grown was also assessed. Individual crop gross margins were prepared and used to determine the financial outcomes from individual crops, annual crop cycles and for an extrapolated five-year period and related to the investment cost of the structures as well as the opportunity cost of not investing.

A further evaluation of the structures from the farmer perspective was also conducted in Cambodia. A face-to-face interview was used to collect both quantitative and qualitative data. Three study groups are included – (1) farmers who are collaborating directly in the project with a trial greenhouse, (2) farmers outside the project who have some experience with and use another type of protective structure and (3) farmers who do not use any sort of greenhouse.

Activity 3.3 Identify optimal varieties for year-round production of tomato, chilli and 2 leafy vegetables in Cambodia and tomato, chilli and cabbage in Lao PDR

Refer to 3.6 below.

Activity 3.4 Determine potential for extending crop production into the late dry; improved water use efficiency and soil moisture management

With the primary project production focus on the wet season, a preliminary assessment of water related challenges formed the basis of the potential for dry season extension and this was coupled with a training strategy. Alongside a series of practical water management training workshops that was delivered for the project team in both countries, a preview of existing irrigation practices on the collaborator

sites was conducted to inform the training content and a collaborative on-farm dry season trial looking at irrigation and fertiliser application in Siem Reap was introduced with a sister project (SMCN/2014/088 'Integrating soil and water management in vegetable production in Lao PDR and Cambodia') to provide an initial pathway into extending the dry season production. For the water management element, the trial compared three treatments; (1) farm practice of a single 4mm daily irrigation, (2) farm practice splitting the applied volume into two 2mm applications per day and (3) matching the application volume to crop water need (two maturity stages) with a single 4mm daily irrigation (early stage) and a single 6mm daily irrigation (mature stage).

Subsurface drip irrigation

Australian based research into water use efficiency, energy efficiency, satellite based scheduling and basic economics of sub surface drip irrigation was also conducted with the dual aim of improving the application of efficient irrigation technology and providing an inspiration target and technology awareness for in-country partners as an element of capacity building in irrigation practices (drip irrigation).

The five-year demonstration trial with lucerne, compared flood irrigation applied at standard intervals in a border check system (BC), irrigation applied by a centre pivot (CP) at a 30 mm evaporation deficit, and irrigation applied by sub-surface drip irrigation at 60 mm (SSD60) and 30 mm (SSD30) evaporative deficit intervals. All treatments aimed to apply similar quantities of water estimated at 180 mm per cut/harvest The field application rate was 2.5 mm/h and was run for 12 hours on SSD30 and 24 hours on SSD60. The centre pivot was a 5 span T&L brand system with the capacity to apply 15 mm/day, set on a two-day rotation applying 30 mm per pass. The BC system was typically irrigated once or twice between cuts, SSD60 was irrigated two to three times, and the CP and SSD30 were irrigated six times. All other agronomic practices were the same over the five-year period.

Activity 3.5 Identify major disease constraints for wet season production. Design and implement management strategies to control major disease issues

Review and collation of the most common pest and disease problems for each crop of interest, area of research project activity and growing season were compiled in the initial stages of the project through a range of sources including literature, field experience and observation, historical calendars, reports and informal interview. A workshop was held with all project partners to priority rank these issues (for each crop and location).

A series of IPM interactive training workshops were developed and delivered for the project team and were also opened to NGO staff and private enterprises to participate. These workshops centred on common IPM tools and constraints to adoption. This activity was also designed to inform the development of priority training and capacity building research trials.

Demonstration trial: A long-term crop rotation trial was established in Lao PDR.

> Three treatments were assigned with coriander as the primary crop cultivated in protected cropping: (1) *Control* – continuous coriander monocrop, (2) Two crop rotation - coriander and tomato, (3) Three crop rotation - coriander – tomato – lettuce. Yield and financial return, as well as inputs were measured.

Demonstration and capacity building experiments in biological control agents were also undertaken. Specific training for project team members was conducted on identification of key diseases and confirming presence in crops. In Lao PDR , this training integrated with a field disease survey focused on solanaceous crops and a

biological control agent experiment for the control of Bacterial Wilt in tomato. These activities had the dual purpose to build technical capacity of the team and professional linkages between the organisations.

Demonstration trial: Application of biological control agents against bacterial wilt in tomato

> Four treatments were assigned to tomato cultivated in protected cropping under plastic and shade: (1) *Beauveria bassiana* (100g/m^2 preplant in soil and every 10 days as side dress and foliar spray), (2) *Bacillus thuringiensis* (100ml/m^2 preplant in soil and every 10 days as side dress and foliar spray), (3) Physical and soil nutritional control (preplant – cultivate – molasses (1kg/m^2) – cultivate – water (150L/m^2) – plastic cover (3 weeks) – cultivate), (4) single cultivation.

In Cambodia, demonstration trials looking at physical barriers to pests (plastic splash skirt) and the application of biological control agents were planned, however, the failure of trial structures in the first season pushed out schedules for field site activities and these trials were postponed while feasibility work for the protected cropping production took priority.

A field program was developed to complement the production and protected cropping capacity and development activities. IPM training was conducted for farmers and extension staff as part of the field days. Additionally, a series of informal interviews of farmers were conducted during field trips and field days to assess knowledge and skills on crop health, crop rotation, diagnosis of problems, their current access to information about pest and disease identification and management recommendations and what they thought about extension and advisory services and the potential for commercial (fee based) advisory services in future, if it allows for timelier and more personalised location specific recommendations.

A range of agrichemical supply business operators were also informally interviewed on (i) current pest and disease identification practices of their clients, (ii) the current involvement (if any) of agrichemical suppliers into crop problem identification and management and (iv) what they thought about potential to take on a more advanced and trained role in the information value chain – providing commercial (fee based) advisory services as a part of the business.

An extension staff survey was also conducted at field days as a secondary data measure to gauge farmer practices with respect to pest and disease management. All field days also included a pre and post evaluation to assess impact of the activity.

A review of available extension materials was conducted, and new resources were also produced based on the key priorities identified by project teams in both countries and these were cross matched with production activities.

Activity 3.6 Optimise management practices for dry, late-dry and wet season production through on-farm replicated and demonstration trials

As part of the capacity building program, a series of crop trials were conducted in the protected cropping test structures, with the aim being to improve crop trial design and management skills, develop new learning about production and performance of example crops and assess the potential for different crop varieties (types) to be used as part of a year-round protected cropping rotation.

Crop trials (looking at management practice and/or variety of crop) were conducted within the structure assessment process and so all trials also included two of the protected cropping system treatments (plastic, shade or plastic and shade) and a control (open field). Outside rows and edge plants were maintained as buffers. Relevant existing farmer practice was set as the control treatment. Trial design and

treatment complexity were matched with the experience, confidence and available resources of the project partners conducting the work.

Varieties of crops (crop types) initially proposed to be used in project trials were adjusted to accommodate farmer preferences and to target potentially higher value products based on a preliminary return on investment assessment for trial structures.

Activity 3.7 Develop technical recommendations for extension materials

The culmination of the project activities in protected cropping, food safety and postharvest is the provision on key information resources to the project team, their peers and their networks.

The adopted approach was to generate several information formats using the key learnings developed and/or collated via project research and review activities. End user analyses of both primary target groups (in-country partners/professionals and farmers) was used to identify the best options.

In addition to written reports, simple awareness videos, dual language posters and guides focussing on project recommendations were developed through project activities These are made available to in-country partners to support and be freely used in their ongoing work and disseminated to other projects and in-country networks. Dissemination is direct to collaborating NGOs and government organisations, through professional and project networks, via the forum events (Obj 4.1) and the provision of an online resource share point (Obj 4.2) as well as existing online portals.

Activity 3.8 Up-scale technical recommendations utilising demonstration trials

Although the primary activity of this project was set on evaluation and analysis, to action up-scaling of appropriate technologies and practices, trials were dually developed as field demonstrations of protected cropping, drip irrigation, mulching and raised beds as well as different varieties (types) of crops. Trials were located in three provinces of Cambodia and two provinces in Lao PDR and fully run by the in-country partners and in collaboration with local farmers.

A series of field days were conducted at each site coinciding with the demonstration of improved practices and technologies and integrated where available with other projects, organisations, events and personnel.

Technical information, recommendations and resources on protected cropping, integrated pest and disease management, food safety and postharvest practices were planned and collated based on identified knowledge needs and are freely available to provide a precursor to up-scaling opportunities.

A poster series in English, Khmer and Laos on key topics as well as some short videos were produced over the course of the project to provide in-country teams with resources (for farmers) and provide broader awareness of the project developments.

Discussions were conducted with NGO and government organisations over the duration of the project to canvass opportunities for up-scaling outcomes beyond the remit and timeframe of this work.

Objective 4. To foster communication and collaboration between government, NGO and private sector vegetable industry stakeholders

Activity 4.1 Convene regional vegetable industry forums to forge networks between public, NGO and private sector vegetable professionals, and facilitate the exchange of ideas on sector development

Based on a vegetable forum conducted as a part of a previous project, a regular event to facilitate networking and collaboration was proposed. A dual strategy was developed behind this activity. Firstly, through broad consultation with potential participants and actors, the project team sought to determine the underlying need and desire by a wide range of organisations to improve collaborative opportunities and information sharing. This was used to structure the events and resources. The second element involved assessing the financial feasibility of these events and the potential for continuation post project.

Activity 4.2 Develop concept of an extension hub/platform hosting research and extension outputs developed by ACIAR and other projects

A process of informal group feedback conversations was initiated and integrated with general discussions, team meetings and other events with project team members and collaborators throughout the project period. Additionally, the broad consultations with potential participants and actors with respect to the forums (Obj 4.1) were also used to canvass issues relating to an extension platform.

The approach taken was designed to be reflective and was implemented when in-country partners were planning or discussing project activities and drafting reports, with the aim being to raise the issue of ‘once the research or information gathering is complete, how will it be accessible to the target audience?’.

Over the course of the project, multiple team and collaborator discussions illustrated that common views on sharing and accessing extension resources across the region are held, but also that the sustainable development of an extension hub is a perennial problem.

From these talks, simple models were teased out and then added back to subsequent discussions to identify potential challenges and shortfalls. The preferred concept was initiated as a pilot.

6 Achievements against activities and outputs/milestones

Objective 1: To analyse opportunities and evaluate interventions that enable smallholders to successfully engage with and deliver high quality safe product into local and regional markets.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Build research capacity in: 1) Market analysis and development including design of research approaches, selection of appropriate methods, sampling and analysis 2) Participatory action research approaches including facilitation skills and the use of *clustering for building agro-enterprises (capacity building for this activity detailed under 1.4)*	1) Training needs analysis documenting and prioritising training needs and planned approach to addressing these 2) Report from Cambodian and Lao PDR participants of Crawford Agribusiness Master Class detailing approaches that should be incorporated in current study and options for implementing an Agribusiness Master Class in Cambodia and Lao PDR. (3) Research training delivered in market analysis and value chain research approaches	Dec 2014 Mar 2015 Mar 2016	A training needs analysis was conducted in 2014/15 in Cambodia and Lao PDR. Changes in the Cambodian team caused an initial delay to this activity. The identified language and knowledge gaps necessitated a redirection of the training approach towards more practical face to face methodology. Ms Bo Sokum (formerly CARDI) and Ms Chitpasong Kousonsavath (NUOL) successfully completed the Agribusiness Masterclass. The initial training approach (market analysis training workshop) was redirected towards a greater emphasis on face to face training, mentoring and feedback on practical research skills and activities. Training has been provided by value chains expert during the design and implementation of surveys and price data collections during 2015 and 2016. Training is also ongoing as part of continuing survey and price data collection in wholesale markets. Research capacity is being further developed through the process of analysing data and reporting.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.2	Analyse local and regional market opportunities for 5 vegetable crops in Cambodia and Lao PDR	Identification of market opportunities and constraints for small holders in Kandal, Siem Reap and Kampot in Cambodia and Vientiane (peri-urban) and Champasack in Lao PDR.	Apr 2016	The start of this activity was originally delayed due to the late appointment of the project's value chain expert. In Cambodia, scoping visits were undertaken in 2015/2016 to design the wholesaler surveys. A price data collection template was also developed. In March 2016, an inventory of wholesalers of tomato, chilli, bok choy, Chinese kale and lettuce in Phnom Penh and Siem Reap markets was compiled and a sampling strategy defined. The surveys in Phnom Penh were completed in May 2016.
		Report on wholesale price data collection system	Jun 2019	A portfolio of wholesale survey reports was prepared based on the research and a comparative analysis report was prepared from the wholesaler surveys. (Appendices 1 – 6)
		Prepare a comparative analysis on investigated supply chains	May 2019	In Lao, the initial scoping study was undertaken in October 2015 to design the value chain study. A series of checklists were developed for focus groups and semi-structured interviews for cabbage, tomato, chilli and coriander supply chains. This included sampling strategies and methodology for collecting price data. The survey work in Paksong and Vientiane began June 2016.
		Support in-country partners to publish on price differences in veg markets	Jun 2019	
1.3	Map social, economic and biophysical components of 3 vegetable supply chains in each of Cambodia and Lao PDR	Supply chains (social, economic and biophysical aspects) characterised, stakeholders consulted and interventions identified and prioritised	Apr 2016	A series of supply chain reports were prepared on the opportunities and constraints for smallholders selling bok choy, cabbage, chilli (2), coriander, cucumber and tomato. (Appendices 7 – 13) These reports detail the mapping of biophysical characteristics of supply chains. Insufficient production/supply of some crops (tomato and chilli) impacted on mapping activities. Low tomato production in Cambodia in 2015, led the team to map the cucumber supply chain instead. The mapping of chilli was also initially delayed. Low cost imported chilli from Vietnam impacts the market and can significantly affect supply orders from wholesalers. Wholesale price data surveys were also conducted. Preliminary results for daily price collection in Phnom Penh were presented at the 2016 annual project meeting. Daily wholesale price collection in Lao PDR commenced in early 2017. Reports of the price data surveys for selected crops were prepared. (Appendices 14 – 17) In addition, Ms Srey Sinath (CARDI) completed a desk top review entitled 'Market and value chain study gaps'.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.4	Review clustering approach used in the Philippines in HORT/2006/066/ refine, contextualise and determine appropriate methodology for implementing in Cambodia and Lao PDR. 1) Desk top review of relevant literature 2) Key Filipino personnel to visit Cambodia and Lao PDR to meet with project partners and to gain an understanding of the cultural context, attitudes to group formation, opportunities for initiation of groups and to review and refine the agro-enterprise development process to make it relevant to these countries	Literature review Refined agro-enterprise development process for implementation in Cambodia and Lao PDR	Dec 2014 Dec 2017	Ms Bo Sokum (formerly CARDI) undertook a draft literature review with respect to Cambodia and a preliminary overview of clusters with respect to Lao PDR was drafted by Mr Souphalack Inphonephong as a precursor to his candidature for PhD. A literature review on clusters was to be a component of this research, however his study did not progress. Initial delays in the implementation of the market analysis and value chain activities subsequently resulted in this activity being completed later. Discussions with SNV in Cambodia in 2017 and with Filipino cluster development experts culminated in a cluster development workshop and training activity in both Cambodia and Lao PDR in October 2017. Various activities around clusters unrelated to this project occurred in recent years which has expanded the experience base out of The Philippines. Furthermore, due to the reduced project timeframe, the original concept was revised - a refocussed approach to undertake analyses of 'successful' and 'failed' groups was initiated to better understand the factors contributing to group outcomes.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.5	Implement, evaluate and refine clustering approach			These activities were changed at project mid-term and were not conducted, and the idea of coordinators was abandoned.
	1) Selection of Agro-enterprise coordinators	6 AC's selected	Dec 2017	Assessment of existing models, approaches and clusters was used to determine the approach regarding the implementation of adapted cluster models.
	2) Training of AC's in the Philippines	Successful completion of training program		Workshops and training activities on cluster development in both Cambodia and Lao PDR were convened in late 2017. Following this, case study analysis of select farmer groups was conducted. (Appendix 18)
		Further refinement of agro-enterprise clustering approach with specific consideration given to i) group selection & formation; ii) engagement of other supply chain partners in the process; iii) opportunities for linking with FBA's and iv) exit strategy	Jul 2018	
	3) Implementing the adapted cluster model in 1 location in each of Cambodia and Lao PDR	Report on cluster development for each group of clusters	Dec 2018	
		Evaluation of the process		
		Recommendations and refinement of agro-enterprise cluster model		
		Publication of 2 papers in peer reviewed journals		No publications were achieved in this task as the expected PhD and associated research was discontinued.
	Complete a research survey on farmer groups to define characteristics leading to success of failure	Report on attributes of farmer cluster groups	May 2019	

Objective 2: To determine quality constraints and food safety risks (pesticide and microbial) in current production systems and develop strategies for delivering high quality safe vegetables to market.

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Build research capacity in: 1) Postharvest 2) Food Safety including identification of food safety hazards associated with fresh produce, assessing the risk of contamination and developing strategies for dealing with these risks	1)Training needs analysis documenting and prioritising training needs and planned approach to addressing these 2) Four undergraduate final year research students completing their research thesis on projects related to ASEM/2012/081 3) Develop and deliver ToT's 1) Postharvest Workshop 1 & 2 2) Postharvest Workshop 3 & 4 3) Food Safety Workshop 1 & 2 4) Food Safety Workshop 3 & 4 Support in-country partners to deliver further field day on PH/FS and develop ongoing program	Dec 2014 Dec 2018 Dec 2014 Dec 2016 June 2015 June 2017 Jun 2019	A training needs analysis was conducted in 2014/15 in Cambodia and Lao PDR and this informed the content of the training workshops conducted. There was limited prior knowledge in Lao PDR and support in setting up a postharvest laboratory was also provided. Two RUA students completed studies on food safety of production techniques on leafy vegetable and cucumber, respectively, and two student completed final year research projects on evaluating the quality loss and shelf-life of leafy vegetables and cucumber, respectively. Two NUOL students undertook research projects on Risk assessment of leafy vegetables in Vientiane Province and Vientiane Capital, respectively. Postharvest workshops were delivered in both Cambodia and Lao PDR to key researchers and students undertaking postharvest. Dr Ku also provided 'hands-on' training of collaborators during pilot consignments. A food safety workshop was conducted in Cambodia in 2016, and in Lao PDR the training was held in June 2017. The second round of postharvest workshops and training in food safety were completed in 2018 to allow for completion of the mapping supply chain and the evaluation of the risk assessment work first. 'Hands-on' training of collaborators during field activities and supporting the project team to prepare and deliver training to others continued throughout the project. In-country partners directly provided training and materials through training activities to GRET teams and further materials are being developed for a more comprehensive train the trainer program for GRET.

No.	Activity	Outputs/ milestones	Completion date	Comments
2.2	Undertake a participatory risk analysis to identify, characterise and evaluate food safety risks in vegetable production systems	1) Critical review of food safety approaches in SE Asia – their successes and failures and links to ASEAN GAP and other systems 2) Risk assessment completed for 7 vegetable production systems	Dec 2014 Dec 2015	Appendix 19: *Safe vegetable production in ASEAN countries: Status and opportunities for improvement* Appendix 20: *Risk assessment of vegetable production, Cambodia* Appendix 21: *Risk assessment of vegetable production, Lao PDR*
2.3	Improve disinfestation techniques and postharvest handling practices for fresh produce to minimise the risk of foodborne illnesses	Recommendations on improved disinfestation techniques and improved postharvest handling practices to minimise the risk of foodborne illnesses	Oct 2017	Documentation of postharvest handling training for farmers/suppliers/collectors was prepared and formed the basis for extension materials and in-country training. Dual language posters on postharvest handling were produced. These are provided to participants at extension and training events.
2.4	Reduce microbiological contamination through improved on-farm practices	Recommendations on improved on-farm practices to reduce food safety risks	Oct 2018	Documentation of safe vegetable production training for farmers/suppliers/collectors was prepared and formed the basis for extension materials and training. Dual language posters on food safety were produced. These are provided to participants at extension and training events. Appendix 22: *Minimising biological contamination through improved disinfestation techniques, postharvest handling practices and on-farm practices*

No.	Activity	Outputs/ milestones	Completion date	Comments
2.5	To determine and deploy appropriate postharvest technology for reducing losses and improving quality out-turn for domestic (Cambodia and Lao PDR) and regional supply chains (Lao PDR)	1) Losses are evaluated in key supply chains and appropriate interventions determined. 2) Private sector partners are engaged in postharvest research and development 3) Improvements to supply chains (domestic and regional) are tested and evaluated. 4) Recommendation for improved postharvest management are developed. Produce a simple awareness video on recommended practices 5) A full economic analysis is undertaken of postharvest improvements	Jul 2015 Jul 2015 Jan 2018 Jul 2018 Jul 2019 May 2019	Appendix 23: *Postharvest Technology Development for Reducing Losses and Improving Quality Turn-out for Supply Chains in Cambodia and Lao PDR* A number of organisations were involved in discussions throughout the project to date with the most promising collaborations coming from *BeFresh* who are pursuing further trials to assess the in situ use of ethylene absorbent sachets. In addition to developing recommendations, ongoing training activities were conducted by in-country partners. Dual language posters on postharvest handling and food safety were produced: *Postharvest handling of vegetables; Producing safe vegetables.* These are provided to participants at extension and training events. (Appendix 24) A photo video for Lao PDR was produced to facilitate dissemination of key messages. *9 simple steps for safe, quality leafy produce in Lao PDR* [English] https://www.youtube.com/watch?v=3iXK2rHgaEU&feature=youtu.be [Lao] https://youtu.be/GnOa3WAoy6g A photo video for Cambodia was produced to facilitate dissemination of key messages. *9 simple steps for safe, quality leafy vegetables in Cambodia* [English] https://www.youtube.com/watch?v=hqj9UYAytaM [Khmer] https://www.youtube.com/watch?v=FePxXBS_9ig Appendix 25: *Economic analysis of postharvest improvement for bok choy and tomato in Cambodia and Lao PDR*

Objective 3: To develop integrated crop management strategies that enable farmers to produce and market vegetables year-round (particularly during the late dry and wet seasons).

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Build research and extension capacity in water management IPDM and protected cropping			
3.1.1	Undertake a training needs analysis of collaborating research, extension and NGO staff	Training needs documented, prioritised and training program developed	Dec 2014	A training needs analysis was conducted in 2014/15 in Cambodia and Lao PDR. A series of informal discussions were held with the production teams in both Cambodia and Lao PDR and with the group leaders to canvass the level of awareness and base knowledge on managed environment cropping, vegetable production, irrigation and pest and disease (IPM) issues. This process was aligned with the expected project activities and matched learning needs to expected activities. An increased emphasis on specific crop management was incorporated into the ongoing training program and research activities as significant knowledge gaps were identified. (Appendix 26)
3.1.2	Identifying, developing and mentoring final year RUA and NUOL students undertaking project linked research projects in water management, IPDM and protected cropping	At least 8 final year undergraduate students complete their research thesis on project related activities in water management, IPDM or protected cropping	Oct 2018	Four students undertook project-linked research in 2015. Unfortunately, delayed construction and damaged to the structures in Kandal Province caused two thesis projects to fail. These students completed new projects in 2016 alongside another four students. A further eight students conducted project-linked research in 2017 bring the total of students involved in project research trials to sixteen Topics included impact of protected cropping, impact of plant density, lime application, tomato pollination.
3.1.3	Design and deliver ToT workshops on protected cropping, IPDM and water management	PC workshop 1&2 PC workshop 3&4 WM workshop 1 WM workshop 2&3 WM workshop 4&5 IPDM workshop 1&2 IPDM workshop 3&4 IPDM workshop 5	Mar 2015 Nov 2017 Jan 2015 Jan 2016 Jan 2017 Sep 2017 Jun 2018 May 2019 Aug 2019	Project start delays pushed back the initial training schedule and subsequently there were some ongoing schedule changes to co-ordinate with field and trial activities. 7 x Protected Cropping (97 pax) 1. Phnom Penh, CARDI, 2015 2. Vientiane, HRC, 2015 3. Paksong , 35km Res Stn, 2015 4. Vientiane, HRC, 2017 5. Phnom Penh, GDA, 2017 6. Phnom Penh, GDA, 2018 7. Vientiane, HRC, 2018 6 x Water Management (132 pax) 1. Vientiane, HRC, 2016 2. Phnom Penh, CARDI 2016 3. Kampot, on farm 2018 4. Siem Reap, on farm 2018 5. Champasak, 35km Res Stn 2018

No.	Activity	Outputs/ milestones	Completion date	Comments
				6. Vientiane, HRC 2018 5 x IPDM (72 pax) 1. Kandal, 2018 2. Phnom Penh, CARDI, 2018 3. Vientiane, HRC, 2018 4. Phnom Penh, RUA & GDA, 2018 5. Champasak, 35km Res Stn, 2018 Additional training with production, food safety and postharvest teams was conducted on delivering farmer field days. 5 x Effective farmer field day (121 pax) 1. Vientiane, HRC, 2017 2. Phnom Penh, CARDI, 2017 3. Vientiane, HRC, 2018 4. Kandal, CARDI & GDA, 2018 5. Kampot, CARDI & GDA, 2018 The in-country partners also delivered their own protected cropping training for other organisations/projects based on this initial train the trainer program.
3.2	Review the use of low cost protected crop systems in similar conditions (eg Philippines and Vietnam) and develop appropriate designs for trialling in Cambodia and Lao PDR			
3.2.1	Assess efficacy of existing structures used in similar situations	Review of protected cropping structures in SE Asia	Sep 2014	Appendix 27: *Review of Low Cost Protected Cropping (LCPC) for Cambodia and Lao PDR* Design recommendations to be evaluated in field trials were included. A double module design with split roof heights, incorporating a fixed vent space and a wide span. A plastic covered area and a shade covered area are both being evaluated. Detailed designs were developed, and 8 structures were erected in 4 locations each in Cambodia and in Lao PDR.
3.2.2	Prepare suitable protected cropping options for trialling	Designs developed for evaluation and use in focus locations	Apr 2015	
3.2.3	Evaluate protected cropping structures in use in focus locations	Report on physical and economic values of test structures Finalise economic return on investment models with crop rotation case studies to illustrate economic feasibility	Dec 2016 July 2019	Conditions within the structures and in an adjacent open field trial area were monitored continuously from construction. Air temperature and relative humidity data was used to gauge the performance of the structures in terms of growing conditions as well as crop trials). The structures were also assessed for construction issues and subsequent damage during the season. Appendix 28: *Cambodia first season structure performance* Appendix 29: *Lao PDR first season structure performance* Studies of the costs of production for selected crops and investment outlook for projected cropping were

No.	Activity	Outputs/ milestones	Completion date	Comments
				undertaken. Several gross margins budgets were prepared. Appendix 30: *Gross Margins Vegetable Crops Cambodia 2019* Appendix 31: *Gross Margins Vegetable Crops Lao PDR 2019*
3.2.4	Develop appropriate protected cropping designs for use in Cambodia and Lao PDR	Report on protected cropping designs that best offer practical feasibility and economic viability for use in Cambodia and Lao PDR Prepare a construction guidebook and simple video for building structures Support in-country partners to develop and conduct construction training Conduct farmer feedback conversations to determine experiences and adoption opportunities with structures	Dec 2018 Jul 2019 Jun 2019 May 2019	Appendix 32: *Analysis of Crop Production with a High Low Plastic Roof Shelter* Appendix 33: *Construction guide: High Low Plastic Roof Shelter* There is also a Khmer version. A Lao translation was not completed. Two photo videos for Cambodia and Lao PDR were produced to facilitate dissemination of key messages: *Rain shelters for growing vegetables* [English] https://www.youtube.com/watch?v=MToxL4sH5yU&t=2s [Lao] https://youtu.be/Pge8pbYuiTY [Khmer] https://www.youtube.com/watch?v=4XUxhS6a1CA *Building a High Low Plastic Roof Shelter* [English] https://www.youtube.com/watch?v=icDRe_BQ-bI&t=2s [Lao] https://youtu.be/zRT6HDTRdGc [Khmer] https://www.youtube.com/watch?v=s5QPOyNlUiQ Appendix 34: *Benefits and Farmers' Perception of 'High Low Plastic Roof Shelter': Key Findings from a Survey of Growers in Kandal And Kampot Provinces*
3.3	Identify optimal varieties for year-round (main season, late dry and wet season) production of tomato, chilli and 2 leafy vegetables in Cambodia and tomato, chilli and cabbage in Lao PDR	Field variety evaluations are conducted in Cambodia (Kampot, Siem Reap) and Lao PDR (peri-urban Vientiane and Champasak) Field and market evaluations for screening trials completed	Dec 2017	Twenty-eight field trials looked at a variety of crops* grown in the protected cropping environments with a range of treatments applied. These trials provided a stage for practical component of the training program with a focus on the identified knowledge gaps and helped collaborators build field research skills as well as gain management experience of protected cultivation of vegetables. Field trial notes in Appendix 35. *There are mixed concepts with respect to 'varieties'. Western agriculture defaults to assume crop varieties is about different varieties/cultivars of the same species, while a broader notion is a 'variety/range of crops'. In this project, local partners assumed the broader concept, and this

No.	Activity	Outputs/ milestones	Completion date	Comments
				was adopted as it was also a better match with training needs, analysis of protective structures and project resources. Subsequently, evaluations for screening trials were redundant, however, crop selections were negotiated between farmers and collaborators with a focus on potential crop value (market evaluations) as the economic considerations are important to the feasibility of protected cropping and crop rotations (field evaluations) were factored in to improve IPDM outcomes. Additionally, baseline data was collected from 80 farmers and 19 vegetable crops. This activity integrated with Obj3.6
3.4	Determine potential for extending crop production into the later dry season (April-May) through improved water use efficiency using appropriate water collection and delivery systems and soil moisture management			
3.4.1	Evaluate different irrigation strategies through a series of on-farm replicated and demonstrated trials in Siem Reap (Cambodia) and Champasak (Lao PDR)	1) Project team are competent at using soil moisture monitoring equipment and class A pan for irrigation scheduling 2) Replicated and demonstrated trials designed, conducted and compared 3) Economic analysis completed comparing the different irrigation strategies	May 2015 May 2017 Dec 2017	Limited availability for travel by the projects' irrigation component expert forced some delays. Irrigation application rates were targeted in initial field demonstrations and discussions with a view to build on this with soil moisture monitoring and low-cost sensors. The expected dissemination and field testing of the Chameleon soil moisture meter (used in project LWR/2014/029) was not possible. Soil moisture sensors were placed at field sites. Six water management training workshops included a focus on soil moisture monitoring. 1. Vientiane, HRC, 2016 2. Phnom Penh, CARDI 2016 3. Kampot, farmers 2018 4. Siem Reap, farmers 2018 5. Champasak, 35km Res Stn 2018 6. Vientiane, HRC 2018 Drip irrigation systems were installed in protected cropping trial sites and an irrigation trial was integrated into project trials with complimentary project SMCN/2014/088 in Siem Reap.

No.	Activity	Outputs/ milestones	Completion date	Comments
3.4.2	Subsurface Drip Irrigation (SSDI) trial and scheduling development 1) Determine and publish WUE, energy use and net profitability of SSDI lucerne hay compared to flood irrigation. 2)Determine and publish minimum energy requirements for SSDI compared with flood and spray irrigation 3)Development of scheduling tools (in the form of an automated spreadsheet and/or iPhone app) for highly efficient irrigation systems that are at higher risk of management mistake from variable and high evapotranspiration (Australia)	WUE determined and results published Energy requirements for SSDI determined and results published Scheduling tool application developed and released	Dec 2016 Dec 2016 Dec 2017	Appendix 36: *Subsurface Drip Irrigation (SSDI) demonstration and scheduling development* Irrisat app in google engine has been developed in conjunction with another project and its adaptability to lucerne and vegetables has been ground truthed and further developed. The App is live. More than a hundred users are currently trialling it - https://irrisat-cloud.appspot.com/#.
3.5	Identify major disease constraints for wet season production. Design and implement management strategies to control major disease issues.			
3.5.1	Determine major pest and disease constraints in wet season (Cambodia & Lao PDR)	1) Pest and disease survey locations selected and survey designed. 2) Surveys conducted over growing season. 3) Data collated and integrated into related objectives	Oct 2015 Oct 2015; 2015; 2017; 2018;2019 Oct 2019	Surveys in Cambodia and Lao PDR were conducted at sites selected for protected cropping structures, and in surrounds, during growing seasons by project team researchers. (Appendix 37) Collaborative work across partner country institutions ensured coverage of locations & development of skill sets. Collaboration with participating growers provided in-field training for identification of disease constraints & adaptive framework for partner country staff when new constraints were put forward by growers. Linkages were established between HRC and PPC in Lao PDR to enable research and diagnostic capabilities. Techniques for planning, collecting, storing, documenting, identifying specimens were taught and applied by the project team during all field surveys.

No.	Activity	Outputs/ milestones	Completion date	Comments
				Surveys and farmer interviews identified a lack of access to personnel with knowledge on how to grow a healthy crop, how to diagnose crop problems and to obtain crop pest and disease management information. A common issue for both Cambodia and Lao PDR is the lack of resources for government extension or advisory staff to visit farms in a timely manner when crop problems occur.
3.5.2	Implementation of management trials under glass-house conditions	1) Pest and disease models selected. 2) Trials designed and established at CARDI & PPC. 3) Data collated and integrated into extension materials Examination of knowledge & perceptions of IPM. 4) Disease management workshops.	Jul 2017 Mar 2017;2018; 2019 Nov 2017;2019 Oct 2019	To accommodate a delayed start of IPM component, all activities were combined with 3.5.3 (and dove-tailed with 3.3/3.6) so that all trials were conducted under protected cropping structures. To evaluate management options, field visits incorporated grower discussion to determine knowledge and utilisation of pest management practices. Excursions to farmers' fields and interviews with farmers and extension staff in project areas highlighted that there are existing practices and/or interest in alternatives to chemical pest and disease management options. In general, farmers were open to learn more about various IPM tools potentially available to them. Despite a history of training and implementation of projects for IPM, adoption of practices was low. IPM workshops with partner country staff and representatives from private enterprises were conducted in Lao PDR and Cambodia to identify potential constraints for the adoption of IPM. Five 'IPM tools' training workshops delivered complementing field surveys, site visits and field days: 5 x IPDM (72 pax) 1. Kandal, 2018 2. Phnom Penh, CARDI, 2018 3. Vientiane, HRC, 2018 4. Phnom Penh, RUA/GDA, 2018 5. Champasak, 35km, 2018 Project team in Lao PDR led activities, identifying management options and research questions for trials. Research trials were established in Vientiane Capital and Pakse, in collaboration with PAFO and PPC. Crop rotation and the application of biocontrol agents were the major themes. HRC Crop rotation trial was used for grower workshops to demonstrate
3.5.3	Implementation of management trials under field conditions	1) Research questions finalised and trials designed. 2) Trials established by 3) Trials assessed and data collated.	Mar 2017 Apr 2018 Nov 2018; Oct 2019	

No.	Activity	Outputs/ milestones	Completion date	Comments
				benefits of the management approach. HRC committed to a long-term trial for crop rotation. Some misunderstanding of trial design and experimental procedure led to PAFO abandoning the biocontrol trial established in Pakse. Cambodia's trials were not established as they did not have sufficient access to a protected cropping structure and considered use of farm sites for this work to be too high a risk.
3.5.4	Implementation of seed health checks	1) Methodology assessed and selected 2) Experiments designed and conducted at GDA 3) Results collated and assessed	Not completed – activities varied	In consultation with project teams, based on resources and needs analysis, and in consideration to projects conducted by other agencies, implementation of seed health checks was not undertaken. Upon review, it was found that improvements in the overall production of nursery material could be achieved initially with production of training material included in 3.7. Seed health check training was also implemented in projects funded by other agencies and so more training was redirected to IPM tools to avoid duplication of activities.
3.6	Optimise management practices for dry, late-dry and wet season production through on-farm replicated and demonstration trials	Field evaluations of low cost protected cropping systems (Kandal, Kampot) and improved technologies (Siem Reap, peri-urban Vientiane & Champasack) are conducted. Support and plan development of ongoing field day program on PC, IPM and PH/FS.	May 2015; May 2016; May 2017; May 2018 Aug 2019	This activity integrated with Obj3.3, 3.5 and 3.7 Training workshops were conducted to build knowledge and crop management skills. Sixteen protected cropping trials sites were set up. Twenty-eight production focused cropping trials investigated different management problems and potential solutions, as well as IPM biological control agent trials and crop rotation trials, were conducted with high low plastic roof shelters at the demonstration sites. 6 Field Days were run at trial sites; Kandal (1), Kampot (2), Vientiane (2), Paksong (1) (150 pax).
3.7	Develop technical recommendations for inclusion in PADEE extension materials and similar programs in Lao PDR	Technical packages on production, irrigation & disease management are developed and released Collate recommendations and extension	Dec 2017 Jul 2019	In collaboration with the knowledge transfer group of East West Seeds, existing Khmer language grower guides were evaluated for content and suitability for growers practicing protected cropping. Recommendations for adjustment to information and training associated with grower guides was put forward for Cambodian agencies to consider. Lao PDR has not been part of East West Seeds Knowledge Transfer portfolio previously. Engagement

No.	Activity	Outputs/ milestones	Completion date	Comments
		materials for dissemination Produce poster package	May 2019	between HRC/PPC and EW Seeds KT contributed to Lao PDR being added to the suite of countries covered under the 'Grow How' section of EW Seeds KT website. The Lao PDR landing page for EW Seeds KT Grow How section went live in November 2019. A portfolio of project resources was prepared, accommodating the various elements of the project and target audiences: ➢ Construction guide (English, Khmer) (Appendix 33) ➢ Videos (English, Khmer, Lao) • Rain Shelters for Vegetable Production (Benefits of Greenhouses) • Building a High Low Plastic Roof Shelter (Greenhouse construction) • 9 simple steps for safe quality leafy produce in Lao PDR • 9 simple steps for safe quality leafy vegetables in Cambodia ➢ Project Posters (English, Khmer, Lao) (Appendix 39) • Benefits of Greenhouses • Greenhouse Design • Cladding & Crop Selection • Crop Rotation • Postharvest handling • Producing safe vegetables ➢ HRC Scientific Posters • Coriander Production • Tomato Production • Broccoli Production • Lettuce Production • Greenhouse Design Construction • Economics of Greenhouse Vegetable Production • Research & Development of Greenhouse ➢ Training workshops ➢ Field Days & Technical workshops • Program/content (+market engagement) & lesson plan ➢ Economic Case Studies (Appendix 32)

3.8	Up-scale technical recommendations utilising demonstration trials linked to large scale development projects in Cambodia and through PAFO in Lao PDR	Field demonstration sites of new varieties/crops, drip irrigation, plastic mulch, raised beds and protected cropping are established in Kampot, Siem Reap, peri-urban Vientiane and Champasak Conduct series of field days at each site coinciding with demonstration of improved practices and technologies Technical packages on integrated crop management are developed and released (including fact sheets and posters) Support partner organisation to develop further PC demonstration trial and training opportunities Facilitate inclusion of technologies and recommendations into upscaling programs Facilitate in-country teams to draft impact plans for PH/FS and PC	Dec 2018 Oct 2019 Oct 2019 Aug 2019	Activities linked with Obj3.1, 3.3, 3.5 and 3.7 throughout project in training activities and resource development including: • 3 Technical Workshops; Kampot 2018, Vientiane 2018 & Paksong, 2018 aimed at extension workers, agricultural college staff, university staff, other research centre staff (90 pax) • 6 Field days; Kandal, Kampot (2), Vientiane (2), Paksong (150 pax) • 4 Regional Vegetable Forums; Vientiane, 2017 and 2019, Phnom Penh, 2017 and 2018. (622 pax) • Farmer visits to research site (443 pax) • Formal visitors (project/govt/ngo) to research site (151 pax) • 31 Agricultural students • Training events delivered off site to other projects; Lao (5), Cambodia (4) • Greenhouse management training delivered to out of project audience; Lao PDR (100), Cambodia (77) • 1 International Conference presentation; Green KOREA Conference 2017 • 1 National University forum presentation; Scientific Forum of Agriculture Research and Innovation, NUOL 2018 • Construction guide (English, Khmer) • 4 Videos (English, Khmer, Lao) • 6 Project Posters (English, Khmer, Lao) • 7 HRC Scientific Posters • Economic Case Studies Several impact activities have been conducted by in-country partners including providing training and materials through to GRET and SNV teams. GDA and CARDI hosted GRET to visit the Kampot protected cropping trials and postharvest laboratory facilities. Discussions were held with NGO and private partners to develop upscaling opportunities (SwissContact and iDE). EastWest Seeds adapting their existing knowledge transfer materials with project input.

Objective 4: To foster communication and collaboration between government, NGO and private sector vegetable industry stakeholders.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Convene bi-annual vegetable industry forums 1) Develop implementation plan 2) Initiate cross-sector organising committee 3) Attract external funding and sponsorship for events 4) Develop program 5) Deliver forums 6) Review forums and make recommendations for improving future events 7) Produce electronic proceedings for each forum 8) Implement smaller focussed forums in interim year	Implementation plan Committee External funding Program and keynote speakers identified Forums delivered Report including recommendations Proceedings Implement smaller focussed forums in interim year Support Lao team to deliver a further regional vegetable forum	Jul 2017 Jul 2017 Sep 2017 Nov 2017 Jan 2018 Nov 2018 Oct 2019	Four regional vegetable forums were convened by the project (612 participants). These events were enabled by the project team and were supported with external sponsorship. The over-riding theme of the forum program was sharing knowledge to promote development of the vegetable sector. **Fostering a safe and sustainable vegetable sector, Phnom Penh, 2017** **Fostering a safe and sustainable vegetable sector, Vientiane, 2017** In conjunction with each of these forums, a technical workshop was held on forming farmer groups and agri-clusters – *Developing and implementing successful partnerships in the vegetable sector*. **Innovations of production and supply chain systems for improved off-season vegetable, Phnom Penh, 2018** **Supporting the adoption of improved practices and new technologies by smallholders for sustainable year-round production of safe fresh vegetables, Vientiane, 2019** The Tropical Agriculture Research and Information Share Point www.tarisp.group was also launched at this event.
4.2	Develop an extension hub/platform hosting research and extension outputs developed by ACIAR and other projects 1)Liaison with other projects particularly PADEE, HARVEST and CAVAC to determine resource available for horticultural extension hub 2)Liaison with public, NGO and private sector partners to determine the	Database of horticultural extension outputs Recommendations for what the extension hub should look like Concept note developed Initiate a pilot open publication portal hosted by partner organisations to facilitate online publication of short communications, research notes	Dec 2017 Feb 2018 Jul 2018 Jul 2019	A range of discussions were held throughput the project. Key challenges are the temporary nature of projects, absence of a 'permanent' facilitator and inconsistent funding. Convening a regular forum has similar challenges. As a component of the forums, a forum handbook was prepared which collated agencies, companies and NGO projects as a form of directory to aid collaborations and awareness. The general concept of approaches to providing an online and free means of sharing resources was revisited several times by the project teams and a pilot online share point was developed by the project team. The concept behind this share point is to enable an open access site for agricultural communications and the sharing of research, trial reports, short communications and extension resources on tropical agriculture. Multidisciplinary articles, student reports and freely available extension and

No.	Activity	Outputs/ milestones	Completion date	Comments
	best option for a consolidated extension hub 3)Development of an extension hub concept and timeline for implementation	and research trial reports Support in-country teams to write and publish short communications, research notes and trial reports		learning materials related to agricultural and vegetable development in the tropics are welcomed. People can share (upload) resources and reports and preview and download shared resources. The online concept platform is operational and called "Tropical Agricultural Research and Information Share Point' or TARISP. www.tarisp.group

7 Key results and discussion

Objective 1. To analyse opportunities and evaluate interventions (including cluster farming) that enable smallholders to successfully engage with and deliver high quality safe product into local and regional markets

Activity 1.1 Build research capacity in market analysis and development

Initial training needs assessment indicated the project teams were aware of concepts and generally across theoretical elements but did not possess enough research skills and were not ready for a higher-level market analysis training course that was part of the project planning. Two partners were selected to participate in the Crawford Agribusiness Master Class to further develop their understanding of research approaches that could be undertaken. Following this review of the situation, it was decided that the project would conduct a hands-on, mentoring training approach of project partners. Subsequently, instead of a formal program and in place of delivering further group training, a range of market analysis research activities were developed and a practical training approach to market analysis and value chain research was pursued to accommodate the greater learning needs of the team.

The small teams worked alongside the component lead to conduct analyses of the initial supply chains and reports were drafted as templates. With subsequent analyses, the component lead stepped back to providing guidance and mentored our market research teams as they took the lead on the analyses and drafted the reports. This strategy capitalised on existing knowledge and capacity of the researchers and supported practical exposure to the science and necessary skills, while completing comprehensive research.

Training via a practical hands-on method was also adopted for the other market research elements and formed a key part of the survey and price data collection undertaken in wholesale markets.

Personnel changes over the first half of the project caused some significant delays in activities, however, the impacts on project outputs would have been more significant had a more linear training approach been followed. The adopted practical guidance training strategy provided an existing framework that enabled the project team to cover resource and capacity gaps when they became evident. It is important to note, that this mentoring approach to training would not have worked as well without the good understanding of the pre-existing knowledge base. The proposed research activities, and required knowledge and skills, need to be well defined and the mentor/s must be adaptable.

This training approach worked well in this instance as the initial needs analysis involved significant in-depth personal discussions and enabled the component lead to gain a detailed understanding of where team members' skills were placed and the personal confidence levels of the individuals.

Potential problems such as activity inertia and poor data quality that can result from limited technical supervision, can be common with training and development projects involving off-site expertise. The adopted practical training model proved highly valuable in this instance as research activities were able to start quickly as the mentor/trainer can lend their own experience and confidence to the newer researchers. Additionally, the ongoing guiding expertise can make necessary and timely decisions to minimise wasted resources in situations where the research is not proceeding well.

The process of hands-on collecting and analysing data and reporting was a key part of building research capacity and is demonstrated through the subsequent ownership

and leadership by in-country partners of market research activities in the later part of the project.

Activity 1.2 Analyse local and regional market opportunities for 5 vegetable crops

Market analyses, undertaken in conjunction with and as a foundation to the training and capacity building, sought to identify market opportunities for smallholders in the target provinces in both Lao PDR and Cambodia and to understand the constraints to greater market engagement.

The analyses showed that vegetable wholesalers operate in highly fragmented, very crowded markets, characterised by intense competition and a lack of product and functional specialisation. Large numbers of small and informal wholesaling businesses compete selling a variety of vegetables to a large and very diverse customer base.

Large buyers are conspicuously absent from wholesalers' customer portfolios who mostly sell to a variety of traditional retailers. Only a minority supply supermarkets. The modern retail segment in Cambodia is expanding but remains very small. Sales to hotels are common in Siem Reap on account of its large tourism sector.

Proportion (%) of Phnom Penh wholesalers who supply markets out of the city

	Phnom Penh	Siem Reap
Tomato	80	36
Chilli	77	29
Chinese kale	88	14
Bok choy	85	17
Lettuce	78	25

Wholesale traders perform various marketing functions besides primary and secondary wholesaling. Most are acting as retailers, directly supplying consumers. Numerous leafy vegetable wholesalers in Phnom Penh are directly involved in farm production and collection activities.

Phnom Penh not only stands out as a vegetable consumption centre, it is the main vegetable market in Cambodia and is also an intermediary distribution hub, attracting large quantities of produce that are subsequently wholesaled to other provinces across the country.

Proportion (%) of Phnom Penh wholesalers trading produce of different domestic origins

	Kandal	Other Provinces
Bok choy (N = 13)	100	0
Chinese kale (N = 17)	100	12
Lettuce (N = 13)	92	8
Chilli (N = 26)	78	88
Tomato (N = 25)	36	0

Yet, relatively few Cambodian farmers are accessing this market. There is strong presence of imported produce, with Vietnam accounting for a high share of the Phnom Penh market for fruit vegetables such as tomato and chilli, while most or all supply of dry vegetables such as garlic, onion, shallot, potato and carrot comes from China.

One single district in Kandal (S'ang) accounts for a disproportionate share of the supply of leafy vegetables. Farmers in S'ang have a strong competitive edge in Phnom Penh because of geographical proximity and close ties to wholesalers, who often live in the same or a neighbouring village. Direct sourcing from farmers is the norm amongst leafy vegetable wholesalers in Phnom Penh, with village collectors in Kandal and other wholesalers in the city. Tomato is quite different with most supplies

imported from Vietnam. Only a minority of Phnom Penh wholesalers purchase tomato from farmers or village collectors.

Chilli procurement chains are more diverse, as both domestic and imported origins are widely traded. Wholesalers in Phnom Penh tend to rely on farmers and collectors for supplies of Cambodian chilli and on other wholesalers, importers and/or suppliers in Vietnam for imported chilli.

Wholesaler survey locations

Procurement of vegetable in Siem Reap City is quite different as illustrated by the leafy vegetables sector. The main suppliers are wholesalers in Phnom Penh or local wholesalers who bring leafy vegetables from the capital. Only a minority of wholesalers buy these vegetables from farmers and village collectors due to limited production within the province and neighbouring areas.

A highly skewed geographical distribution of domestic supplies is an important reason why so few farmers across Cambodia are supplying vegetables to the capital. These studies illustrate that market access is a significant challenge for farmers in almost all regions other than Kandal and there is a need to develop effective and efficient supply chains for vegetable sectors to develop.

Cambodia is normally depicted as a country that relies heavily on imports to meet its vegetable consumption needs. While such assertion is true, it does not apply to all vegetable types. Cambodia is nearly self-sufficient in the production of highly perishable leafy produce, for example, as domestic growers can take advantage of proximity to market, supplying a fresher product, with better appearance and longer shelf life, than importers.

> (See Research Report – Structure and conduct of vegetable markets in Cambodia, Appendix 6)

Activity 1.3 Map social, economic and biophysical components of supply chains

Mapping of the key components of different vegetable supply chains identified and confirmed significant economic opportunities, particularly in terms of the stable seasonal price variations, which could be exploited by local farmers using appropriate protected cropping systems. Prices for all model crops showed clear

Vegetables		Origins	Grades	Prices	Traders	Data collection period
Chilli	4 types	Cambodia, Vietnam	No	Daily wholesale selling price (around 13:00)	2	1 April 2016 - 31 March 2019 (3 years)
Tomato	1 variety	Cambodia, Vietnam, Thailand	Unripe		2	
Lettuce	standard	Cambodia	No		2	
Chinese kale	standard	Cambodia	No		2	
Bok choy	standard	Cambodia, Vietnam	No		2	

seasonality. The Market Information System in Cambodia focussed on 5 crops. The study improved current understanding of price seasonality, the reliability of this seasonality and the impact of origin price.

For all chilli types analysed in Cambodia, marked inter-seasonal price differences (figure 1) were identified indicating potential economic benefits could be realised through targeted production schedules. However, chilli prices are heavily influenced by market conditions in Vietnam, which is the dominant origin of chilli sold in Cambodia. Protected cropping is likely to enable Cambodian farmers to increase the supply of chillies during high-price periods by establishing crops during the rainy season. Price curves are generally aligned across the product category.

(see Research Report: Wholesale price patterns for chilli in Phnom Penh, Cambodia, Appendix 15)

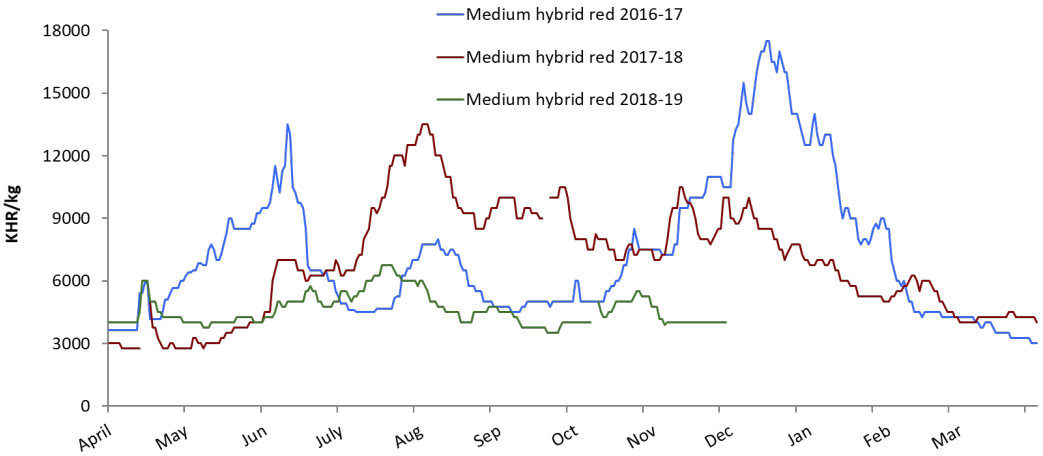


Figure 1: Seasonal price patterns - medium red hybrid chilli

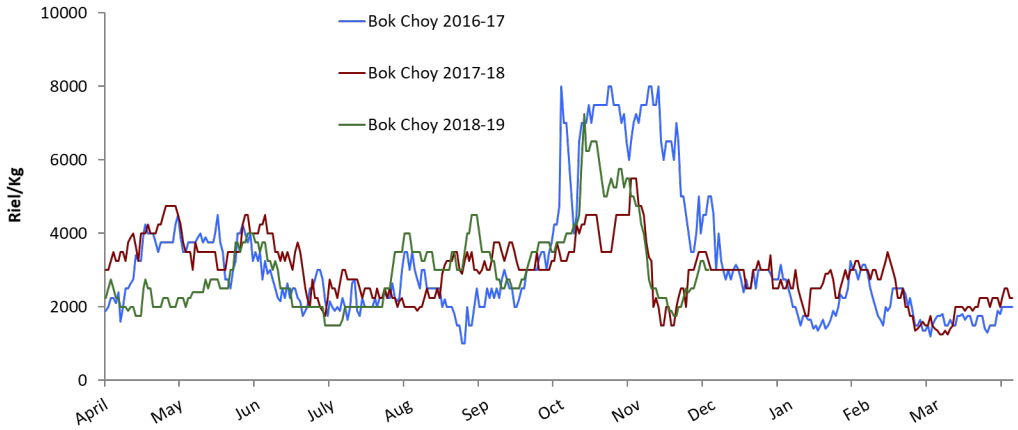


Figure 2: Seasonal price patterns – bok choy

Bok choy followed a clear seasonal pattern (figure 2). Prices peaked towards the end of the wet, a period when vegetable production is typically low because of heavy rainfall, high temperatures, and high humidity. Farmers have strong price incentives to supply bok choy during certain times of the year, particularly towards the end of the wet season and to a lesser extent the end of the dry season.

(see Research Report: Wholesale price patterns for bok choy in Phnom Penh, Cambodia, Appendix 14)

Similar to bok choy, there is a clear seasonal pattern in the wholesale prices for both Chinese kale and lettuce in Cambodia (figure 3). Domestically grown Chinese kale and lettuce were available in Neak Meas market every day and there was significant inter-daily and inter-weekly price volatility. Wholesalers avoid keeping stocks of these vegetables because of their very short shelf life. Likewise, prices are sensitive to a sudden reduction in the amount of produce arriving at the market because there is limited stock that traders can draw upon to compensate for a decline in new supplies. In addition, poor product storability is a major source of marketing risk for both farmers and traders, however, also offers farmers an opportunity to invest in the production of leafy crops such as lettuce, bok choy, coriander and Chinese kale.

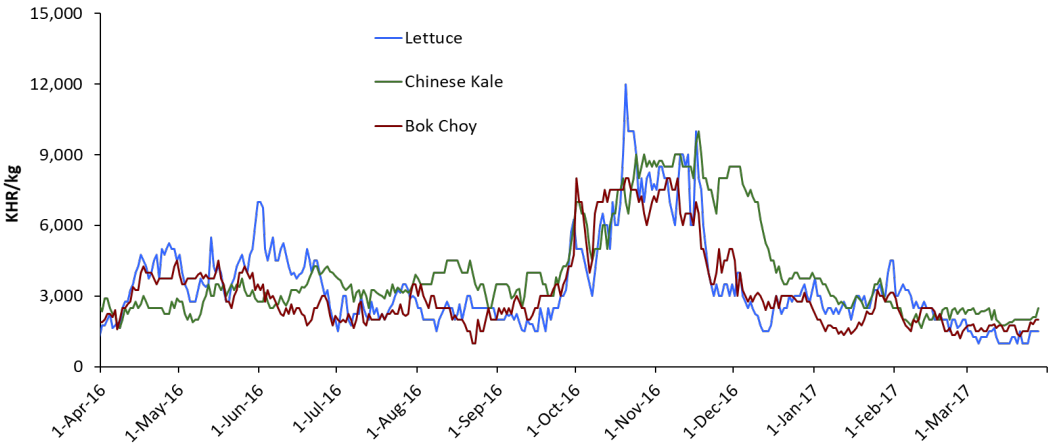


Figure 3: Seasonal price patterns - comparative: leafy vegetables

(see Research Report: Wholesale price patterns for Chinese kale in Phnom Penh, Cambodia, Appendix 16)

(see Research Report: Wholesale price patterns for lettuce in Phnom Penh, Cambodia, Appendix 17)

For leafy vegetables (lettuce, Chinese kale, bok choy), prices vary significantly within and between seasons. The commonly held, simplistic distinction between dry and wet seasons was found to not provide a useful guidance for farmers (and their advisors) in crop planning decisions. Vegetable crops vary in their seasonal price patterns and crops tend to have unstable patterns. From the market perspective, not all crops are necessarily a low risk decision for investing in protected cropping, for a solely wet season focus.

Crops such as tomato which have a high import component due to their relative transportability pose more challenging market access issues. Annual price curves for tomato (figure 4) can vary significantly between years indicating a poor stability of seasonality and this constitutes a high risk for farms in crop planning. Domestic supply of tomato tends to be during the low-price season (January to March), however, it was also found that during this time, Cambodian tomato is wholesaled for a lower price than Vietnamese tomato.

The development and implementation of this market price information system was very successful and used minimal resources. Interest was generated from non-

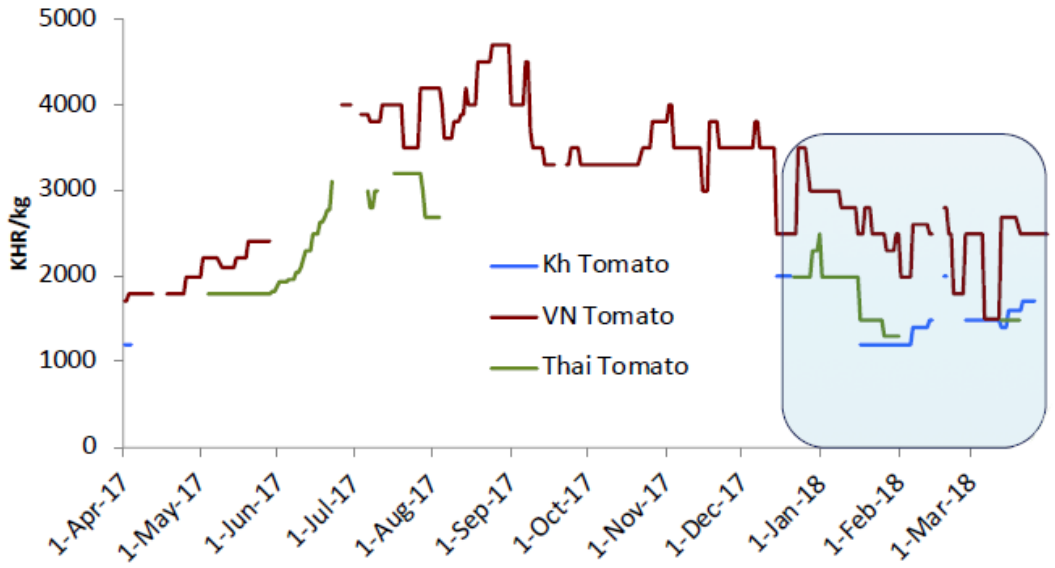


Figure 4: Seasonal price patterns - tomato

government organisations, commercial sector and farmers for more pricing data. CARDI was, through this work, in a unique position to continue this relevant and high profile work on their own, and potentially, as a commercial service, but chose not to take on this initiative as the project involvement was completed.

Coriander in Lao PDR was identified to be an excellent crop for investment in protected cropping due to its market value, perishability and significant productivity gains that can be achieved in a managed environment. Chinese kale demonstrates similar market attributes for exploitation by Cambodian farmers.

In terms of the biophysical mapping work, the absence of both cool chain and physical protection of fresh produce postharvest is contributing to significant losses and this could be improved with a range of simple practice changes. Overall, actors in the supply chain were unaware of the impacts current practices have on quality and shelf life.

While appropriate protected cropping is likely to enable farmers to increase the supply of leafy vegetables during high-price periods, improved postharvest management is necessary to maintain quality and reduce losses, even over short supply chains. Coriander was found to have lost 3.8% total weight between harvest and delivery at the collector, with a further 2% product weight lost by arrival at point of sale. The main cause of postharvest loss is due to excess temperature leading to wilting and water loss and deterioration of chlorophyll resulting in yellowing. Additionally, following food safety risk assessments, it was determined that the practiced washing procedures need to be changed.

(see Research Report: Coriander Supply Chain in Lao PDR, Appendix 11)

Likewise, the current Bok Choy supply chain provides no temperature protection postharvest which increased the rate of metabolism and enhanced water loss and yellowing. Wilting development was fast. High temperature also accelerated the enzymatic browning at the cut surface of produce whilst rough handling and the absence of physical protection during loading and unloading contributed to physical injuries which further increased the oxidation of phenolic substances and resulted in browning and promoted pathogenic deterioration. Shelf life of the produce was significantly shortened. For product being transported to Siem Reap, 29% was found to be unsaleable upon arrival due to loss of quality.

(see Research Report: Bok Choy Supply Chain in Cambodia, Appendix 7)

For chilli, the observational studies illustrated similar postharvest practices in both countries and that there was no cooling of produce after harvest in either supply chain. Additionally, prior to placing freshly picked chilli into collection buckets, harvesters pressed fruits into holding belts (around their waists) to enable faster pick times. The produce was then packed into sacks for transport. All these actions contributed to mechanical injuries and reduced quality. The absence of grading to remove damaged and diseased fruits prior to packing is also expected to have been a contributing factor to overall postharvest loss. In Cambodia, approximately 8% of chilli delivered to market is discarded due to rotting.

(see Research Report: Chilli Supply Chain in Cambodia, Appendix 9)

(see Research Report: Chilli Supply Chain in Lao PDR, Appendix 10)

For Cambodian cucumber, despite a relatively short supply chain, postharvest loss has previously been found to be 20%[3]. Supply chain mapping identified that rough handling is a significant contributor to loss of quality with 23% of delivered product found to be bruised. It was also determined that physical damage (bruising and cuts) were also caused during the harvest activity. In addition, this produce is generally transported in mixed consignments with other vegetables, leading to increased yellowing due to ethylene when the transport period is lengthened. Loss due to disease was also found to be a factor in wet season consignments. The core temperature at time of packing is a significant predictor of shelf life.

(see Research Report: Cucumber Supply Chain in Cambodia, Appendix 12)

The cabbage supply chain assessment in Lao PDR confirmed the significant size of this industry, being the second most important crop after coffee in terms of area under production. Production does not fluctuate much between years. The industry also has both domestic (Vientiane) and export markets (Ubon, Thailand) with the dominate supply in the wet season. Paksong grown cabbage has a market reputation as being ‘safer’.

Smallholder farmers sell directly to Thai importers, local wholesalers and local collectors supply wholesalers in Vientiane. This industry is quite well established with relatively stable marketing networks. A consequence of this stability was found to be very little technical or marketing innovation and the information flow along the chain, especially with respect to technical information, is poor. Spot market transactions are common. In the domestic (Vientiane chain), there is a high risk of payment default, while the export chain is hampered by a lack of border facilities. In all supply chains, physical postharvest loss is high, especially in the wet season.

Biophysical mapping of this industry identified insect damage, rather than deterioration, as the primary contributor to postharvest loss with damaged leaves being routinely removed. However, as insect damage in the field can be variable, subsequent measures of postharvest loss may also vary due to the sampling and assessment procedure. Cracking is the second most significant factor. Although production issues may lead to cracking, rough postharvest handling also needs to be considered. The overall supply chain loss is variable across samples and predominately due to insect damage. Typical loss is significant with up to 18% loss recorded on arrival at point of sale in Vientiane.

(see Research Report: Cabbage Supply Chain in Lao PDR, Appendix 8)

Tomato is commonly seen as a ‘desirable’ crop from both external actors and farmers. The market and price analysis work found that this crop may not be the best choice in developing vegetable sectors in Cambodia or Lao PDR, primarily due to the dominance of imports into the market. A review of the Bolaven Plateau (Lao PDR) tomato supply chain found that despite a perception that this is becoming a major

tomato production centre, there are very few producers, mostly Vietnamese migrants. Lao farmers perceive this crop as being too risky with high entry barriers (costs and expertise).

Most production is sold locally though there is some distribution to Vientiane. Like markets in Cambodia, there is significant competition from imported Vietnamese product. An analysis of the Paksong to Vientiane supply chain (see Activity 2.5), found undesirable ripening is a major impact on supply chain value and is a significant constraint to further development.

(see Research Report: Tomato Supply Chain in Lao PDR, Appendix 13)

Activity 1.4 Review of agro-enterprise clustering for Cambodia and Lao PDR

Activity 1.5 Evaluate and refine clustering approach

Clustering of agro-enterprise groups is commonly seen as a way of providing advantage and market power for small agribusinesses in order to overcome challenges in market engagement, supply chain dynamics and/or production costs and can be promoted through development projects, NGOs and government agencies. Review and evaluation of this approach found that whether collective action is an appropriate vehicle for improving farmers' access to markets will depend largely on the structure, conduct and performance of the marketing system. In the specific case of vegetables in Cambodia, the evidence gathered indicates that, some exceptions aside, farmers may have more to lose, than gain from cooperative marketing arrangements.

The highly fragmented, traditional market structures described in the mapping and supply chain analyses, are not conducive to successful cooperation in the marketing sphere. In market environments characterised by small transactions and little or no product differentiation, the rationale for farmers to get together to undertake assembly functions is highly questionable. Scale is a disadvantage. There may be some rationale for vegetable growers to work together to access markets when high-quality, high-value channels are targeted. However, opportunities for smallholder participation in premium vegetable chains are presently scarce in Cambodia. Cooperative marketing enterprises may enjoy some advantages where buyers have differentiated quality requirements and are willing to pay a premium to access the right quality. In this situation famers could have an incentive to cooperate.

In Cambodia, vegetable marketing groups are very linkage dependent. For success, they require a mutually beneficial relationship with a supply chain actor, essentially a premium distributor. Most groups in Cambodia are centrally located for access to Phnom Penh and have been supported by development projects. Market size is the main challenge, though the fragmented market is also characterised by supermarkets and premium grocers showing a preference for working with individual farm enterprise and avoiding small informal groups. This is likely a result of it being more difficult to ensure reliable and consistent quality from informal groups and/or being more difficult to interact or negotiate with the suppliers.

Existing vegetable cooperatives are all the result of project support. A key characteristic of these groups is that the membership is too large for the target market. Members have very little business incentive to remain in a group. Despite long periods (years) of external support, the groups have very poor marketing capacity. A similar situation exists in Lao PDR. For example, membership in a registered group is required for access to premium organic markets, but the current markets are not large enough to accommodate new groups.

In Lao PDR, several coffee production groups have been functioning for a few years, though the development of rice and vegetable groups has only been recent.

Vegetable producer groups have been formed both through projects and by self-motivated farmers. Traditionally, access to training to improve management practices, has been the primary purpose. The formation of groups focussed on aggregating produce to supply larger markets is rare and appears to result from highly fragmented market places, restriction to traditional market channels serviced by small-scale collectors and the absence of supermarkets.

All the groups studied showed similar structures and consisted of producer members, elected management committees and an accountant. Through the survey and group analysis process, several factors identified by members and stakeholders (active and inactive) were categorised.

Technical production support, including training, is a valuable element in all groups and essential for ongoing success of individual enterprises and bringing a group together, yet technical training was not identified as having an impact on the ongoing success of the cluster. However, declining productivity in organic coffee production resulted in some farmers resorting to chemical fertilisers which in turn, resulted in producers not meeting organic standards. In this situation, the cause of group failure was attributed to members not meeting standards and certification, yet it could potentially be addressed through improved technical production support.

Another key factor is infrastructure support. Like technical training, providing necessary infrastructure may be a critical component in establishing a group, but does not materially impact on ongoing success.

Finance and access to money is anecdotally considered an important factor, but the analysis found that it was not an indicator of outcome. (It may be more likely an indicator of whether a group is established, not whether it ends.) In vegetable groups, members in both the groups studied were self-financed, primarily due to the high costs associated with accessing capital. In the coffee industry, groups appear able to leverage funding and provide financial support to members to increase production, but this did not ultimately determine outcome for the group. In rice, there was no indication that financial services or support made a significant difference in group success.

Access to inputs is a common problem in all groups with actual supply and/or costs of necessary inputs bearing significantly on farm viability, but not directly on the ultimate outcome for the group.

The management skills of the group would be expected to have a role in success. Although identified as an important part of establishing a group and for ongoing smooth operation, the skills of the managing team were not isolated as a determining factor for success by the stakeholders. However, slow payments to members and a lack of transparency in the group, notably around prices and payments, led to loss of trust by members and was likely a contributing factor in the failure of the coffee group.

Overall, rules and regulations do not appear to be key impactors on the final outcome of a group in any of the industries, though when group standards and certification is considered, in the case of organic coffee, members not adhering to rules and standards, was a factor in failure of the group. Though, as noted earlier, diminishing returns (productivity) by members was a root cause of the noncompliance.

The only factor that was identified as instrumental in whether a group succeeded or folded is access to market, and to this end, whether a group is supported in securing an outlet for their product. In vegetables, this was borne out by whether a group could negotiate physical access for their members to sell product, whilst in rice, limited market opportunity reduced incentive for farmers to remain in a group.

In situations where farmers have a secure and viable market outlet, they have the opportunity to succeed and, subsequently the value of a cluster or membership in a group appears to lie in whether being part of a group, provides a smallholder with superior access to market.

In this regard, the viability a group of producers is not different to an individual producer. A producer without access to an economically viable outlet for their product, will not succeed. Furthermore, it is not certain that groups are necessarily better at gaining access to a viable market, but if an intervention can ensure better market access, the long-term viability of the smallholder can be supported.

Interestingly, the emphasis on organic production in Lao PDR and subsequently access to and use of organic inputs raises the business stakes for smallholders as costs increase but not farm productivity. This in turn necessitates higher returns, putting more pressure on the need for access to a viable market. With Cambodia showing similar priority, the viability of a promoted production system needs to be well understood.

(See Research Report – Clusters for Producers in Lao PDR, Appendix 18)

Objective 2. To determine quality constraints and food safety risks (pesticide and microbial) in current production systems and develop strategies for delivering high quality safe vegetables to market

Activity 2.1 Build research capacity in postharvest management and food safety

An assessment of training needs of the postharvest and food safety teams was undertaken by the component leader in the first year. Informal discussions with team members and their supervisors were held to determine knowledge gaps and capacity building opportunities and this informed the basis for the design and development of the postharvest and food safety training programs. Most postharvest staff did not have a strong background in postharvest. In food safety, staff were found to be unfamiliar with hazard identification and risk assessment procedures and had limited knowledge of food safety issues.

The training programs encompassed both a series of workshops and 'hands-on' training and mentoring during research and analysis activities over the course of the project. Workshops focussed on the skills and background knowledge necessary for participants to conduct project research and analysis tasks including on-farm risk assessments, supply chain mapping, planning and implementing research trials and development of recommendations for stakeholders:

Postharvest	Food safety
• Quality aspects of fruit and vegetables • Fundamental postharvest science (including handling & cool chain) • Operation and use of key postharvest equipment • Quality assessments of vegetables • Protocols/methods for mapping supply chains	• Chemical, biological and physical contamination • Fundamental food safety science (including contaminants and hygiene) • Protocols/methods for risk assessments • Conducting field work • Presenting assessments and results

The postharvest and food safety project training targeted staff in project collaborator organisations and the second round of food safety training was also extended to farmer groups.

Training content was updated as project activities evolved, and local context learnings were incorporated. Supplementary training on planning and delivering farmer training (field day) was provided in conjunction with the protected cropping teams. This training included both a theory and planning component and the teams planned and delivered field days.

Training workshops

	2014	2016	2017	2018
Postharvest	• Phnom Penh (19) • Vientiane (10)			• Phnom Penh (21) • Vientiane (22)
Food safety		• Phnom Penh (15)	• Vientiane (18)	• Phnom Penh (21) • Vientiane (17)
Effective farmer field days (incorporating PC, WM, PH & FS)			• Vientiane (21) • Phnom Penh (30)	• Vientiane (22) • Kandal (40) • Kampot (28)

An important element in building research and extension capacity is to engage with young professionals entering the industry. Four university agricultural students over the course of this project were connected with the project teams and involved themselves in the various field trials as part of their final year research projects. Through these interactions, project workers were also able to develop their knowledge and skills in conducting field experiments, data collection, analysis and writing of reports and working with students.

Activity 2.2 Participatory risk analysis to identify, characterise and evaluate food safety

To understand the current situation for safe vegetable production, systematic risk assessments were conducted on farms in both Cambodia and Lao PDR.

Ninety-one risk assessments were conducted in Cambodia (Kandal province) to gain an understanding of the food safety risks. From the 51 leafy vegetable farms evaluated, 18 high risks, 13 medium risks and 4 low risks were identified while from 40 cucumber farms, 24 high risks, 5 medium risks and 4 low risks were identified.

In Lao PDR, a total 140 farms in Vientiane Capital (plus 30 conventional leafy vegetable enterprises in Vientiane province) were assessed. From the 60 conventional leafy vegetable farms evaluated, there were 37 high risks, 21 medium risks and 12 low risks identified. GAP leafy vegetable farms showed a similar profile with 18 high risks, 9 medium risks and 6 low risks identified across 30 farms. Although issues relating to application of agrochemicals were not present from the 40 organic leafy vegetable farms evaluated, 11 high risks, 13 medium risks and 9 low risks were still identified. For the 40 conventional tomato farms assessed, a similar profile of risk emerged with 18 high risks, 10 medium risks and 7 low risks identified.

On-farm risk assessments

Production system	Number of farms	High risks	Medium risks	Low risks
Lao PDR				
Leafy vegetable - conventional	60	37	21	12
Leafy vegetable - GAP	30	18	9	6
Leafy vegetable - organic	40	11	13	9
Fruiting vegetable - conventional	40	18	10	7
Cambodia				
Leafy vegetable	51	18	13	4
Fruiting vegetable	40	24	5	4

Farm production practices resulting from a lack of awareness, knowledge and skills are the primary cause of high-level food safety risks.

Across all farms, the high risks that were found predominantly related to the inappropriate use of chemicals and a lack of personal/farm hygiene practices. Risk of chemical and/or biological contamination rendering vegetables potentially unsafe for consumption was common. In some conventional leafy vegetable enterprises, untreated sewerage is being used for fertiliser. In organic farms, issues around the risk of biological contamination were the main concern.

Despite having participated in chemical use training, farmers (conventional and GAP) prefer not to follow product directions, are not aware of approved chemical suppliers and use unapproved products, commonly mix multiple chemicals and do not necessarily observe withholding periods.

Most farmers across all production systems use animal manures and sewerage water is used in many production systems. Overall, farmers have very little awareness of the need for hygiene during production, harvest or postharvest; toilets and washing facilities are not readily available.

Medium level risks are generally associated with postharvest handling and lack of chemical application records, however, on organic farms, although agrochemicals were not found to be used, a few medium level risks associated with poor understanding of the rules and policies governing use of chemicals were evident.

Low level risks are generally related to poor record keeping. Although the lack of records is not directly affecting the contamination risk, it significantly affects traceability and ultimately impacts on quality assurance.

One half of organic certified farms also claimed to be GAP certified. Farmers do not appear to have a clear understanding of what the system is they are following, other than being chemical free. Of GAP certified farmers, only 23% said they were following GAP. This is potentially due to the group certification system, even though not all individuals in a group would meet GAP standards.

The risk assessment process highlights that produce from all the production systems (conventional, GAP and organic) have high food safety risks and are not necessarily safe for consumption.

Further and more rigorous training in agrochemical use and governance is paramount and training needs to target all farmers, collectors and chemical retailers. Ongoing training on pest and disease identification is also important. Improved advice on authorised suppliers and labelling for better identification of approved

chemicals would also improve farmer practice. Farmers, collectors and retailers need significant training on hygiene issues and the impact on quality and safety of vegetables. Given the attitudes about chemical use and absence of basic hygiene practices that have been identified through this risk assessment process, training programs need to include an element of post training follow-up to foster implementation and improved practices.

(See Research Report – Risk assessment of vegetable production, Cambodia, Appendix 20)

(See Research Report – Risk assessment of vegetable production, Lao PDR, Appendix 21)

Activity 2.3 Improve disinfestation techniques and postharvest handling practices

Activity 2.4 Reduce microbiological contamination through improved on-farm practices

Monitoring of produce management practices along the supply chain and on-farm food safety risk assessments highlighted that biological contamination is a ready and real risk to the supply of safe, quality vegetables in both Cambodia and Lao PDR. Numerous sources of contamination were identified including soil, manure, water and product handling (people).

Despite some dissemination of food safety programs including GAP and HACCP, the risk assessments and supply chain monitoring has shown that multiple critical practices are not yet in place.

It was found that normal practice in both countries is to place harvested product directly on the soil as it is picked and before it is packed. Even when produce is picked into a harvest container, the container is placed on the ground. Some farmers follow a previous recommendation[3] to place a sheet of paper or similar under the container, however, monitoring found that this practice is inadequate in preventing contact between harvested product and soil, particularly during wet conditions.

It is recommended that the clean harvest container be placed on a small stool.

A similar problem occurs when produce is being packed at the farm or at a collector's premises. Vegetables may be placed directly on the floor or ground and/or soiled containers may be stacked causing product to come into contact with dirt. It is recommended that the clean pallets are placed on the floor, onto which produce or containers can be placed.

A third risk point is that harvest tools (knives, secateurs) as well as containers (for harvest, storage and transport) are not routinely washed and disinfected. It is recommended that all tools and containers are washed before use and disinfected with a chlorine solution.

The supply chain mapping activities also found that the current washing procedure for crops such as coriander, which is harvested as a whole plant, fails to properly wash off soil. A three-rinse practice was refined and tested on-farm with collaborating smallholders and is recommended as minimum practice.

Although a number of practices across the farm and supply chain can be improved in terms of disinfestation and postharvest handling, by clearly identifying the primary sources of risk, a priority list of basic practices was compiled.

[3] *Good agriculture practices for production of fresh fruit and vegetables in ASEAN countries - Food Safety Module (2007)*

When implemented, the identified food safety risks could be significantly reduced in both countries. A priority list of disinfestation and handling objectives were collated:

- Postharvest equipment and containers need to be in good condition, cleaned and prevented from subsequent contact with contaminants.
- Equipment (tools, containers) need to be disinfected after cleaning.
- Harvest containers should not be used for storage or transport of produce.
- Harvested product must not come into contact with soil.
- Containers used for produce must not come into contact with soil.
- Only clean water should be used for washing produce.
- Transport vehicles need to be clean and contaminant free.
- Fresh produce should not be transported in a mixed load with chemicals or animals.

The risk assessment process also identified several high/medium risks associated with on-farm practices primarily around the issues of hygiene.

Handwashing was found to be uncommon. This is a particular risk because if hands are not properly washed, all subsequent hygiene procedures can be ineffective as equipment and produce can become contaminated after cleaning. Observation of the common farm practices and general layouts of smallholder properties was used as a reference point and known good practices were reviewed to determine a best fit recommendation. It is recommended that handwashing with liquid soap be done before beginning or returning to work, after going to the toilet, after smoking and before and after eating. A clean towel or paper towel is required to dry hands after washing.

Again, by clearly identifying the primary sources of risk, a priority list of basic practices was compiled to provide priority hygiene objectives. When implemented, the identified food safety risks could be significantly reduced in both countries:

- Farmers and farm workers need to be educated in personal hygiene practices and on the potential contamination of produce.
- Toilets and washing facilities need to be available and conveniently located for workers in production and packing areas
    - Hands need to be washed before handling produce.
- Animal manures used for fertiliser and soil conditioning must be properly composted before use.
- Domestic animals must be kept out of the crops and postharvest areas.

Following the field work and testing the on-farm workability and appropriateness of the suggested practices, the key recommendations were incorporated into a training workshop for postharvest and food safety and complementary dual language posters were prepared which focus on key recommendations. Simple videos to help disseminate the recommendations and allow farmers to learn the recommended practices have also been produced.

> (See Research Report – Minimise biological contamination through improved disinfestation technique, postharvest handling practices and on-farm practices, Appendix 22)

Activity 2.5 Determine and deploy appropriate postharvest technology for reducing losses and improving quality out-turn

Postharvest loss along the food chain is significant. The biophysical mapping of the supply chains of bok choy, cucumber, cabbage, tomato, chilli and coriander in Cambodia and Lao PDR highlighted the main factors leading to this postharvest loss. Important problems are exposure of vegetables to high temperatures after harvest, packaging that does not provide produce with physical protection and substantial rough handling along the supply chain. For some product, supply chain mapping identified specific challenges, for example, in tomato there is significant undesirable ripening during transportation.

Due to the inaccessibility or non-existence of necessary postharvest infrastructure, low cost and readily applied technologies were investigated as options.

Improvements in postharvest handling and cool chain are needed and significant economic advantage could be realised by farmers and marketers with simple intervention. Wet microfibre towels and replacing plastic bags with stackable plastic crates were shown to be a useful and economically viable technology to better maintain harvest quality and product value for a range of vegetable products. Logistical challenges to enable collection and reuse of the towels and crates need to be addressed. These interventions may also contribute positively to reducing plastic waste.

The incorporation of ethylene absorbent sachets in the tomato product supply chains was found to be highly effective in maintaining product quality and marketability.

Case study – Bok Choy (Cambodia)

The Kandal – Siem Reap bok choy supply chain is an 18 hour, 350km journey. Typically, produce is tightly packed in plastic bags of up to 15kg per bag. During the supply chain, from a starting temperature of 33°C, temperatures could rise to as much as 42°C. On arrival, a 3.6% loss in total weight was measured and 29% of produce was ultimately lost due to wilting. It was determined from the trials and supply chain monitoring that high temperature and rough handling are the primary causes of the rapid loss of quality and value of this product.

Trials were conducted in which plastic bags were replaced with stackable plastic crates (8kg holding capacity) which were lined with plastic film and covered with a wet material – mircrofibre towel or disposable carpet.

The passive cooling effect of the wet materials provided a significant reduction in produce temperature from 34°C to 26.5°C for the first 6 hours after which the temperatures gradually rose to 30°C.

Assessment of produce at the end of the supply chain trial showed that the interventions reduced weight loss (37.3% reduction with microfibre towel), improved assessable quality and resulted in storage life (at 25°C) being increased by 25%.

Further trials found only minor reduction in weight loss compared with current practice, however the quality and value of the produce (figure 5) was maintained. A lower score represents better quality.

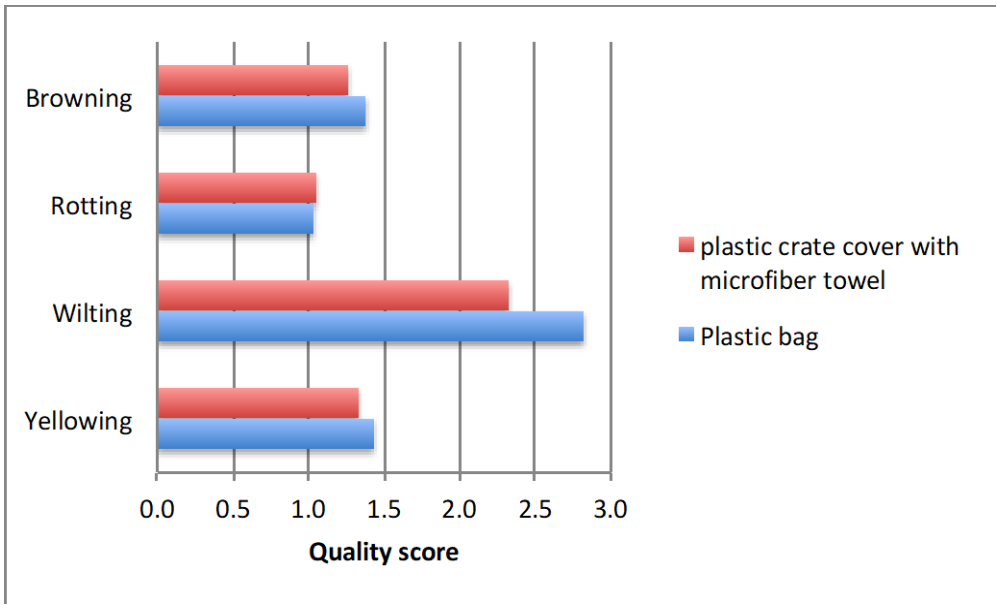


Figure 5: The quality attribute scores of bok choy on arrival at Siem Reap wholesale market.

In addition to the technical evaluation, a preliminary feasibility assessment was also conducted to consider logistics and economics. The financial feasibility of these interventions is positive. The partial budget analysis illustrates a good return is achievable from the application of the technologies, however, viability is market selective as the materials need to be collected and returned to realise the full economic value and lower costs. The towels can be purchased for US$3.00 and are estimated to last 1 year (100 deployments). The crates cost US$8.50 and will conservatively last 3 years (100 deployments per year). An additional minor cost is a single use liner each time the crate is used.

Market analysis in Cambodia determined the higher quality bok choy delivered to market can obtain a KHR500-1000/kg premium as well as a gain in total quantity of produce sold due to the reduced weight loss on arrival at point of sale.

Overall, smallholders using both crates and microfibre towels (at a cost of KHR470 per 8kg travelled) could realise a net gain of approximately KHR500/kg harvested. Over a whole year, successful implementation of these practices represents an additional KHR5.7m (US$1,425.00) for the local farming economy, from a single crop supply chain.

The logistics involved in collecting crates and towels and returning them to farmers/collectors for reuse is expected to be a challenge as the constraint on adoption of these items is market selective. However, the results show that the quality and shelf-life advantage gained for retailers from these simple interventions is significant. The popularity and subsequent growth of small retailers focusing on organics and chemical free produce in the larger cities is expected to provide market

outlets with a clear incentive for improved quality and more collaborative relationships with suppliers. However, the supply chain monitoring activities also found that handling practices within wholesale and retail outlets is suboptimal and requires improvement.

While this project work has identified and proven the value of these simple interventions, substantial follow-up work is necessary in fostering collaborative supply chains and implementing improved practices with all actors.

Case study – Coriander (Lao PDR)

The Vientiane Capital coriander supply chain from Hatxayphong district to the Ozi wholesale market involves a 15 hour, 30km journey.

Monitoring of the supply chain found that the temperature conditions around the coriander is up to 37°C at the farm and is cooled to 21-25°C when washed and repacked with ice at the local collector's premises up to 8 hours later. There is a 3.8% loss in weight between harvest and arrival at the collection point, with a further 2% loss recorded by the time the product arrives at the point of sale.

The high temperatures contribute to, and subsequent weight loss reflect, a loss in quality. Although marketability is generally preserved by refreshing the product with water, the nutritional quality and shelf life are irreversibly affected. The potential for microbial contamination is also high resulting from the washing practices.

Trials investigated the impact of using a wet microfibre towel over harvest baskets to address the issue of excess postharvest heat in the product compared with the current practice of covering the baskets with a sack. Unlike the trials with bok choy in Cambodia, results were inconsistent. The evaporative cooling impact of the microfibre towel was only evident at high ambient temperatures of 35°C. In trials where ambient conditions were milder (23-25°C), little benefit was achieved.

Overall, a minor extension of shelf-life of the coriander was found, though the benefit was not significant in these trials. Based on evaluation of the trials, it is hypothesised that this improvement was a result of the introduction of a 3 step washing process using clean water and a subsequent reduction in microbial contamination of the product.

A definitive conclusion cannot be drawn from these trials and further work would be necessary to determine whether microfibre towels and/or improved washing procedures are a feasible intervention in this product supply chain.

Case study – Tomato (Lao PDR)

The Paksong – Vientiane Capital tomato supply chain is a 24 hour, 700km journey. Typically, produce of varied stages of ripening is packed, ungraded, into 25kg boxes. An increase of 6-8°C in fruit temperature during the transport period, coupled with the mixed maturity of tomatoes resulted in 95% of tomatoes having entered the ripening stages on arrival at the point of sale. Subsequently, this requires that the fruit is sold immediately to avoid incurring product loss.

Trials investigated the efficacy of ethylene absorbent sachets[4] in delaying undesirable ripening of tomato in the supply chain. Undesirable ripening of tomatoes during transport and/or storage from farm to market, limits the marketable timeframe of the product, reducing market value. Supply chain monitoring identified exposure to high temperatures after harvest and a failure to grade fruit prior to packing are

[4] *The project partnered with private collaborators to conduct this research. Bioconvercion (Spain) provided ethylene absorbent satchels and technical advice.*

contributing factors, with the ethylene generated from ripening fruit stimulating the ripening of the remainder of the consignment.

Enclosing ethylene absorbent sachets into a 10kg box of green tomatoes significantly delayed fruit ripening and resulted in a 50% increase in green fruit after a 7 day storage period and met the acceptable market criteria of 75% of green fruit in a box at point of sale (figure 6). Fruit packed without the ethylene absorbent sachets could only be stored for 3.5 days before failing to meet this benchmark. All fruit in both treatments ripened normally after removal from the box and no bruising on tomato was found.

In addition to the technical evaluation, a preliminary feasibility assessment was also conducted to consider economics. The financial feasibility of using ethylene absorbent sachets is strong with a partial budget analysis completed that illustrates a significant additional financial return is achievable from the application of this technology.

The market analysis concluded that an acceptable market outcome is achieved if 75% of a consignment of green tomatoes remain unripe (green) upon arrival at point of sale and that this fruit is valued at approximately LAK10,000/kg. Ripened and second grade fruit are valued at LAK6,000/kg.

The ethylene absorbent sachets are valued at LAK1800 each, with 4 sachets required per 10kg box, and are single use.

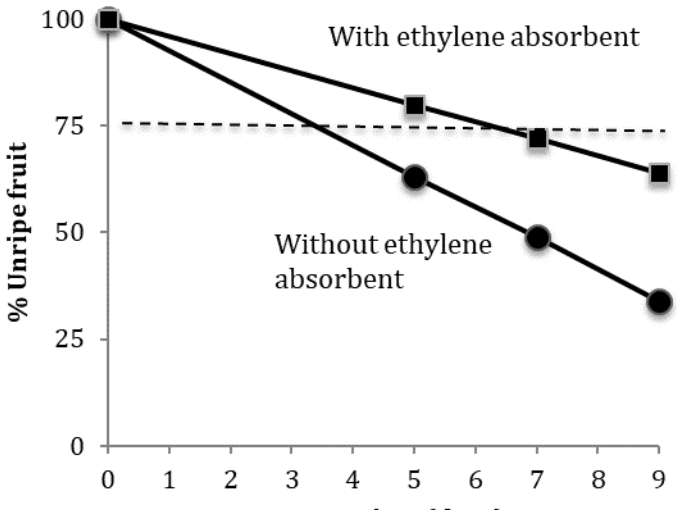


Figure 6: Proportion of unripen fruit

On delivery at market, the net financial gain if all product is sold on the first day was found to be approximately LAK2,800/10kg when using ethylene absorbent sachets. Superficially, this net gain of upon delivery of unripened fruit is marginal, however, the actual value is realised in shelf life and subsequently in how many days the product can be held and marketed at the premium price. Delayed ripening with the ethylene absorbent sachets enables high value, quality fruit to be stored for up to 7 days and this product has a further 3 days out of storage before value declines. In contrast, tomato stored without the ethylene absorbent sachets can only be maintained at a higher price point for 3.5 days.

If a consignment of tomato is held for 24 hours after receival before being sold, the use of ethylene absorbent sachet means that an additional 25% of the consignment of tomatoes can still achieve a price premium, compared with the untreated, ripened fruit. Assuming this quality fruit is sold for LAK8,000/kg, the net financial gain was found to be approximately LAK12,800 when using ethylene absorbent sachets. This equates to an approximate benefit to cost ratio 280:1.

Case study – Cucumber (Cambodia)

The Kandal – Phnom Penh cucumber supply chain is a 75km journey taking from 6 – 10 hours. Cucumbers are normally harvested in the early morning, temporarily stored under shade before being packed into plastic bags (approximately 15kg). The cucumbers are collected in the middle of the day from the farm and taken as mixed loads to Phnom Penh.

Temperature monitoring has shown that despite a relatively short supply chain, the cucumbers were consistently around 30-33°C, mirroring ambient conditions. Fruit on arrival showed a high level of bruising due to the rough handling along the supply chain. Shrivelling and yellowing were the main factors that determined subsequent disposal of stored product.

As cucumber is sensitive to ethylene and was found to be transported in mixed loads with other vegetables, it was anticipated that ethylene from other products could contribute to yellowing and increased postharvest deterioration of the cucumber. Trials were conducted using ethylene absorbent sachets enclosed with the bagged cucumbers, which were then assessed at 2, 5 and 7 days of storage. No identifiable difference in yellowing or other deterioration was evident with the use of the ethylene absorbent sachets. As equipment for measuring ethylene concentration is not currently available in Cambodia, further investigation as to whether ethylene is a contributing factor to postharvest deterioration in this supply chain could not be completed. Further research would be needed to determine an actual cause, though based on the mapping work and the ethylene trial results, pre- and postharvest physical damage are likely to be key issues.

> (See Research Report – Postharvest technology development for reducing losses and improving quality turn-out for supply chains in Cambodia and Lao PDR, Appendix 23)
> (See Research Report – Economic analysis of postharvest improvement for bok choy and tomato in Cambodia and Lao PDR, Appendix 25)

Objective 3. To develop integrated crop management strategies that enable farmers to produce and market vegetables during the late dry and wet seasons

3.1 Build research and extension capacity in water management, IPM and protected cropping

The component leader assessed capacity development and training needs of the in-country project partners to gauge background knowledge and learning requirements with respect to the planned project activities on wet season production. Informal discussions with team members and their supervisors were held to determine knowledge gaps and capacity building opportunities and this informed the basis for the design and development of the training programs. Feedback and information were also gathered from discussions and structured questions during in country travel, project communications and visits to field sites. Lao PDR and Cambodia face similar research capacity issues with limited experienced personnel across a range of disciplines particularly protected cropping, vegetable production, pathology, entomology, food safety and postharvest science. In Lao PDR, there have been linkages to the Crawford Fund pathology work being conducted at Pakse and the Bolaven Plateau. This work is building research and diagnostic capacity in plant pathology at the provincial level in this province, however the needs analysis identified that staff in this region and the other project focus areas, needed further support. Some staff had basic irrigation knowledge, resulting from previous projects and experience, though were not confident in the technologies or practices.

Most production staff did not have a background in greenhouses and were unfamiliar with the designs, concepts and how to manage protected cropping environments.

Project workers from all the collaborating institutions indicated that further knowledge of greenhouse management, vegetable production techniques, irrigating crops (especially in greenhouses) and more information about pests and diseases was needed. From the needs analyses, key training areas were identified and workshops focussed on the skills and background knowledge necessary for participants to conduct project research and analysis tasks, particularly protected cropping design elements and management principles. The training programs encompassed both a

series of workshops and 'hands-on' training and mentoring during research and analysis activities over the course of the project. Additionally, project teams indicated they needed some practical formats of information and activities they can use when training farmers, so the training is effective. This element was developed as supplementary training on planning and delivering farmer training (field day) and was provided in conjunction with the postharvest and food safety teams. This training included both a theory and planning component. The teams planned and delivered field days including feedback and evaluation and prepared extension resources.

Semiformal training was developed and delivered as workshops and in-field demonstration and mentoring to build targeted knowledge and skills with the project teams. A comprehensive suite of training across protected cropping, integrated pest and disease management and water management was prepared and presented with a dual approach – to teach and consolidate knowledge and skills of the project teams and to enable them to take the training forward as trainers. Additional training in planning and delivering field days was included to assist in-country partners to deliver subsequent training activities to farmers and peers in an effective and confident manner.

The protected cropping training focussed on key principles of protected cropping, design and construction of low cost and effective design. Training on research practices was incorporated into the protected cropping training and field activities with a focus on field investigations, trial design and replication as well as metrics, data collection and analysis.

This was a very successful approach as the training ensured the participants had the necessary knowledge and skills to undertake the project field activities, which in turn, provided a practical training component that reinforces learning.

Seven protected cropping workshops were delivered reaching 97 participants. Six water management workshops covering soil moisture monitoring and irrigation application were delivered with a total of 132 participants. Five IPDM training workshops with a total of 83 participants focussed on identification, monitoring and management strategies and there were a number of smaller targeted IPM technical training activities for project staff. Team members were also able to participate in other training activities including Crawford Fund activities in Champasak province.

Training workshops

	2015	2016	2017	2018	2019
Protected cropping (PC)	• Phnom Penh (21) • Vientiane (21) • Paksong (17)		• Vientiane (18) • Phnom Penh (16)	• Kampot (43) • Vientiane (12)	
IPDM				• Kampot (8) • Phnom Penh (20) • Vientiane (16) • Phnom Penh (8) • Vientiane (3) • Paksong (15) • Paksong (4)	• Vientiane (3) • Phnom Penh (12) • Vientiane (20)
Water management (WM)		• Vientiane (14) • Phnom Penh (20)		• Kampot (39) • Siem Reap (40) • Paksong (22) • Vientiane (18)	
Effective farmer field days (incorporating PC, WM, PH & FS)			• Vientiane (21) • Phnom Penh (30)	• Vientiane (22) • Kandal (40) • Kampot (28)	• Vientiane (25)

An important element in building research and extension capacity is to engage with young professionals entering the industry. Sixteen university agricultural students over the course of this project were connected with the project teams and involved themselves in the various field trials as part of their final year research projects. This was double the target number and resulted from a strong interest by students in the vegetable protected cropping trials being undertaken in the project. This success was facilitated by the emphasis on strong communication and collaboration links between organisations involved in the project. Through these interactions, project workers were also able to develop their knowledge and skills in conducting field experiments, data collection, analysis and writing of reports.

(See Research Report – Capacity Development and Training Needs - production, Appendix 26)

Activity 3.2 Review the use of low-cost protected crop systems and develop appropriate designs for trialling in Cambodia and Lao PDR

Develop design

A review of the low cost protected cropping options and challenges was completed and formed the basis of a trial design that was subsequently constructed at several sites in both countries and evaluated by the project teams.

To evaluate the performance and feasibility of a simple rain protection structure and to gauge the relative benefit of plastic cladding and shadecloth, a review of structures and designs used in comparable regions was conducted to develop a trial design. This was then field tested, and the performance of the structure evaluated. The review aimed at identifying specific options that would be worth assessing.

By assessing deployment conditions and smallholder needs, the review determined a design which can be installed at a similar cost point to a tunnel structure and perform better in the tropical environment. These criteria are deemed necessary to facilitate farmer adoption.

The use of protected cropping is in the early stages of industry development in both Cambodia and Lao PDR and like many developing greenhouse industries, the use of cheap tunnel type structures is occurring. These designs are unsuitable for warm to hot climates as they have limited capacity to vent excess heat and humidity, but tend to be readily accessible, relatively cheap and subsequently are promoted by projects and organisations that do not have adequate technical knowledge to make informed decisions. The adverse impact on a developing protected cropping industry can be substantial.

A plastic raised canopy will provide protection of crops and soil from heavy rain and provide some shading benefit during the hot dry season. A shadecloth canopy will provide protection of crops from extreme heat and some dispersion of heavy rain. A combination of plastic and shade can provide superior options for farmers.

The use of modules in the design assists affordability by enabling build size and future expansion to be adjusted to meet farm budgets. It also embeds ventilation into the structure to ensure performance is maintained as farmers build larger structures. Proportionate variation in module dimensions can be readily implemented to accommodate specific site issues or budget constraints.

High low plastic roof shelter (4 modules)

The curved roof simplifies effective tensioning of cladding materials which improves their performance and longevity. The inclusion of permanent passive vents in the roof, although only a small vent area proportionally, are placed at the peak of the roof between each module to optimise the exit of heated air.

The framework is simple and accommodates the use of local building materials and facilitates adoption and construction by farmers.

The proposed post heights and steepness of the roof were expected to provide effective exit of heated air. The proposed height of the structure presented a reasonable compromise between internal air volume to stabilise growing conditions and facilitate ventilation as well as ensuring good access for farmers, whilst limiting vulnerability to wind. In specifically windy locations, increased bracing can be easily accommodated.

Named the *High Low Plastic Roof Shelter*, the recommended wide span roof vented curved canopy design can be built to variable dimensions and any number of modules. The proposed dimensions are based on the approximate prices and dimensions of available building materials at the time. The dimensions of available plastic film are a key influence. Minor, proportionate variation in structural dimensions are optional for farm construction with the primary aim to ensure that the base design (with alternate modules) is followed as this ensures the performance of the structure for farmers.

Trial structures were built in each of the target provinces in each country. In Cambodia, all selected sites were with collaborating farmers. In Lao PDR, one site in each province was a research centre, with other sites being with collaborating farmers. Sixteen sites were selected for construction and evaluation of the trial design.

The replication of structures on different sites accommodated the project budget constraints and optimised the extension and awareness of the project by providing wider access to the project activities by famers and other stakeholders.

In the first season, two 4-module structures were installed in each of Kandal and Kampot provinces in Cambodia and Vientiane and Champasak provinces in Lao PDR. The structures were erected by project teams with contractors and collaborating farmers.

In the following year, two modified 4-module structures were installed in each of Vientiane and Champasak provinces in Lao PDR.

Construction problems with the initial structures in Cambodia resulted in damage to the cladding on these structures early in the wet season and subsequently the trial program in Cambodia was delayed by one year. One Lao structure also failed at the end of season during a storm event, but this did not impact on project trials. In the third year, two modified 4-module structures were installed in each of Kandal and Kampot provinces in Cambodia.

High low plastic roof shelter (timber/bamboo, 2 modules)

The experience and learning from the initial construction and subsequent failure of materials was effectively harnessed in the next construction phase with new structures not only incorporating design improvements identified in the performance analyses, but there was also greater attention on building technique and better materials were sourced in both countries.

> (See Research Report – Review of Low Cost Protected Cropping (LCPC) for Cambodia and Lao PDR, Appendix 27)

Assess performance

Growing conditions within the structures and in an adjacent open field trial area were monitored continuously. Air temperature and relative humidity data was used to gauge the performance of the structures in terms of growing conditions. The structures were also assessed for construction issues and subsequent damage during the season. An informal design and feedback discussion activity was conducted with the teams in each country to understand which aspects of the designs were working, what problems were occurring and to tease out their ideas on what improvements could be made.

Overall the trial design worked extremely well and no significant design alterations were necessary. Some modifications were developed to further improve it. These included adjusting the way in which the module roofs overlapped, increasing the roof curvature to improve runoff during heavy rain events and, when using bamboo as the framing material, some components were replaced with timber to provide a straight edge. These modifications were identified by the project partners to make construction easier and demonstrate a significant increase in team capacity and knowledge over the first phase of the project.

In terms of performance, the structures met target parameters and were able to provide weather protection for crops without generating poor growing conditions. The

primary metric being targeted was air temperature (excess heat) as this is the main problem with other low-cost structures, particularly plastic tunnel houses. Monitoring of all the sites found that the structures were able to adequately ventilate excess heat.

The project design can provide growing conditions comparable with ambient and is substantially superior to the low-cost benchmark tunnel house (figure 7).

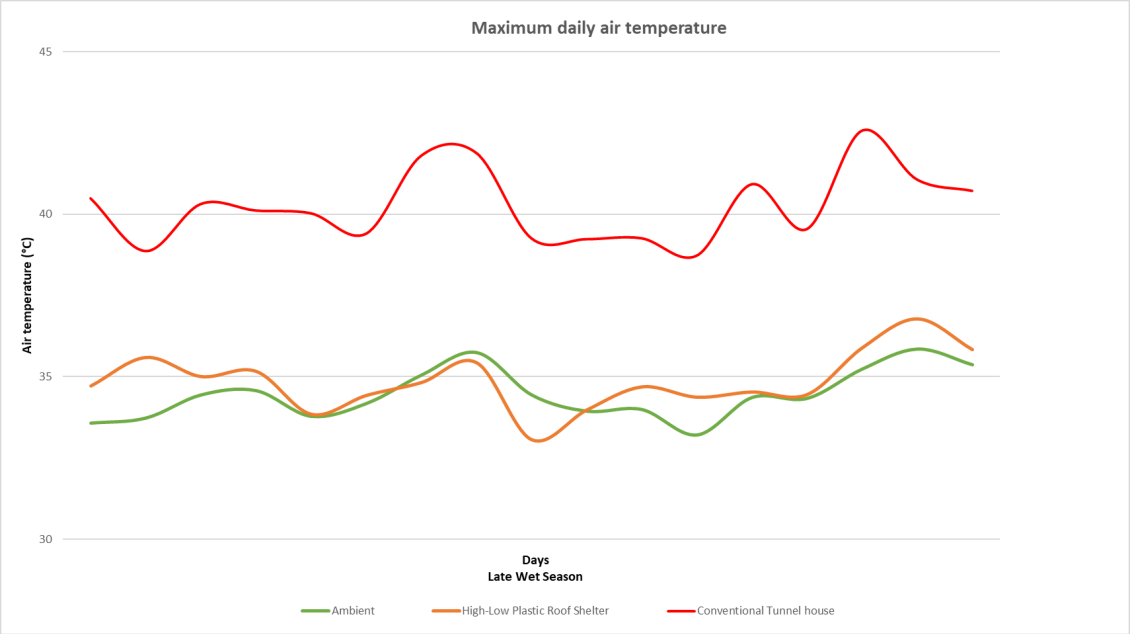


Figure 7: Typical air temperature profiles (tunnel house compared with project design and ambient)

Performance assessment was conducted in two phases. The first round of trials compared three production conditions – plastic, shade and open field. The second phase combined plastic with shade and again compared three production conditions – plastic, plastic & shade and open field.

The project design with plastic cladding, protected crops from rain and storm events without adversely trapping heat or humidity around the crops. The shade cloth provided marginally cooler conditions (2 – 3°C) compared with the plastic cover. This was in line with expectation as the shade enables greater air exchange and reduces incoming radiation levels. Rain is also able to penetrate the structure covered in shadecloth which further aids cooling.

The use of crop trials as an element of the structure evaluation and performance confirmed further information. Under shade, the reduced light conditions and increased cooling benefited leafy vegetable crops. Conversely, flowering/fruiting crops performed less well due to the lower light levels and some moisture damage, though fruiting crops can benefit in the dry season as extreme heat is moderated. Over the whole year, either plastic and/or shade provided superior growing conditions compared with the open field.

The project trials and evaluations indicate that, not only is the High Low Plastic Roof Shelter superior to other low-cost protective structures, common vegetable crops can be feasibly grown, not only during the wet season, but year-round.

Broccoli growing under the combined plastic and shade clad protective structure produced a 475% increase in marketable yield compared with open field production. Cucumber growing in the High Low Plastic Roof Shelter achieved a 126% yield

increase over unprotected cultivation. Yield of Chinese kale was increased 63% and coriander output was 835% greater with low cost protected cropping.

Research trials consistently found the High Low Plastic Roof Shelter produced a significant benefit compared to open field production, and the singular impact of using appropriate protected cropping is greater than the improvements obtained from other management practices.

Two optional modifications were enabled in the project design – shadecloth and insect netting. Shadecloth covering was evaluated in the trials and showed that shading can have both beneficial and adverse impacts depending on ambient conditions and crop selection. In the final design High Low Plastic Roof Shelter, the shadecloth can be installed as a moveable screen enabling the farmer to flexibly manage the growing conditions.

Insect netting was not evaluated in this project, but the high low module vent design was developed to provide enough air exchange in anticipation that structures would be enclosed with netting in the future. Further research on this is needed to ensure that an overall benefit is achieved, or whether additional modifications are necessary, before being promoted to smallholders.

> (See Research Report – Cambodia first season structure performance, Appendix 28)
>
> (See Research Report – Lao PDR first season structure performance, Appendix 29)
>
> (See Research Report – Construction Guide, Appendix 33)

Economic analysis

In addition to the technical performance evaluations, the economic feasibility is a key criterion. A full analysis of the material and construction costs of the final project design determined that the High Low Plastic Roof Shelter costs approximately US$5.30/m^2. This compares very favourably with other available designs which range from US$5.20 – 7.00/m^2. Material costs were also reduced over the course of the project enabling better quality materials to be used at a similar price point.

Construction labour is a significant proportion of the building cost. The design is made simple and with a construction guide, farmer self-building is an option and can be a strategy for reducing the financial outlay for smallholders.

Economic analysis determined that a likely payback period for a farmer making this investment can be less than one year, on a structure with an expected useful life of more than 10 years (cladding replaced every 3 years). Specific financial details depend on crop selection, yields achieved and market prices. Analyses considered gross margins for crops, annual crop cycles (days/crop) and capital and maintenance costs when a protective structure is used. (Cost of finance is not included).

Gross margins were prepared for several crops grown in Cambodia and Lao PDR and an annual cropping cycle was developed in conjunction with the collaborating farmers.

Five-year projected income benefit (gross margin)

Site	Open field (180m^2)	Protected cropping (180/m^2)	Benefit of investment
Cambodia 1 (Kampot)	US$1530	US$5770	US$4240 (+277%)
Cambodia 2 (Kampot)	US$1666	US$3775	US$2109 (+126%)
Cambodia 3 (Kandal)	US$2070	US$4620	US$2550 (+123%)
Lao PDR 1 (Vientiane)	US$3710	US$4800	US$1090 (+29%)
Lao PDR 2 (Vientiane)	US$2480	US$5085	US$2605 (+105%)
Lao PDR 3 (Paksong)	US$2520	US$6200	US$3680 (+146%)

A five-year farm model crop financial analysis was conducted for three farms in Cambodia and three in Lao PDR. In each case study, the financial return of two different situations (pre-project open field production and protected cropping production) for an equivalent footprint is assessed over a 5-year period.

Each of the farmer case study models indicates a production and financial benefit from growing vegetables in the 'High Low Plastic Roof Shelter' compared to open field production. Consistent across the many field experiments conducted during the wet season months, higher crop yields and good quality was achieved for crops grown in the protective structure. Additionally, when farmers sold their vegetables, particularly in the wet season months, they received premium prices.

Although the farmers achieved an improved financial position, a review of the crops they selected for growing in their greenhouse identified a poor crop rotation practice. Many crops were from the same botanical family and this increases risks of pest and disease. Eventually this would lead to diminishing returns due to increasing management costs and/or lower yields.

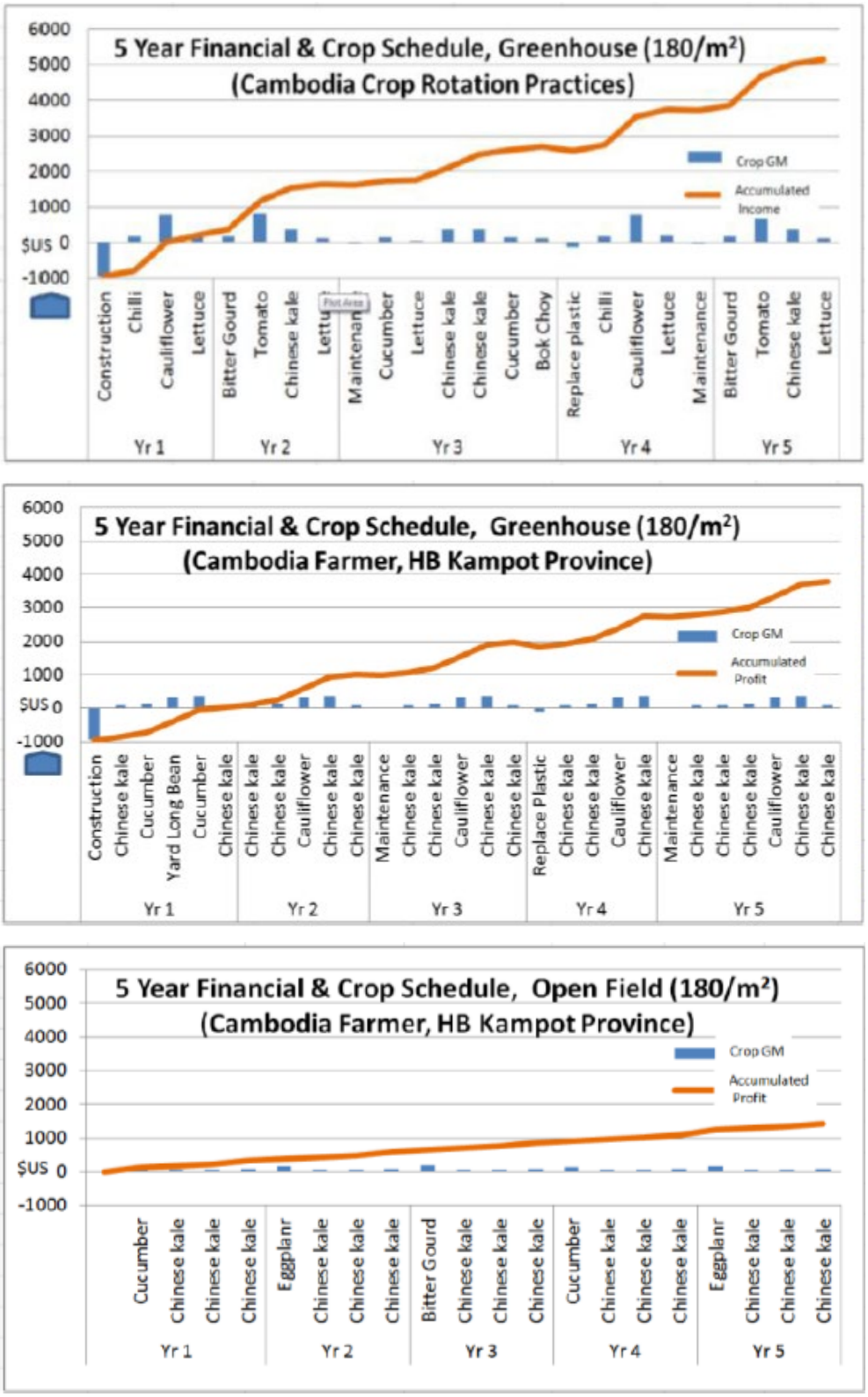
A theoretical 5-year cropping model was developed using crops the farmers are familiar with and following a good crop rotation practice. In Cambodia, the accumulated 5-year income in the High Low Plastic Roof Shelter was calculated to be US$5125. The average income from the three Cambodian open field case studies is US$1755, indicating that a realistic, good cropping practice could realise a 5-year net benefit to Cambodian farmers of US$3370. This is a potential income increase of 192% over pre-project practice.

A similar result was found in Lao PDR. A potential good cropping practice income of US$6415 (over 5 years) indicates the net financial benefit of using a High Low Plastic Roof Shelter could be US$3512 or an increase of 121% over current practice. Simple financial comparison from the farmer perception survey[5] found that cash profit from greenhouse production is 2.6 – 3.4 times that of open field production.

(See Research Report – Analysis of crop production with High Low Plastic Roof Shelter, Appendix 32)

[5] *Research report: Greenhouse evaluation - farmer perceptions (Appendix 34)*

Figure 8: Illustration of 5-year financial position of open field, basic protected cropping and good practice (rotation) protected cropping



Farmer perceptions

Key qualitative responses from farmers that reflected a positive attitude towards adopting any type of protected cropping were that the structure makes it possible to grow year-round, and especially in the wet season. It is easier to manage the crops, the conditions inside the greenhouse are described as good for crops and there is a capacity to protect crops from pests (reduce chemical use). Higher prices can be achieved. Reasons against adoption of any protected cropping reflected resource issues (lack of labour, land or capital), with two exceptions: Farmers identified excess heat and difficulty in preparing ground (equipment access) in non-project structures as a reason for not adopting protected cropping.

Overall, farmers involved directly with the project design greenhouse are strongly in favour of further investment and consider the technology a game-changer. Farmers involved with other structures see benefits of protected cropping but are not as positive, suggesting that their experiences with inferior structures are somewhat negative. Farmers with little or no exposure to protected cropping cite various obstacles to adoption.

(See Research Report: Greenhouse evaluation - farmer perceptions, Appendix 34)

Activity 3.3 Identify optimal varieties for year-round production of tomato, chilli and 2 leafy vegetables in Cambodia and tomato, chilli and cabbage in Lao PDR

Refer to 3.6 below.

Activity 3.4 Determine potential for extending crop production into the late dry; improved water use efficiency and soil moisture management

Effective water management is identified as a critical element in ensuring year-round production of safe fresh vegetables is achieved. A field audit of irrigation in both Cambodia and Lao PDR was undertaken to provide context for the training activities. In Cambodia, irrigation systems were found to be of good design and appear to reflect the efforts of previous and current projects and commercial promotion of drip irrigation systems. However, on many farms, there is insufficient pressure in the irrigation systems which is adversely affecting the uniformity distribution of water application. Irrigation plots need to be subdivided and run separately. Better maintenance of pumps and pipes is also required. Overall, irrigation scheduling is not well practiced, and water application rates are not adequately meeting crop water demand over the crop cycle.

In Lao PDR, most farms reviewed have a non-regulated dripper system. In these systems, any variation in water pressure will result in large variations in water application rates. Variation in water pressure needs to be carefully monitored and addressed to ensure crops are not over or under irrigated.

Six practical based water management training workshops were delivered for the project teams, other technical/professional staff and farmers in the targeted areas, reaching 132 participants across both countries. Based on the needs analysis and the farm irrigation field review, conducted at the beginning of the project, these activities concentrated on developing knowledge and skills in understanding soil types, water holding capacity, soil moisture monitoring and determining crop water requirements and irrigation output. Training combined a knowledge-based component with practical fields tasks. Installation of drip irrigation and planning a layout for greenhouses was also included to integrate with the protected cropping trials.

With the primary project focus on addressing wet season production capacity (with protected cropping), a preliminary assessment of water challenges with respect to

dry season production in Cambodia was undertaken as a precursor to future research needs. Informal discussions held with project partners, agencies working in the region and farmers in Siem Reap characterised the issues. Early dry season production is good as crops draw down soil moisture levels and growing conditions are favourable. Correspondingly, market prices are weaker during this period due to good supply. Farmers however have limited water storage and rely on the shallow ground water which declines as the season progresses. Towards the end of the dry season, market prices can rise significantly as few farmers have enough water to produce another crop. Three basic strategies for extending crop production were identified:

1. Increase water access and storage

This strategy is a longer-term development opportunity and not in the scope of this project and so was not pursued. Ultimately, this approach will depend on economic viability and capital investment. A focus on improving farm returns is an important preliminary step.

2. Improve efficiency of the water use to extend potential cropping period

This strategy is a medium-term capacity building opportunity. The training and capacity building program initiated in this project has begun this work. Further training and promotion of soil moisture monitoring and drip irrigation is required, and project teams have been able to consolidate their knowledge and skills and now have the capacity to take such a program forward into the future.

Evaluation of current farmer practices found that there is an important obstacle to address. Currently many farmers, in order to extend their water supplies and in expectation that they are being more efficient, are under irrigating and/or applying water ineffectually resulting in poorer crop returns per unit of water used.

3. Improve returns on water use to achieve better outcomes for available water

This strategy is a short to medium term opportunity and was pinpointed as a way of preparing farmers financially for ongoing development and improvement and was concluded that it also addresses the challenge of under irrigating and/or applying water ineffectually which is resulting in poorer crop returns per unit of water used.

As the project had limited time and opportunity to conduct water management trials, a collaborative on-farm dry season trial looking at irrigation and fertiliser application in Siem Reap was instigated. Compared with current practices in the region, in which a fixed volume of water is applied daily, the irrigation trials demonstrated that more closely matching irrigation volume with crop needs produced a 40% higher average yield when compared with current practice of a single fixed daily application and 143% higher yield compared with a fixed, split twice daily irrigation (figure 9). This was necessarily a simple trial and reinforced the training content to facilitate farmer understanding of the importance of knowing crop water requirements.

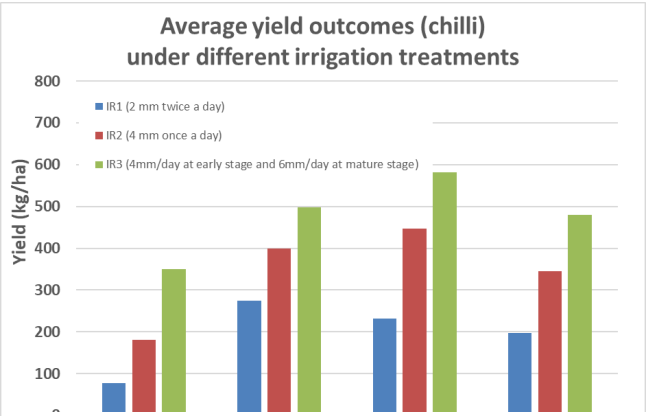


Figure 9: Average chilli yield outcomes under different simple irrigation strategies

The Australian based research into water use efficiency, energy efficiency, satellite-based scheduling and basic

economics of sub surface drip irrigation was used in training content to highlight to participants the technology and potential for improving water efficiency.

The precision irrigation systems (Centre Pivot and subsurface drip) were more effective than flood irrigation in applying the ideal amount of water. This reduced both water logging and moisture stress. With subsurface drip, applying 30 mm twice was more effective than applying a single 60 mm irrigation, resulting in reduced water logging, faster regrowth and better stand persistence. A 65% increase in yield can be achieved where an irrigation system is upgraded from simple flood irrigation to subsurface drip. From this trial and the financial analysis of operating and energy costs, yields and market prices for lucerne hay, it is estimated that the payback period for investing in this improved irrigation technology is approximately three years. Five extension activities were conducted with Murray Dairy industry (150 irrigators) on irrigation scheduling and system layouts as part of this research.

In addition to this work, the adaptability of satellite-based irrigation scheduling using irriSAT[6] was investigated in NSW with the view to using this technology with a broader range of crops to improve water management decisions. The irriSAT App is an irrigation scheduling tool that can be used to aid irrigation decisions. The App went live in 2017 and as of end of 2019, there are 2052 registered users.

(See Research Report – Subsurface Drip Irrigation (SSDI) demonstration and scheduling development, Appendix 36)

Activity 3.5 Identify major disease constraints for wet season production. Design and implement management strategies to control major disease issues

Pest and disease lists were compiled and prioritised. In Cambodia, flea beetle, army worm, leaf miner and diamond back moth were identified as key pests. Damping-off and 'unknown viral' diseases are the major crop disease problems. Damping-off and Bacterial Wilt were identified as the major problems in Lao PDR. This was confirmed in the field as well as nursery situation. Field disease survey for bacterial wilt in solanaceous crops identified all samples collected in Champasak to be positive for *Ralstonia solanacearum*, which is thought to be the first report of this disease in eggplant in the Paksong district. The HRC team, in collaboration with the Plant Protection Centre, are preparing to write up this finding for publication.

Farmer Field days in both Cambodia and Lao PDR focused on (i) demonstrating 'how to inspect' crop symptoms as a whole, (ii) learning to observe cues on pathogen distribution, (iii) how it has entered the crop, (iv) how it is possibly being spread and (v) estimating incidence and severity using visual scales.

Training in Lao PDR upskilled the project team in identifying pathogens to species level where this is critical to the management. This was done during a disease survey as part of a preliminary study when setting up a biological control agent experiment for the control of Bacterial Wilt in tomato at the Southern Agricultural research station, where there is a history of Bacterial wilt disease. The team were also trained in how to manually confirm the presence of bacteria from parts of symptomatic tomato and eggplant plants by looking for evidence of bacterial ooze and further identified this bacteria as *Ralstonia solanacearum* using AgidaBEB1 identification kits. This training was guided by Ms Khonesavanh Chittarath, plant pathologist of the Plant Protection Centre of the Lao Ministry of Agriculture in Vientiane. A collaboration between the PPC and the HRC was established through these project activities.

As a component of the IPM adoption interactive workshops, a constraint analysis and a series of five action plans were developed (Appendix 38). Many farmers were

[6] https://irrisat-cloud.appspot.com/#.

found to be generally reluctant to adopt crop rotation and fallow periods to manage pests and diseases as they are concerned about choosing an alternative crop with a lower market value than their main crop of choice. A number of farmers attending field days claimed to be practicing crop rotation, however, in most situations, rotated crops were from the same botanical families. Two demonstration trials were conducted to support the training and build confidence and capacity in the local team. One trial investigated the application of biological control agents (BCA), soil amendment and cultivation. Another investigated benefit of crop rotation.

Crop	Issue to investigate	Treatment	Key Results
Tomato	• Bacterial wilt causes significant crop losses and poor yields	• BCA - *B.bassiana; B.thuringiensis* • Soil amelioration • Cultivation	• Application of biological control agents delayed both the incidence and severity of bacterial wilt *Trial was mistakenly terminated when disease incidence was widespread and following staff changes
Coriander	• Crops are not being properly rotated and incidence of pests and disease is high	• Coriander monocrop • Coriander – tomato rotation • Coriander – tomato – lettuce rotation	• Blind assessment by farmers indicated a strong quality/appearance difference between coriander grown as part of a rotation and mono-cropped coriander with rotated crops being found to be better quality • Coriander grown in a 3-crop rotation had an average higher yield than 2-crop rotation which was marginally higher than monocropping (not significant in this trial). *These results are preliminary. The trial is ongoing to determine longer term impacts of rotation

Pre and post plant field surveys of extension staff were conducted. Surveys of extension staff before and after field days were used to assess the benefit of the activity for their capacity to further extend the learnings on crop rotation as an IPM tool. The responses showed, across all extension staff, an increase in self-confidence in their knowledge about crop rotation and their confidence to share and promote this practice to farmers. The likelihood that they would recommend this practice to their clients increased after the workshop. Both female and male extension staff indicated that they would be able successfully encourage their famers to adopt crop rotation as an IPM tool.

Activity 3.6 Optimise management practices for dry, late-dry and wet season production through on-farm replicated and demonstration trials

Twenty crop trials across eight field sites were conducted in Lao PDR and there were a further eight trials over four sites in Cambodia. The trials harnessed multiple objectives. All crop trials were conducted within the protected cropping structures and included two structure system treatments (plastic, shade or plastic and shade) and a control (open field) in order to assess the greenhouse technology. Trials also included management practices and/or performance of crop varieties (crop types) to identify crops and practices suited to a sustainable year-round protected cropping program.

Additional objectives of these trials were to provide research experience for the project teams, as well as training and demonstration opportunities. An initial focus on tomato and chilli and leafy vegetables (Cambodia) and cabbage (Lao PDR) were modified to target higher value products potentially needed to justify the greenhouse investment costs (based on a preliminary return on investment assessment for trial structures) and to accommodate preferences of collaborating farmers.

High value crop varieties for wet season production were identified from farmer experiences and market analyses and included cauliflower, tomato and Chinese kale in Cambodia and in Lao PDR, coriander, spring onion, lettuce, tomato and broccoli were favoured. The demand for coriander and spring onion in Vientiane was reported at a field day to have increased with the improved product quality and supply. Both the project market research and the farmer trial results are showing the high prices for these crops in wet season.

Crop	Issue to investigate	Treatment	Key Results
Coriander	• Low yields in the wet season with poor establishment due to rain impact	• Protected cropping • Mulch (rice husk, rice straw)	• Protected cropping (with shade cover) generated significantly higher yields (835%) compared with open field production. • Mulch (rice straw or rice husk) improved plant establishment and yield compared with no mulch. • Shading coriander resulted in improved leaf quality (green leaf colour).
Broccoli	• Is crop nutrition suboptimal? Yields and quality can be improved with optimum nutrition (potassium levels benefit head development (product quality)	• Protected cropping • Potassium (K) fertiliser rate	• Protected cropping (plastic and shade cover) resulted in significantly higher yields (475%) compared with open field production and plastic cover alone (155%). • Potassium fertiliser applied at 130kg/ha produced significantly higher yields (39%) than 50 kg/ha K and 14% higher than 80kg/ha.
Tomato	• Bacterial wilt disease causes significant yield loss in Champasak Province	• Protected cropping • Grafted plants (disease resistant rootstocks)	• Protected cropping (plastic cover) produced significantly higher yields (up to 100%) compared with open field production and between 25% and 42% higher yields compared with shade cover. • Grafted plants produced significantly higher yields (32%) compared with the standard locally used variety.
Tomato	• Yields can be increased by improved fruit set	• Protected cropping • Pollination techniques	• Pollination techniques, CPA hormone spray and mechanical vibration had no significant effect on yield improvement in these trials.
Cauliflower	• Poor seedling establishment due to (a) rain impact and disease infection and (b) heat stress with plastic mulch. • Variable head quality (small size, uneven shape, yellow colour) due to rain and/or heat	• Protected cropping • Mulch (straw & plastic)	• Protected cropping (plastic cover) produced significantly higher yields (>100%) than open field and 20% higher than combined plastic & shade cover. • Cauliflower heads grown under plastic were larger and heavier (8%) compared to combined plastic & shade cover. • Rice straw laid over plastic mulch provided cooler conditions for seedlings and increased plant establishment. • Some open field crops were completely destroyed by heavy rain, producing no yield
Chinese kale	• Yields can be increased by optimising plant population	• Protected cropping • Plant population	• Protected cropping (shade cover*) produced significantly higher yields (63%) compared with open field production. **Plastic & shade combination not evaluated* • Shading Chinese kale produced better leaf quality (longer and wider).

Crop	Issue to investigate	Treatment	Key Results
			• Higher plant populations did not result in higher yields compared to standard farmer plant population practices.
Cucumber	• Yields can be increased by optimising plant population	• Protected cropping • Plant population and trellis	• Protected cropping (plastic cover) produced significantly higher yields (126%) compared with open field and 26% higher than plastic & shade combined. • Plant population and trellis treatments/practices were inconclusive.

(See Research Report – Field trial notes, Appendix 35)

Activity 3.7 Develop technical recommendations for extension materials

Activity 3.8 Up-scale technical recommendations utilising demonstration trials

Misalignment of project timeframes reduced the capacity for full integration of project learnings and resources into the PADEE project. However, a collaborating partner, iDE, facilitated and supported the selection of farmer sites in Cambodia, which were selected from the PADEE collaborators to foster this integration. The forum events in both countries (Obj 4.1) as well as collaborative project networking with NGO, government organisations and the private sector in Cambodia and Lao PDR, enabled outputs and learnings including training delivery by in-country partners, to be extended to a range of other programs and projects. In addition, an online share point was established as an activity of the project team and all resources have also been made available for sharing and dissemination through that portal[7].

Technical recommendations included in project reports, resources and training materials cover design and use of low cost protected cropping for wet season and year-round production of vegetables as well as crop rotation and the production of key crops, practices for producing safe vegetables and good postharvest management. All recommendations are also supported with economic analysis.

Training workshops delivered for project teams, peers and related projects (NGO and government programs), as well as farmers, focussed on background knowledge, good practice recommendations and shareable training resources, training plans and presentation content.

Dual language posters (Khmer/English, Lao/English)

- Protected Cropping : describes the benefits of an appropriate greenhouse
- Greenhouse Design : describes the key features of the High Low Plastic Roof Shelter developed by the project
- Covering & Crop Selection : describes the key use of plastic and shade covers for different crops
- Crop Rotation : describes the key aspects of selecting crops from different botanic families
- Producing Safe Vegetables : describes essential recommended practices for food safety
- Postharvest Handling of Vegetables : describes key recommended practices for good postharvest management

Lao PDR Scientific extension posters

- Coriander Production in the Greenhouse
- Tomato Production in the Greenhouse
- Broccoli Production in the Greenhouse
- Lettuce Production in the Greenhouse
- Greenhouse Design Construction

[7] *Tropical Agriculture Research and Information Share Point: www.tarisp.group*

- Economics of Greenhouse Vegetable Production
- Research & Development of Greenhouse

Videos – farmer awareness (English, Khmer and Lao)

- Rain shelters for vegetable production (Benefits of greenhouses)
- Building a High Low Plastic Roof Shelter (Greenhouse construction)
- 9 Simple steps for safe quality leafy vegetable in Cambodia
- 9 Simple steps for safe quality leafy produce in Lao PDR

Analysis of the economics of crop production with a High Low Plastic Roof Shelter

- Six farmer case studies and two composite case studies
- Farmer perceptions on the high low plastic roof shelter

Demonstration, training and extension activities were conducted over the full course of the project with the view to building awareness and background confidence in technologies and practices being evaluated and recommended. This approach was taken as the project needed to identify, analyse, and prove feasibility of interventions in order to provide a stage for up-scaling. Many subsequent activities were conducted by the in-country partners.

The Lao team also developed a collaboration with East West Seeds and actively reviewed existing extension resources for suitability to the Lao context. Three 'Grow How' cropping guides and five technical guides relevant to the project were then generated jointly with East West Seeds:

- 'Grow How' Tomato
- 'Grow How' Yard Long Bean
- 'Grow How' Pak Choi
- Seedling production
- Insects as vectors
- Bacterial Blight
- *Tuta absoluta* (tomato leaf miner)
- Safe use of pesticides

Nine farmer field days covering protected cropping, crop production, IPM, food safety and postharvest handling were organised and delivered in Kampot, Kandal, Vientiane and Champasak. There were 150 direct participants.

Complementary to the farmer extension, three technical workshops were held in Kampot, Kandal and Champasak with a total of 90 participants. These events specifically targeted extension workers, agricultural college staff, university staff and other research centre staff as these people will be influential in future upscaling of recommendations.

Representing the project team at the Horticulture Research Centre (HRC), Vientiane, Mr Phathana Sengounkeo presented on the protected cropping design and recommendations at the international Green Korea Conference in 2017. The HRC collaborated with the Korea International Cooperation Agency in running five training and extension activities in protected cropping at the project demonstration trials in Vientiane. Two events focussed on local farmers (40 participants) and three events were for technical/professional PAFO and DAFO staff (60 participants). A further five greenhouse management training workshops were run by the in-country partners off-site for other projects (100 participants).

Four formal visits to the project demonstration sites in Vientiane were orchestrated and included 111 visitors from KIOCA projects, 23 local farmers, 50 farmers from outside of Lao PDR, 23 students from Lao training institutions, 11 agricultural

university students and 15 staff from the Asian Food and Agriculture Cooperation Initiative (AFACI).

Five project promotions (articles) were published by HRC team in the NAFRI newsletter in the latter part of the project focussing on the value and benefit of the greenhouse production:

- Vegetable production in the greenhouse, May 2018
- Integrated pest management (IPM) on vegetables, June 2018
- Greenhouse Management, Crop Production, Postharvest Technology and Food Safety in Vegetables, July 2018
- Research & Development for Vegetable Production in the Wet Season for Improving the Income of Smallholder Farmers, Jan-Jun 2019

Four regional vegetable forums were run by the project. These events were facilitated by the team and fully funded with external sponsorship with the over-riding theme of sharing knowledge to promote development of the vegetable sector:

- Fostering a safe and sustainable vegetable sector, Phnom Penh 2017
- Fostering a safe and sustainable vegetable sector, Vientiane 2017
- Innovations of production and supply chain systems for improved off-season vegetable, Phnom Penh 2018
- Supporting the adoption of improved practices and new technologies by smallholders for sustainable year-round production of safe fresh vegetables, Vientiane, 2019

Farmers were also a key outreach target for the recommendations from this project to establish a base for future up-scaling. In addition to attendance at training and field days, 343 farmers visited protected cropping demonstration trial sites to look at the structures and crop demonstration trials.

Objective 4. To foster communication and collaboration between government, NGO and private sector vegetable industry stakeholders

Activity 4.1 Convene regional vegetable industry forums to forge networks between public, NGO and private sector vegetable professionals, and facilitate the exchange of ideas on sector development

Four regional vegetable forums were convened by the project. These events were enabled by the project team and were supported with external sponsorship. The over-riding theme of the forum program was sharing knowledge to promote development of the vegetable sector.

These activities facilitated links for regional stakeholders across the vegetable industry and were designed to foster trans-disciplinary approaches to vegetable production within the farming system. Throughout each event, there was an exhibition of posters and displays highlighting the many organisations, projects and initiatives that were underway and involved development of the vegetable sector. A forum handbook was also published for each event. The handbook summarised the many programs and projects being undertaken and provided a reference and contact for developing further collaborations.

Fostering a safe and sustainable vegetable sector, Phnom Penh, 2017

This forum presented a comprehensive overview of the current status of the Cambodian vegetable sector with the main sessions focussing on experiences and challenges with different kinds of food safety and production standards, the political

environment and on the options for partnerships and different market arrangements that can foster improved opportunities for smallholders.

The event was supported by SDC-CHAIN project, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Life With Dignity (LWD) and World Vision. HEKS and NGO Forum participated in planning and organisation. There were 160 registered participants representing government, development and private sectors.

Fostering a safe and sustainable vegetable sector, Vientiane, 2017

This forum presented an overview of the current status of the Lao PDR vegetable sector with the sessions focussing on markets, smallholder organisations and current research priorities. Experiences with different kinds of food safety and sustainability standards were presented and discussed as well as the political and policy environment. The options and examples of partnerships and different market arrangements that can foster improved opportunities for smallholders were addressed.

This forum was opened by Dr Phuangparisak Phravongviengkham, the Vice Minister of the Ministry of Agriculture and Forestry. He called for practical policy recommendations to be generated from presentations and discussions during the Forum, to be included in a report presented to the Government of Lao PDR by the National Committee on Commodity Production and Food Security. These recommendations were subsequently compiled by NAFRI and project staff, and contextualised with the help of Mr Samm Musoke, a Policy Advisor to MAF, funded by the FAO.

The event was supported by Catholic Relief Services (Laos) and the Korean Environment Institute. There were 120 registered participants representing government, development and private sectors.

In conjunction with each of these two forums, a technical workshop was held on forming farmer groups and agri-clusters – *Developing and implementing successful partnerships in the vegetable sector*. The workshops were facilitated by cluster farm experts and explored the elements of supply chains and actors, different models of partnership and the personal, political, technical and financial environments which supply chain partnerships navigate.

Innovations of production and supply chain systems for improved off-season vegetable, Phnom Penh, 2018

This regional event brought together key stakeholders to share research and development results for improving off-season vegetable production and quality. The presentations and discussions focused on more technical aspects of production and supply chain systems as a follow up to the previous forums.

It was supported by Agro-ecology Learning Alliance in South East Asia (GRET/ALiSEA), Life With Dignity (LWD), World Vision, DunChurchAid (DCA), Banteay Srey, Cambodian Horticulture Quality (CHQ of Plant and Food Research PFR) New Zealand, Oxfam, Caritas Cambodia, World Renew, and Anakot Kumar (AK). There were 210 registered participants representing government, development and private sectors.

Supporting the adoption of improved practices and new technologies by smallholders for sustainable year-round production of safe fresh vegetables, Vientiane, 2019

This final regional forum brought together key stakeholders to share experiences and expertise on the challenges, strategies and research that offers effective impact, increased awareness of confidence in interventions and ultimately moves target audiences toward adoption.

The Tropical Agriculture Research and Information Share Point (www.tarisp.group) was also launched at this event. This project-initiated resource hub offers all stakeholders throughout the region, an online portal to actively share project work, trials and information resources. A Seed Swap, hosted by ECHO Asia, demonstrated the value of simple activities which help to bring smallholders to participant in improvement programs and access information.

It was supported by ECHO Asia, USDA - Creating Linkages for Expanded Agricultural Networks (CLEAN), SDC - Enhancing Nutrition of Upland Farming Families (ENUFF), KOPIA Centre in Laos, Life With Dignity (LWD), The Lutheran World Federation in Lao and SwissContact. There were 122 registered participants representing government, development and private sectors.

Activity 4.2 Develop concept of an extension hub/platform hosting research and extension outputs developed by ACIAR and other projects

The Tropical Research and Information Share Point (TARISP) was developed by the project team as an online share point to provide a platform for soft publishing and sharing research and extension resources across the regional development sector. This format was the preferred option to address key challenges identified in establishing a broad open access extension hub.

The portal is an open access site for agricultural communications and the sharing of research, trials reports, short communications, multidisciplinary articles, student reports and freely available extension and learning materials related to agricultural and vegetable development in the tropics. The forum does not hold the copyright of the published articles and no articles are peer-reviewed.

The share point enables anyone to upload their reports and resources and make them freely available. This provides an avenue to minimise the loss of learnings that might otherwise not be published and provides a platform for further dissemination of resources and reports, produced by research and development organisations.

Files are uploaded into main categories and in addition to the author/s name and organisations and resources title, up to 10 keywords can be included for ease of searchability and for search engine optimisation.

Anyone can search the share point for resources, reports and other files that have been shared, and freely download the resource, if desired. To maintain the integrity of the hub with minimal maintenance, the user community can readily police content and flag any uploaded item they feel is inappropriate.

The online portal, www.tarisp.group, was launched at the 2019 Regional Vegetable Forum, in Vientiane.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Advances in the development and application of market price reporting systems, biophysical mapping of supply chains, quantification of the food safety risks on-farms, accuracy and reliability of pest and disease diagnosis both in the field and laboratory and implementation of sustainable protected cropping production systems were achieved under the auspices of this project.

The project team have contributed to a change in scientific practices through research conducted as part of this project. Dr Sambath successfully completed her PhD in food science: Sambath, S. (2018) *Effect of 1-MCP and Modified Atmosphere on the Storage Life of Tomato, Pak Choy, Choy Sum Held at an Ambient Tropical Temperature*. The University of Newcastle, NSW, Australia.

Dr Sambath published in the journal *Fruits*: Sambath, S., Wills, R.B.H., Ku, V.V.V. and Newman, S. (2018) Retention of green colour of tomatoes marketed as a green vegetable at ambient conditions in Cambodia with modified atmosphere storage and fumigation with 1-methylcyclopropene (1-MCP). *Fruits.* 73 (5), 265-272.

The postharvest team have also published in the *Journal of Horticulture and Postharvest Research*: Ku, V.V., Inthalangsee, B. and Wills, R. (2019) Use of maturity sorting and reducing ethylene with potassium permanganate to enhance marketing of tomatoes in Laos at ambient tropical temperatures, *Journal of Horticulture and Postharvest Research*, 2, : 61-68.

The use of ethylene absorbent sachets to delay ripening of tomatoes was presented in the regional vegetable forum in 2018 in Phnom Penh. Participants at this forum included government departments, multiple international NGOs and private companies and individuals involved in the fresh vegetable industry. It is expected that the impact from demonstrating the efficacy of this technology in tropics will underline changes in research and commercial practices in postharvest handling within the short to medium term.

In 2020, based on these results, Project ALBA, is going to be using the ethylene absorbent sachets in their tomato supply chain.

Two project team members were externally funded to present posters at the TropAg2019 conference. Their work represents key elements of the scientific impacts of this project and international exposure of their work has the potential to enhance their own professional development, and the recognition of their respective employer organisation. Dr Sonnthida Sambath (CARDI) presented on *Postharvest Innovation to Maintain Vegetable Quality in Developing Countries with Inaccessible Cool Chain Facilities*. Dr Thongkhoun Sisaphaithong (HRC, NAFRI) presented on *Low Cost Protective Structures Providing Suitable Growing Conditions for Vegetable Crops Year-round in the Tropics*.

The postharvest project team in Lao PDR are impacting on the scientific practices across Lao PDR as the postharvest training material developed and used for this project has been adopted into other government projects to support vegetable development, nationally. Two staff from CASC who were trained as part of this project (Mr Bountieng Phonesavanh and Ms Vienthong Vinaiya) have now begun training government officers in DAFO. This will not only result in significant scientific impacts in five years but represents a substantial impact on capacity in this field. In addition, the project food safety training has been developed by a project team member, Mr Sayvisene Boulom, into further teaching materials at NUOL and is

forming part of a Masters of Public Health. The scientific impact of this is significant as the food safety concepts and skills are reaching a wide range of Lao professionals beyond agriculture including from the Food and Drug Department, Institute of Public Health, nutritionists and the Health Administrative. Mr Boulom's knowledge and skills obtained in this project are also changing scientific practices in other industries. Based on our training materials, he has also developed the verification check list for use in the meat industry and risk analysis for the livestock industry.

The RUA is developing a new subject – *Food safety in vegetable production* – for a future course following project training and field activities conducted by this project. By embedding this knowledge in education courses, within five years, graduates will be influencing scientific practices in public and private organisations throughout Cambodia.

The project developed a novel protected cropping design and evaluated the performance of these structures in terms of crop growing conditions year-round, determined potential high value crops as part of research trials and assessed the economic feasibility of the new design. New out-of-project structures have already been constructed based on the results from project research including:

- Kbal Koh Research Station, Cambodia
- NAFRI, Lao PDR
- Xanthanie Agricultural College, Lao PDR
- Lao-Viet Centre (Champasak province), Lao PDR
- HRC (as part of a hydroponics project), Lao PDR
- 30 structures built by farmers: Luangprabang & Bolikhamxay Provinces, Lao PDR

The construction by institutions indicates a strong interest in ongoing development of protected cropping from this research, while the adoption by farmers is directly following extension of project research outcomes by the project team in Lao PDR.

Several farmers have adopted new cropping programs based on the project's technical and financial results. Improved diagnostic skills and repeated surveys have led to the identification of new research opportunities that can improve IPM adoption. In five years' time, it is anticipated that the increased use of better protected cropping structures and associated practices will result in more use of appropriate crop rotation practices and more smallholders producing high value wet season crops like coriander, spring onion and lettuce. Following the project's IPM field program, the directors of the Horticultural Research Centre and the Plant Protection Centre, in Lao PDR, signed a memorandum of understanding to formalise a collaboration for future projects. This will provide a positive impact on scientific achievement in the medium to long term.

8.2 Capacity impacts – now and in 5 years

The project team confirmed a new design for a low cost protected cropping structure for use in tropics. They also learnt why the design is superior and how to build the structures. They were able use this knowledge to develop and independently deliver training and extension resources, including posters and videos.

The ongoing development of protected cropping and postharvest training by in-country partners and their independent delivery of these to other personnel is a significant capacity impact within the project. In Cambodia, GRET[8] staff attended one of the project field sites in Kampot and later completed training on the merits and

[8] *Professionals for Fair Development organisation*

construction of the High Low Plastic Roof Shelter, on-farm food safety practices and postharvest handling practices in Phnom Penh (2019). These workshops, led by Mr Pao Sinath, were prepared and delivered by CARDI project staff. GRET has expressed interest in gaining further training of their personnel into 2020 demonstrating a strong future capacity impact from the project. The CARDI team are now, outside of the project, developing a more comprehensive train-the-trainer program.

Additionally, SNV[9], who was a collaborating partner in this project, in 2019, engaged the CARDI team to deliver protected cropping training for staff involved in their CHAIN-II project (Cambodia Horticulture Advancing Income and Nutrition Phase II) across four northern provinces of Cambodia.

In Laos, the HRC team have been instrumental in initiating and developing smallholder training and a wide range of extension events as well as organising multiple public visits to the protected cropping demonstration sites. The team collaborated with the Korea International Cooperation Agency (KOICA) in running five training and extension activities in protected cropping at the project demonstration trials in Vientiane. Two events focussed on local farmers (40 participants) and three events were for technical/professional PAFO and DAFO staff (60 participants). A further five greenhouse management training workshops were run by the in-country partners off-site for other projects (100 participants).

Four formal visits to the project demonstration sites in Vientiane were orchestrated and included 111 visitors from KOICA projects, 23 local farmers, 50 farmers from outside of Lao PDR, 23 students from Lao training institutions, 11 agricultural university students and 15 staff from the Asian Food and Agriculture Cooperation Initiative (AFACI). These activities were outside of the project research and development plan illustrating the strong impact on capacity that has resulted.

There is every indication that this drive to use the new knowledge and skills in areas outside the scope of the project will continue well into the future. In five years, it is anticipated that the HRC team will lead the development of protected cropping in Lao PDR using the High Low Plastic Roof Shelter project design. Plans are currently being drafted to train and assist growers not involved in this project in construction and management of these improved protected cropping structures. They have also instigated a long-term crop rotation project which utilises the project greenhouses ensuring future use of their newly learned skills in extension and development activities over the next few years.

The Cambodian team also constructed an additional High Low Plastic Roof Shelter independently of the project at Kbal Koh Vegetable Research Station. Not only is this illustrating the knowledge and skill capacity of the project team at the end of the project, but in five years, it is expected that this structure will be a central part of the vegetable research and extension program at the research centre. In Lao PDR, the HRC team are working with smallholders in Thaxang to construct new structures in 2020 outside of this project. The likely impact of this work in five years is significant. The number of people that have been exposed to the new technology and the ongoing support that the project teams are providing in both Cambodia and Lao PDR in training and promotion beyond the scope of this project are substantial. Of note, the recipients of this ongoing extension of the project learning represent a broad cross section of the agricultural development landscape including farmers, extension workers, researchers, institute and project managers and international development program staff. These people will potentially take this information forward into new programs and projects.

[9] *Netherlands Development Organisation*

The advent of the long-term crop rotation research trial was the learning about crop rotations during the protected cropping trial planning activities. Prior to this protected cropping work, little attention was paid to crop rotation with many farmers and research staff, sequentially mono-cropping a small selection of crops, commonly from the same botanical families. Surveys of extension staff showed an increase in self-confidence to share and promote crop rotation to farmers and a prominent impact of this series of activities is that both female and male extension staff indicated that they now have confidence to be able to successfully encourage their famers to adopt crop rotation as an IPM tool.

This change in awareness (in farmers and extension service personnel) will have far-reaching and long-term impacts as it will facilitate improved pest and disease management, better soil management and potentially higher yields. In five years, it is likely that this new knowledge will have introduced a broader range of crops to the farming communities.

Team members from CASC and CARDI were trained in conducting postharvest research and built their skills conducting the numerous project trials and evaluation activities. They will use this knowledge and these skills in all their future postharvest research. The capacity impact of this work in the medium term will be a generational uplift in expertise. The project team staff will be more senior, and it is likely they will be instrumental in training new staff and embedding a knowledge culture in their respective organisations. Dr Sonnthida Sambath's doctorate in food science was supported through the research program in this project and facilitated the equipping of the CARDI postharvest laboratory with key instruments enabling their ongoing research capacity.

From the training and capacity building work, CASC has established a postharvest laboratory. Basic equipment and sensors used in the training workshops and research trials have equipped this team with the technical capacity to continue the postharvest work. It is expected that in five years' time, this laboratory and team will be centrally involved in research and development projects in Lao PDR, as postharvest specialists.

Mr Bountieng Phonesavanh and Ms Vienthong Vinaiya based with CASC, who were trained as part of this project, have now begun training government officers in DAFO. They have both become recognised as postharvest trainers and it is anticipated that the impact of their new knowledge and skills will extend well beyond the next five years and be instrumental in improving the general skills in postharvest management in Lao PDR. The RUA has implemented the concepts of risk assessment and risk analysis into subjects covering Vegetable Production, Organic Farming and IPM following the knowledge staff had gained during the project training. Dr Khay Sathya based with CARDI has been using knowledge and skills from the project delivered food safety training to conduct his own courses at RUA, BBU (Build Bright University), Asia-Euro University and Khemarak University. In five years, there will be a large cohort of university graduates with an underlying knowledge of food safety risk and its mitigation.

Primary factors causing postharvest losses in both Cambodia and Lao PDR supply chains have been described. Low cost, low technology interventions have been identified and tested and this new knowledge will inform all the future activities of these staff as they continue their careers in food safety and postharvest supply chains. In five years, with the increasing pressure for implementation of good practices and certification across the region, the project team and their trainees will certainly be using this knowledge and the skills they have gained. It is anticipated that passive cooling of produce and greater awareness of high temperature as a spoiler of product value will be commonplace in five years and the full impact from this project learning will be evidenced in increasing demand for cool chain logistics.

Risk analysis and assessment were new areas of knowledge to project teams in both countries. Staff were given training and undertook field experience in conducting farm risk assessments. The capacity impact of this work will be felt as both countries push closer to quality assurance and certifications over the short term. Dr Sonnthida Sambath was supported within this project to undertake her PhD in postharvest and food science in Australia. Her involvement and leadership in research activities and training in the latter half of the project demonstrated the beneficial impact of her new knowledge, skills and confidence. General skills and capacity in field surveillance and field-based diagnostics of pests and diseases have been fostered through supported/mentored surveys and this improved capacity is enabling local partners to extend this type of research. All elements of the project promoted good experimental design and assessment and supported good research practices, supporting the personal capacity of all project team researchers.

These activities illustrate the in-country partners' new capacity and confidence to take their research and learning forward.

8.3 Community impacts – now and in 5 years

The mapping of the cabbage supply chains in Lao PDR unearthed important information about the significance of insect damage as a primary contributor to waste and loss in the cabbage industry. The project team reported the findings to the Department of Agriculture. The uptake of this information by higher levels of government is a significant community impact. Integrated pest management and postharvest components were noted as necessary elements in the new five-year national vegetable program.

Multiple farmer field days have been conducted by project staff in both countries over the latter half of the project focussing on food safety, postharvest management, IPM tools and protected cropping. The overall impact of this capacity building effort is difficult to gauge, however, some organic farmers in Thaxang village (Lao PDR) have now adopted the recommended handling procedures after a single activity. This illustrates a solid community change as the whole village is connected through their organic certification. In many field days, farmers who had previously attended a field day or other project training, confidently shared their previous learnings with other farmers. This provides some evidence that beyond the project, community impacts will be realised through farmer to farmer exchanges in villages.

Evaluation of field day participants, conducted as part of the field days, shows that farmers have a greater awareness of food safety risk and understand more about how to mitigate food safety risks on their farms. The community impact in five years is expected to be an improvement in standard product handling and personal hygiene practices on farm and it is anticipated that there will be an impact on general health of farmers, their families and communities as hygiene practices around fresh produce become normalised. The risk assessment protocols learnt and utilised in this project will, in five years' time, be expected to have become a useful tool for Cambodia in developing GAP farming standards which is likely to contribute positively to whole communities. Mr Lun Vanny (GDA) presented the risk assessment results (Cambodia) at World Accreditation Day 2019 in Phnom Penh. He was interviewed on radio about the project work. This illustrates the community impact is already being realised as broadcast media look to present this information to their listeners. In five years, a major community impact from this farm risk assessment is expected to be the substantial progress towards development of GAP farming as the community becomes more aware of the issues.

SNV also reprinted the project posters for distribution to their co-operating farmer networks, with the larger impact being a broader dissemination of the project knowledge across more communities.

A significant illustration of impact on the wider community is the collaboration with East West Seeds which was established with the Lao project team. A landing page for Lao PDR has been launched on the East West Seeds website [10] and the project team were involved in the development of production guides specifically for Lao growers.

Further community impacts are being felt from the wide interest shown by a range of NGOs working in Cambodia and across the SE Asian region. Postharvest interventions identified and investigated by the project team (microfibre towels, stackable crates and ethylene absorbent sachets) stimulated keen interest for further information and training so that these organisations could use this work well beyond the scope of this project. SNV has requested protocols and training from CARDI in using wet microfibre towels. Project ALBA plans to run their own tomato trials with ethylene absorbent sachets in 2020. GRET had CARDI staff host and train farmers from Siem Reap in postharvest handling and will be engaging the CARDI team to conduct further training for GRET project staff and farmers through 2020. SwissContact has been working to develop large commercial up-scaling projects with these technologies and with the High Low Plastic Roof Shelter.

A community impact in five years is to be expected with these many diverse organisations taking on the know-how and skills from this project and using it directly in their own programs. A further community impact that is expected in the medium term will be the increased commercialisation of protected cropping. Khmer Organic Cooperative sources vegetables from organic growers and the owners are also getting involved in the supply of farm inputs and have made a few approaches to the project team to learn more about the ACIAR greenhouse design as they are keen for their farmers to adopt the technology. This is expected to be a significant community impact and it could be a catalyst for more farmers to make technology investments. During the project, one collaborating farmer in Kandal province was able to develop a new supply chain relationship with a retailer, supplying chemical free vegetables. This was made possible by screening the protected cropping structure. The project design continued to provide good crop growing conditions even when fully screened.

These project interventions are also featured in videos pitched at farmers and technical staff. They have been distributed through CASC, NUOL, CARDI, GDA, RUA and HRC, uploaded to YouTube® and shared on the Tropical Agriculture Research and Information Share Point (www.tarisp.group). It is anticipated that in the medium term, the impact of this broad social media distribution will be a general level of community awareness.

A wider community impact of the project to date has been a strong improvement in communication and trust between the technical and research fraternities and the farmers. In Cambodia, there was initial hesitance to be involved in the research project due to subtle trust concerns with government staff and an indication that past projects, including with NGOs, have not necessarily benefited the farmers. With good communication, the project partners were able to establish a level of confidence and through the success of project activities, especially the protected cropping trials, farmers have increased their communication with government staff on a range of topics presenting a tangible change in community attitude.

In Lao PDR, an initial reluctance for researchers to be forward-leaning with on-farm trials and active engagement with farming communities meant that dissemination of

[10] https://growhow.eastwestseed.com/la/la

research outcomes was slow and inconsistent. The project strategy of placing practical research activities on farms and linking these with research centre trials has changed the relationships between research staff and local villages. The community impact of this is playing out with project staff being invited to conduct training in villages with which they previously had little contact. In five years, it is expected that research projects will not be confined to research centres but involve farmers directly. The IPM adoption workshops highlighted a strong interest by key stakeholders (farmers/producers, produce buyers and agricultural extension organisations – government and private sector) to include more IPM methods into the management of pest and diseases. Recognition by these groups of their shared interest in IPM is likely to build support for adoptable IPM tool options and will influence community culture around pest and disease management going forward.

Partners, and some farmers in both countries, are now experienced and skilled in constructing the protected cropping structures and are able to draw upon different building materials. This has generated broader interest in protected cropping, with a good example being Thaxang village (Lao PDR) hosting a training field day as the farmers, with existing protected cropping experience, sought to learn how and why to construct the improved design.

In addition, the project partner organisations have developed and now demonstrate high confidence in the protected cropping work that they have been involved in and have 'invested' in their own structures, including;

- Kbal Koh Research Station, Cambodia
- NAFRI, Lao PDR
- Lao-Viet Centre, Lao PDR
- HRC (as part of a hydroponics project), Lao PDR

SNV have also taken this project design and integrated it into their CHAIN program as they seek to ratchet up their own development work with proven innovations.

GRET have sought out project partners to train their staff and workers with the protected cropping design developed by this project and, importantly, in the improved postharvest management of fresh produce.

Lotus Educational Fund is currently sourcing funds to build a High Low Plastic Roof Shelter near Savannakhet and to train teachers to use the protected cropping system to grow vegetables as part of their school.

8.3.1 Economic impacts

The economic impacts for collaborating farmers at the conclusion of this project have been immense. In five years' time, with a secondary protected horticulture capacity and agribusiness development phase, these economic impacts could be felt across whole communities if a complete focus on a number of agribusiness supply chains across the region can be undertaken. It is worth noting that the economic impacts of intensive year-round horticulture enable gender inclusive business development as protected cropping creates vastly more opportunities due to the potentially higher profitability per unit of key resources such as labour and land.

A key outcome of this work has been enabling improved vegetable production both in the wet and dry seasons, facilitating year-round financially viable cropping and lower risk.

Although the project funded the trial structures, return on investment calculations using the full capital cost and an annual maintenance cost, which includes the replacement of the plastic cladding every three years, were conducted for each farmer case study scenario. The positive impact to the farmers in every situation was

significant. In most scenarios, the structure is paid back within one year. The expected useful life of these structures is at least 10 years.

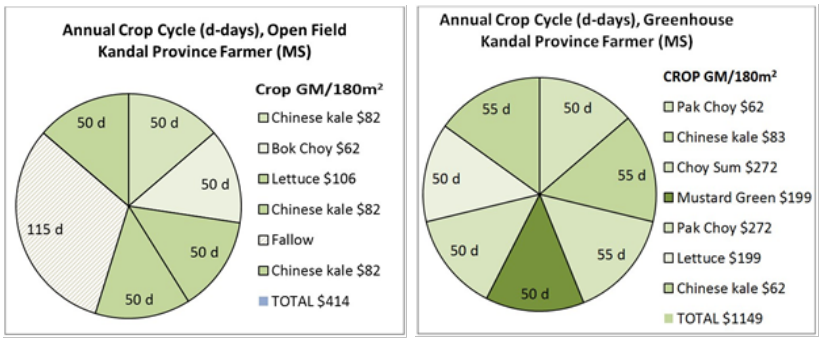
High value crops ideal for wet season production were identified from field trials and matched with market price information. Crop gross margin budgets have been compiled for crops in Cambodia and Lao PDR (Appendices 30 and 31) and summarised in the table below.

Wet season gross margins per hectare | per m²

Crop	High low plastic roof shelter	Open field
Cambodia		
Tomato	US$44,983 | $4.49	US$10,663 | $1.07
Chilli	US$32,194 | $3.22	US$ 6,734 | $0.67
Cucumber	US$19,823 | $1.98	US$ 5,003 | $0.50
Cauliflower	US$43,479 | $4.35	US$11,179 | $1.12
Chinese kale	US$19,415 | $1.94	US$ 2,915 | $0.29
Lao PDR		
Tomato	US$52,942 | $5.29	US$15,142 | $1.51
Broccoli	US$29,427 | $2.94	US$ 7,752 | $0.78
Coriander	US$28,791 | $2.88	US$ 8,541 | $0.85
Lettuce	US$22,517 | $2.25	US$ 6,017 | $0.60
Spring Onion	US$15,752 | $1.58	US$ 3,572 | $0.36

Collaborating farmers were able to improve their incomes (annual financial position) by growing high value crops, with higher yields in the High Low Plastic Roof Shelters. Premium prices were paid to farmers using protected cropping. The market sector was able to confirm demand for product during the wet season and farmers in the project achieved an average financial gain of US$31.50/m², representing an additional US$710 income per farmer per year.

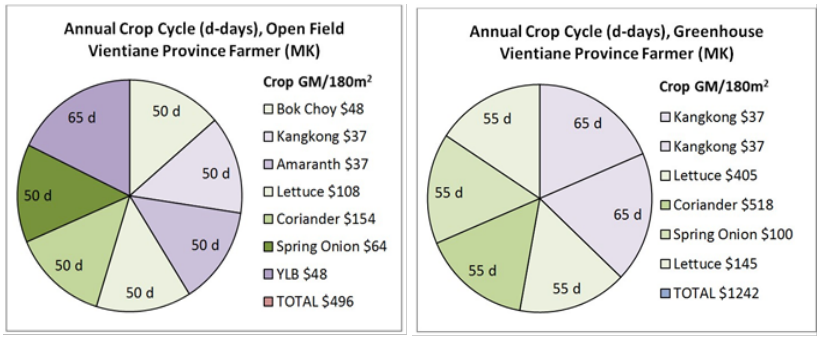
The collaborating farmers, prior to the project, were not materially different to their peers. In Cambodia, Chinese kale is a predominant crop as it can be grown in the wet season and more particularly, across shoulder seasons. The use of an appropriate protected cropping structure enables the farmers to add particular crops that they could not previously grow. Further benefits include that the yield and quality of crops is improved. The average (3 farmers) annual income (from 180m²) without the rain shelter is US$320 ($1.78/m²) and with protected cropping, is US$944 ($5.25/m²). This represents a 195% increase in average income.



Example Cambodian farm crop plans

For Lao farmers, a wider range of crops, especially leafy crops are commonly grown, however low value crops are grown in the wet season. The use of an appropriate protected cropping structure enables the farmers to add particular crops that they could not previously grow and/or gain wet season prices. The average annual

income (from 180m^2) without the rain shelter is US$580 ($3.23/m^2) and with protected cropping, is US$1072 ($5.96/m^2). This represents a potential 85% increase in average income.



Example Lao PDR farm crop plans

By developing a crop rotation plan with the farmers that considers potential economic returns and good agriculture practice, the project developed a possible sustainable cropping plan (Cambodia) that could return US$1025/yr ($5.70/m^2) – a potential 220% increase in average annual income. In Lao PDR, a possible sustainable cropping plan could return US$1283/yr ($7.13/m^2) – a potential 121% increase in average annual income. The concept rotations covered 3 years.

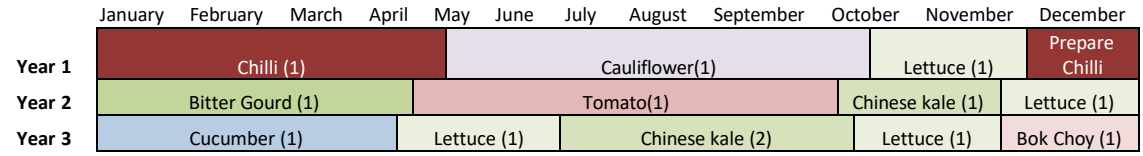
The real-world impact for farmers is that they can increase land productivity, grow more crops per year, actively manage pest and disease risk with preventative practices and target premium price periods for some crops. The significantly higher land and labour productivity also opens opportunities for more inclusion of people with limited resources due to social factors or community expectations.

Case study summary of economic impact

(Cumulative gross margin on 180m^2 site, over 5 years)

	Open field (pre-project)	High Low Shelter (project)	Impact scenario
Kampot 1	US$1530	US$5770	Payback period is approximately 9 months. ROI = 414% (present value over 5 years)
Kampot 2	US$1666	US$3775	Payback period is approximately 1.3 years. ROI = 265% (present value over 5 years)
Kampot 3	US$2070	US$4620	Payback period is approximately 11 months. ROI = 328% (present value over 5 years)

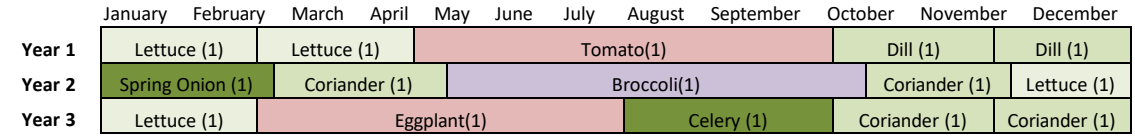
Example crop rotation plan over 3 years



The calculated economic gain of this cropping schedule could be US$5125 (Payback = 11mths, ROI = 347%)

Vientiane 1	US$3710	US$4800	Payback period is approximately 11 months. ROI = 342% (present value, over 5 years)
Vientiane 2	US$2480	US$5085	Payback period is approximately 11 months. ROI = 363% (present value, over 5 years)
Vientiane 3	US$2520	US$6200	Payback period is approximately 9 months. ROI = 446% (present value, over 5 years)

Example crop rotation plan over 3 years



The calculated economic gain of this cropping schedule could be US$6415 (Payback = 7mths, ROI = 467%)

Return on investment calculations assume an upfront capital cost of US$1000 (180m^2 structure), US$50 per year maintenance (which includes replacing plastic every 3 years). Discount interest rate is assumed to be 3%pa.

8.3.2 Social impacts

Food safety on-farm and in the post-farm supply chain, postharvest management of fresh produce and protected cropping were new concepts for most of the project team. There was little awareness of quality in fresh product, nor an understanding of pesticide residues or greenhouses for wet season production.

A key social impact of this project has been a change in culture of the project team and their peers around how safe fresh vegetables are to consume and how they can be produced year-round. In five years' time, it is expected that this change in culture will be evident in the general public. The outcomes of this work and the enabling of ongoing research and extension will foster a greater understanding of biological contamination, produce quality and nutrition and will have an impact on the health of communities. The culture of farmers and their families involved in this project has already changed as improved personal hygiene practices are now implemented and

this will positively impact on village and community health in the short to medium term.

The developed skills and capability among staff and organisations responsible for plant protection, both at the research and at the communication level, will have a further, positive impact on production systems and on farmers who ultimately feel the impact of pests and diseases. These smallholders and their families indirectly affect social systems and are important component of the pathways that can bring about change to ultimately benefit communities.

The project teams, and the project-partnered organisations, as a result of the technical expertise that they developed through this project, are now recognised as resources and as technical specialists in low cost protected cropping, food safety and postharvest handling. In both Cambodia and Lao PDR, this is evidenced by the out-of-project engagement of staff to conduct training for NGOs involved in other development projects. This is creating a broader social impact as these professionals develop their own roles in the community. Additionally, the training approach throughout the project has been to support inclusion and across all training activities, women represented one third of participants on average, with a mode of 40%. Surveys of extension staff concerning IPM/crop rotation found that female staff had a lower self-confidence compared with male peers prior to the project activities, however, the inclusive training approach utilised by the project resulted in both female and male extension staff having better knowledge of crop rotation and self-confidence in recommending these practices. The longer-term impact of this participation will be greater social recognition and normalcy of females in these professional, technical and farmer facing roles.

A number of university students were involved in research elements of this project and these young men and women have gained employment in agricultural agencies, NGOs and industry and will take the knowledge and skills learnt in protected cropping, food safety risk assessment and supply chains into their future careers and communities.

A further social impact highlighted in this project has been that vegetable cooperative enterprises generally struggle to develop market linkages on their own and developing partnerships with dynamic, private sector enterprises is often critical. In five years' time, some of the challenges of year-round production will be being met with protected cropping and market differentiation based on technical expertise, not the emphasis on organisational structures.

8.3.3 Environmental impacts

Environmental impacts are an indirect element to this project. There are several areas of work, however, that ultimately have beneficial impacts on the environment including higher farm productivity (reduced fertiliser, water and land footprint) due to the use of protected cropping and reduced supply chain inefficiencies (reduced losses), achieved with better postharvest handling and cooling.

A reduction in the overuse of chemical inputs through the work this project has initiated on food safety, farm risk assessments, protected cropping and crop rotation, will have several positive impacts. In addition to benefiting the consumer through reduced residues in fresh vegetables and benefiting farmers through improved health and safety and lower costs of production, a key environmental impact of this project in the short to medium term will be a reduction in the use of chemicals which ultimately has a positive outcome for soil, water and aerial environments.

One collaborating farmer in Kandal province has already been able to avoid the use of pesticides by using a fully screened High Low Plastic Roof Shelter. Other farmers

have reported using less irrigation water for crops growing under cover during the dry season.

There is significant future impact opportunity in supporting resilient, protected cropping based supply chains to capitalise on the inherent resource efficiencies, waste reduction and social opportunities of this type of production system.

8.4 Communication and dissemination activities

Multiple communications and information sharing activities, as part of the key outreach and impact strategy of the project have been conducted.

- The project convened four Regional Vegetable Forums that brought together government, non-government and private sector personnel and projects to network and share expertise, learnings and experiences in the vegetable research and development space.
  - Fostering a safe and sustainable vegetable sector, Phnom Penh, 2017
  - Fostering a safe and sustainable vegetable sector, Vientiane, 2017
  - Innovations of production and supply chain systems for improved off-season vegetable, Phnom Penh, 2018
  - Supporting the adoption of improved practices and new technologies by smallholders for sustainable year-round production of safe fresh vegetables, Vientiane, 2019
- Policy advice on practical recommendations for the development of a sustainable vegetable sector, developed as an outcome of the second forum (Lao PDR, 2017) were presented to the Government of Lao PDR by the National Committee on Commodity Production and Food Security.
- Two technical workshops (Developing and implementing successful partnerships in the vegetable sector) on the forming of farmer groups and agri-clusters were facilitated by cluster farm experts and explored the elements of supply chains and actors, different models of partnership and the personal, political, technical and financial environments which supply chain partnerships navigate.
- The Tropical Agriculture Research and Information Share Point (www.tarisp.group) was launched at the final forum (Lao PDR, 2019). This project-initiated resource hub offers all stakeholders throughout the region, an online portal to actively share project work, trials and information resources.
- Communication and dissemination materials from Lao PDR have been produced through collaboration with East-West Seeds Knowledge Transfer and a new 'Grow How' landing page has been set up for Lao PDR (Lao and English) (https://growhow.eastwestseed.com/la/en).
- Learning and extension resources have also been included at Lao44 Information for Development website and the The Pha Khao Lao Agrobiodiversity Resource Platform (https://www.phakhaolao.la/en/publications/by-topic/103)
  - 'Grow How' Tomato
  - 'Grow How' Yard Long Bean
  - 'Grow How' Pak Choi
  - Seedling production
  - Insects as vectors
  - Bacterial Blight

- *Tuta absoluta* (tomato leaf miner)
- Safe use of pesticides

- A Seed Swap, hosted by ECHO Asia, demonstrated the value of simple activities which help to bring smallholders to participate in improvement programs and access information.
- Seven protected cropping training workshops focussing on benefits of protected cropping, design and its impact on performance, building a good structure and managing crops in protected environments were delivered to project staff and peers in collaborating organisations and farmers in Phnom Penh, Vientiane and Champasak.
- Six water management training workshops focussing on soil moisture and monitoring, crop water needs and uniform application of water were delivered to project staff and peers in collaborating organisations and farmers in Phnom Penh, Siem Reap, Kampot, Vientiane and Champasak.
- Five IPM training workshops focussing on identifying common pests and diseases and crop rotation were delivered to project staff and peers in collaborating organisations and farmers in Phnom Penh, Kandal, Vientiane and Champasak.
- Four postharvest management training workshops were delivered to project staff and peers in collaborating organisations and supply chain actors in Phnom Penh and Vientiane.
- Four food safety training workshops focussing on risk assessment and analysis and sources of contamination were delivered to project staff and peers in collaborating organisations and supply chain actors in Phnom Penh and Vientiane.
- Six 'effective farmer field day' workshops focussing on compiling and delivering technical information to farmers were delivered to project staff in conjunction with these staff running farmer field days in Phnom Penh, Kampot and Vientiane.
- Five farmer field days were delivered by the protected cropping and postharvest teams, drawing on the field day training provided to them previously, targeting smallholders and NGO staff in Kampot province (2), Vientiane capital/province (4) and Champasak province (3), plus an additional four IPM focussed field days.
- Three technical workshops were delivered by the protected cropping team, focusing on a deeper technical learning targeting professional workers, government and provincial staff. These events were conducted in Kampot, Vientiane and Paksong.
- A technical protected cropping and postharvest skills workshop was delivered to GRET staff (Phnom Penh)
- Four technical protected cropping training workshops were delivered to a total of 77 participants including PDAFF staff, SNV staff, and associated workers in the SNV-CHAIN project in Preah Vihear province, Oddar Meanchey province, Kracheh province and Stung Treng province.
- A portfolio of 6 double sided, dual language (Khmer/English and Lao/English) posters were prepared as a resource for smallholder vegetable farmers. The posters illustrate key information on (1) Greenhouse design, (2) Protected Cropping Benefits, (3) Covers and crop selection, (4) Crop rotation, (5) Producing safe vegetables, (6) Postharvest handling.

- Four simple photo-videos with key words and titles in either English, Khmer or Lao, have been created. The videos are designed to raise awareness and interest in project outcomes: (1) Benefits of Rain shelters, (2) Building a High Low Plastic Roof Shelter, (3) 9 Simple steps for safe quality leafy produce (in Laos), (4) 9 Simple steps for safe quality leafy vegetable (in Cambodia). They have been distributed through CASC, NUOL, CARDI, GDA, RUA and HRC, uploaded to YouTube® and shared on the Tropical Agriculture Research and Information Share Point (www.tarisp.group).

Demonstration trials

- Sixteen protected cropping research and demonstration sites were established over the project period in Kampot province (4), Kandal province (4), Vientiane Capital (3) and Vientiane province (1) and Champasak province (4). The High Low Plastic Roof Shelters were constructed and evaluated at these sites and were also used for crop research and extension trials and field days.
- An irrigation and fertiliser demonstration site was established in Siem Reap in collaboration with the SMCN/2014/088 'Integrating soil and water management in vegetable production in Lao PDR and Cambodia' project. This site was used to conduct a demonstration irrigation trial on matching irrigation application with crop water demands.

Scientific communications

- The postharvest team have been published in the *Journal of Horticulture and Postharvest Research* and *Fruits*: (Appendix 40)

  Sambath, S., Wills, R.B.H., Ku, V.V.V. and Newman, S. (2018) Retention of green colour of tomatoes marketed as a green vegetable at ambient conditions in Cambodia with modified atmosphere storage and fumigation with 1-methylcyclopropene (1-MCP). *Fruits.* 73 (5), 265-272.

  Ku, V.V., Inthalangsee, B. and Wills, R. (2019) Use of maturity sorting and reducing ethylene with potassium permanganate to enhance marketing of tomatoes in Laos at ambient tropical temperatures, *Journal of Horticulture and Postharvest Research*, 2,: 61-68.

Thesis

Sambath, S. (2018) *Effect of 1-MCP and Modified Atmosphere on the Storage Life of Tomato, Pak Choy, Choy Sum Held at an Ambient Tropical Temperature*. The University of Newcastle, NSW, Australia.

Australian based activities

- Five extension events on irrigation scheduling and irrigation system layouts were delivered to Australian irrigators and included training on subsurface drip irrigation and the IrriSAT app in scheduling irrigation.

In project communication activities

- A project inception meeting provided a platform for project staff across components to meet, activity plans to be drafted and for the project leaders to present the background, objectives and underlying strategy of the project to the team.
- Annual project team meetings were held in each country to consolidate activities and results and fine-tune upcoming tasks.

- The mid-term project review was held in Pakse (Lao PDR) and provided an opportunity for intra-project sharing as teams from both countries were able to come together and the opportunity enabled staff to engage personally with their peers, develop project cross-overs and share information, ideas and experiences.
- The end of project review was held in Kep (Cambodia) and provided an opportunity for intra-project sharing as teams from both countries were able to meet again and the meeting was linked with the SMCN/2014/088 project team at the same venue which provided some new cross-overs and information sharing.

9 Conclusions and recommendations

9.1 Conclusions

The project has demonstrated a high performance, economically viable protected cropping structure that mitigates the problems of other cheap structures, provides farmers with production and crop management advantages and can contribute to a significant increase in smallholder incomes. Importantly, this protected cropping provides a significant opportunity for exploitation of diverse cropping and business options and more efficient use of key resources such as land and labour, making this growing industry more inclusive and provides good potential for supporting gender equality in regional communities. From both a good farm practice perspective and a marketing outlook, promotion of diversified crop portfolios should be a rule of thumb in vegetable development programmes across the region.

The project also determined the key biophysical constraints of representative fresh vegetable supply chains in Lao PDR and Cambodia and identified and demonstrated the efficacy and economic viability of three low cost postharvest technologies that contribute significantly to reducing postharvest loss. Improving the management of produce temperature by introducing simple cooling strategies and limiting physical damage from rough handling can provide significant gains in produce value.

Cambodia is normally depicted as a country that relies heavily on imports to meet its vegetable consumption needs. While elements of this are true, it does not apply to all vegetable types. Cambodia is nearly self-sufficient in the production of highly perishable leafy produce. Market engagement research confirmed that seasonal pricing fluctuations could be exploited by smallholders using protected cropping and better postharvest practices, for example, domestic growers can take advantage of proximity to market, supplying a fresher product, with better appearance and longer shelf life, than importers.

The research also showed that a focus on more perishable leafy vegetables could provide a more resilient and faster economic development pathway, than focussing on product with existing significant seasonal imports.

An emphasis on structured and consistent training with guidance during field research activities and mentoring over the duration of the project has developed knowledge and strong skills in the target technical areas, conducting research and disseminating results in an effective way to target audiences.

This approach has taken early and mid-career researchers and inexperienced team members, exposed them to new technical areas and concepts and seen them conduct research and demonstration activities, collate results and confidently take on building the capacity of their peers as well as supply chain actors from farms to markets.

9.2 Recommendations

The project successfully combined an applied, bespoke technology solution to year-round vegetable production with economic and community analysis. This outcome is charged with broad development potential, opportunities for gender equality, climate resilience and agribusiness growth, however, the project was only designed to develop and test a solution and there is a risk that in the absence of further protected horticulture capacity and agribusiness development support, continued promotion of inferior protected cropping options by a multitude of projects and programs focussed

on other aspects of agricultural development, will swamp these achievements and stagnate the industry.

1. **A protected horticulture capacity and agribusiness development phase should be implemented to capitalise on the benefit to the developing vegetable sector and evaluate the net balance of these systems in terms of resources and resilience.**
2. **The development of protected cropping horticulture should be seen as an opportunity to foster inclusion and gender equality in agribusiness due to the wider market and crop opportunities that can be exploited and the greater efficiency of key resources of land and labour.**
3. **A resilience farming project using the learning and successful experience with low cost protected cropping should be initiated to garner smallholder security in view of changing climate patterns and weather extremes.**

The research identified and confirmed simple low-cost postharvest technologies that have a significant technical and financial benefit in fresh vegetable sector productivity, however, there are logistical challenges associated with the successful implementation of these interventions.

4. **A collaborative supply chain development project should be implemented to establish commercial working models of supply chain partnerships implementing the postharvest management interventions.**

The project convened a series of highly successful and popular forums which provided an environment for networking and building collaborations across stakeholder groups, outside of the conventional conference and research space, however, despite strong interest in ongoing events and healthy financial support, there is an absence of a consistent champion to drive the events forward.

5. **The annual convening of a networking and cross-stakeholder R4D project sharing regional event should be undertaken.**

Risk assessment and analysis of vegetable farms as part of this project highlighted a number of critical food safety challenges, and while initial awareness and extension actions were conducted, directed activity integrating mitigation with implementation of quality assurance is required.

6. **A research and development project to establish commercial, certified, safe vegetable collaborative supply chain models should be embarked upon.**

During water management training in Vientiane, feedback from farmers and subsequent discussions with project peers indicated that increasing soil salinity and changing ground water tables are presenting a significant near future problem that will adversely impact on communities across the province.

7. **A regional irrigation improvement and salinity management project should be initiated to improve farming and irrigation practices and head-off a significant problem.**

This project, in developing wet season/year-round production technologies and optimal cropping strategies, identified that crop rotation principles and preventative pest and disease management are not widely understood or practiced. There are also embedded market access and supply chain issues.

8. **A sustainable diversified horticulture cropping systems project should be implemented to establish basic good horticultural management and**

preventive pest and disease practices on a commercial footing with supply chain partnerships.

9. **Advocacy and inclusion of diversified farm crop portfolios (selection and rotation) and seedling quality should be fundamental in all horticulture projects, irrespective of the primary objectives.**

10 References

10.1 References cited in report

1. According to the latest population census, in 2008 the capital Phnom Penh had 1,242,992 inhabitants (www.citypopulation.de/Cambodia-Cities.html).
2. According to the latest population census, Siem Reap had a population of 168,662 in 2008 (www.citypopulation.de/Cambodia-Cities.html).
3. Genova II, C., Weinberger, K., Sokhom, S., Vanndy, M. and Yarith, E. C. (2006). "Postharvest loss in the supply chain of vegetables. The case for tomato, yardlong bean, cucumber an Chinese Kale in Cambodia." Available from http://203.64.245.61/fulltext_pdf/EB/2001-2010/eb0020.pdf
4. Murray-Prior R, Israel FT, Bacus RG, Apara DI, Concepcion SB, Montiflor MO, Axalan J, Lamban RJG, Real RR, Batt PJ and Rola-Rubzen MF. 2011. Reducing poverty through participatory action learning and action research processes with smallholder vegetable farmers in Mindanao. Extension Farming Systems Journal 7:2:109-114.

NB references cited in reports are included in those documents, in the appendices.

10.2 List of publications produced by project

Publications

(Appendix 40)

Sambath, S., Wills, R.B.H., Ku, V.V.V. and Newman, S. (2018) Retention of green colour of tomatoes marketed as a green vegetable at ambient conditions in Cambodia with modified atmosphere storage and fumigation with 1-methylcyclopropene (1-MCP). *Fruits.* 73 (5), 265-272.

Ku, V.V., Inthalangsee, B. and Wills, R. (2019) Use of maturity sorting and reducing ethylene with potassium permanganate to enhance marketing of tomatoes in Laos at ambient tropical temperatures, *Journal of Horticulture and Postharvest Research*, 2,: 61-68.

Thesis: Sambath, S. (2018) *Effect of 1-MCP and Modified Atmosphere on the Storage Life of Tomato, Pak Choy, Choy Sum Held at an Ambient Tropical Temperature*. The University of Newcastle, NSW, Australia.

Technical and extension resources

Guidelines

- High Low Plastic Roof Shelter Construction Guidelines
- 'Grow How' Tomato
- 'Grow How' Yard Long Bean
- 'Grow How' Pak Choi
- Seedling production
- Insects as vectors
- Bacterial Blight
- *Tuta absoluta* (tomato leaf miner)
- Safe use of pesticides

Posters

- Where is the postharvest loss occurring in tomato supply chain?
- Where is the postharvest loss occurring in bok choy supply chain?
- An overview of Cambodian vegetable industry: The adoption of packaging.
- Greenhouse design [English | Khmer | Lao]
- Protected Cropping Benefits [English | Khmer | Lao]
- Covers and crop selection [English | Khmer | Lao]
- Crop rotation [English | Khmer | Lao]
- Producing safe vegetables [English | Khmer | Lao]
- Postharvest handling [English | Khmer | Lao]

Videos

- Benefits of Rain shelters [English | Khmer | Lao]
- Building a High Low Plastic Roof Shelter [English | Khmer | Lao]
- 9 Simple steps for safe quality leafy produce (in Laos) [English | Lao]
- 9 Simple steps for safe quality leafy vegetable (in Cambodia) [English | Khmer]

Research reports and Reviews

All research reports and reviews prepared in this project are included as appendices and are available online – www.tarisp.group.

11 Appendices

Project reports, information resources and all appendices are available online and can be searched and downloaded on the Tropical Agriculture Research and Information Share Point [www.tarisp.group] and appendix documents can be accessed directly via the links provided below.

11.1 Appendix 1: Bok choy markets in Phnom Penh and Siem Reap – Key findings from a survey or wholesale traders

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-1-Bok-choy-Wholesaler-Survey-Report.pdf

11.2 Appendix 2: Chilli markets in Phnom Penh and Siem Reap – Key findings from a survey of wholesale traders

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-2-Chilli-Wholesaler-Survey-Report.pdf

11.3 Appendix 3: Chinese kale markets in Phnom Penh and Siem Reap – Key findings from a survey of wholesale traders

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-3-Chinese-kale-Wholesaler-Survey-Report.pdf

11.4 Appendix 4: Lettuce markets in Phnom Penh and Siem Reap – Key findings from a survey of wholesale traders

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-4-Lettuce-Wholesaler-Survey-Report.pdf

11.5 Appendix 5: Tomato markets in Phnom Penh and Siem Reap – Key findings from a survey of wholesale traders

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-5-Tomato-Wholesaler-Survey-Report-2.pdf

11.6 Appendix 6: Structure and conduct of vegetable markets in Cambodia – Key findings from surveys of wholesale traders

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-6-Cambodian-Wholesaler-Survey-Report.pdf

11.7 Appendix 7: Bok choy supply chain – biophysical mapping in Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-7-Bok-Choy-supply-chain-Cambodia.pdf

11.8 Appendix 8: Cabbage supply chain – biophysical mapping in Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-8-Cabbage-Supply-Chain-Lao-PDR.pdf

11.9 Appendix 9: Chilli supply chain – biophysical mapping in Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-9-Chilli-supply-chain-Cambodia.pdf

11.10 Appendix 10: Chilli supply chain – biophysical mapping in Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-10-Chilli-supply-chain-Lao-PDR.pdf

11.11 Appendix 11: Coriander supply chain – biophysical mapping in Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-11-Coriander-supply-chain-Lao-PDR.pdf

11.12 Appendix 12: Cucumber supply chain – biophysical mapping in Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-12-Cucumber-supply-chain-Cambodia.pdf

11.13 Appendix 13: Tomato supply chain – biophysical mapping in Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-13-Tomato-Supply-Chain-Lao-PDR.pdf

11.14 Appendix 14: Wholesale price patterns – Bok choy in Phnom Penh, Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-14-Wholesale-price-patterns-for-bok-choy-in-Phnom-Penh-Cambodia-April-2016-to-March-2017.pdf

11.15Appendix 15: Wholesale price patterns – Chilli in Phnom Penh, Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-15-Wholesale-price-patterns-for-chilli-in-Phnom-Penh-Cambodia-April-2016-to-March-2017.pdf

11.16Appendix 16: Wholesale price patterns – Chinese kale in Phnom Penh, Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-16-Wholesale-price-patterns-for-Chinese-kale-in-Phnom-Penh-April-2016-March-2017.pdf

11.17Appendix 17: Wholesale price patterns – Lettuce in Phnom Penh, Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-17-Wholesale-price-patterns-for-lettuce-in-Phnom-Penh-Cambodia-April-2016-to-March-2017.pdf

11.18Appendix 18: Clusters for producers in Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-18-Lao-PDR-Case-study-review-on-producers-group-formation.pdf

11.19Appendix 19: Safe vegetable production in ASEAN countries: Status and opportunities for improvement

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-19-Review-Safe-Vegetables-Production-in-ASEAN-countries.pdf

11.20Appendix 20: Risk Assessment for vegetable farms in Kandal Province, Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-20-Risk-assessment-of-vegetable-production-Cambodia.pdf

11.21Appendix 21: Risk Assessment for vegetable farms in Vientiane Province and Vientiane Capital, Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-21-Risk-assessment-of-vegetable-production-Lao-PDR.pdf

11.22Appendix 22: Minimising biological contamination recommendations

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-22-Minimising-biological-contamination-disinfestation-postharvest-handling-on-farm.pdf

11.23Appendix 23: Postharvest technology development for improving turn-out

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-23-Improved-postharvest-management.pdf

11.24Appendix 24: Posters – Postharvest handling of vegetables; Producing safe vegetables

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-24a-Postharvest-handling-of-vegetables-in-3-languagues.pdf

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-24b-Producing-safe-vegetables-in-3-languages.pdf

11.25Appendix 25: Economic analysis of postharvest improvements in Cambodia and Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-25-Economic-analysis-of-postharvest-improvement-in-Cambodia-and-Lao-PDR.pdf

11.26Appendix 26: Training needs analysis – production in the wet season

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-26-Capacity-Development-and-Training-Needs-Analysis-Report.pdf

11.27Appendix 27: Review of Low Cost Protected Cropping

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-27-Review-of-Low-Cost-Protected-Cropping-for-Cambodia-and-Lao-PDR.pdf

11.28Appendix 28: Cambodia – first season structure performance

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-28-CAMBODIA-first-season-structure-performance-Dec-2015.pdf

11.29Appendix 29: Lao PDR – first season structure performance

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-29-LAO-PDR-first-season-structure-performance-Dec-2015.pdf

11.30Appendix 30: Vegetable crop gross margins - Cambodia

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-30-Gross-Margins-Vegetable-Crops-CAMBODIA-2019.pdf

11.31Appendix 31: Vegetable crop gross margins – Lao PDR

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-31-Gross-Margins-Vegetable-Crops-LAOS-2019-1.pdf

11.32Appendix 32: Analysis of crop production with a High Low Plastic Roof Shelter

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-32-Analysis-of-Crop-Production-with-High-Low-Plastic-Roof-Shelter-HLPRS.pdf

11.33Appendix 33: Construction Guide: High Low Plastic Roof Shelter

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-33-Protected-Cropping-Structure-HLPRS-Construction-Guide-English.pdf

11.34Appendix 34: Benefits and Farmers' Perception: High Low Plastic Roof Shelter

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-34-Greenhouse-evaluation-farmer-perceptions.pdf

11.35Appendix 35: Field trials notes

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-35-Field-trials-notes.pdf

11.36Appendix 36: Subsurface Drip Irrigation (SSDI) demonstration and scheduling development

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-36-Subsurface-Drip-Irrigation-SSDI-demonstration-and-scheduling-development.pdf

11.37Appendix 37: Identified crop pest and disease priorities

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-37-Identified-crop-pest-and-disease-priorities-Cambodia-and-Laos.pdf

11.38Appendix 38: Action plans for IPM adoption

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-38-Action-plans-for-IPM-adoption-Cambodia-and-Laos.pdf

11.39Appendix 39: Posters – Benefits of greenhouses; Greenhouse design; Cladding & Crop selection; Crop rotation

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-39a-Poster-Protected-Cropping-Benefits-in-3-languages.pdf

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-39b-Poster-Greenhouse-Design-in-3-languages.pdf

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-39c-Poster-Covers-and-crop-selection-in-3-languages.pdf

https://tarisp.group/wp-content/uploads/2020/02/ASEM-2012-081-Appendix-39d-Poster-Crop-Rotation-in-3-languages.pdf

11.40Appendix 40: Publications

Ku, V.V., Inthalangsee, B. and Wills, R. (2019) Use of maturity sorting and reducing ethylene with potassium permanganate to enhance marketing of tomatoes in Laos at ambient tropical temperatures, *Journal of Horticulture and Postharvest Research*, 2,: 61-68.

http://www.jhpr.birjand.ac.ir/?_action=article&keywords=vivian+ku

Sambath, S., Wills, R.B.H., Ku, V.V.V. and Newman, S. (2018) Retention of green colour of tomatoes marketed as a green vegetable at ambient conditions in Cambodia with modified atmosphere storage and fumigation with 1-methylcyclopropene (1-MCP). *Fruits.* 73 (5), 265-272.

Sambath, S. (2018) *Effect of 1-MCP and Modified Atmosphere on the Storage Life of Tomato, Pak Choy, Choy Sum Held at an Ambient Tropical Temperature*. The University of Newcastle, NSW, Australia.

https://nova.newcastle.edu.au/vital/access/manager/Repository?query=sambath&queryType=vitalDismax&sort=ss_dateNormalized+desc%2Csort_ss_title+asc