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Australian Centre for International Agricultural Research

Final report

project	**Enhancing production and marketing of maize and soybean in north-western Cambodia and production of summer crops in north-eastern Australia**
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1 Acknowledgments

The success of this project has been strongly dependent on the partnerships formed with the Maddox Jolie-Pitt Foundation (MJP) and CARE-Cambodia. MJP and CARE brought to the project established community engagement, participatory extension methods, efficient management and highly motivated staff.

2 Executive summary

ASEM/2006/130 commenced in May 2008. The overarching aim of the project was to improve the functioning of the production – marketing system for maize and soybean in north-western Cambodia as a key to increasing cash income, sustainable growth and poverty reduction for smallholder farmers. The project partners were the University of New England, the NSW Department of Primary Industries, University of Canberra, University of Melbourne, CSIRO, the Cambodian Agricultural Research and Development Institute (CARDI), CARE-Cambodia and the Maddox Jolie-Pitt Foundation (MJP).

In north-western NSW, the aim was to develop strategies for adaptation of farming systems to climate variability and climate change. The effect of the predicted climate changes for 2030 was found to be similar to that by moving Quirindi 250 km to the NNW (Moree) and Moree 200 km to the NNW (St George) in terms of higher temperatures, reduced annual rainfall and increased summer dominance of rainfall. Some of the climate change adaptation options favoured by farmers did not deliver the expected results. These included reducing planting density, skip row configurations, early planting and quicker maturing varieties. Gross margin budgets were used to estimate individual crop profitability under the different scenarios. When additional modelling is undertaken to include rotation crops such as wheat, barley and chickpeas, whole-farm economic case studies will be used to identify optimum business strategies under different climate change scenarios.

In Cambodia, the trial and demonstration program culminating in 2011 included evaluation of maize-legume intercropping systems, weed management in maize and soybean, demonstration of best-practice for growing maize, varietal evaluation for maize, soybean and peanut, demonstration of rhizobium liquid inoculants and on-farm gross margin surveys for cassavas, maize, soybean and peanut. With improved practices, crop yields were significantly higher than farmer practice. For example in 2010, improved practice maize yield was 7.6 t/ha compared to 4.7 t/ha for farmer practice. In the gross margin survey, average farm yields for maize (46%), soybean (66%) and peanut (48%) were also well below the highest yields that were achieved on-farm. It is recommended that further analyses be carried out to identify the important yield determinants for maize, mungbean, soybean, and peanut. Soil fertility, weed management, plant population and variety are among the factors that can be managed to increase crop yields. The gross margin for peanut in 2010 ($1,566/ha) was almost three times that for maize. Despite this, farmers are reluctant to grow peanuts because of the high cost of inputs (including the cost of credit) and the extra labour required at harvest. Another uncertainty is the availability of markets for expanded production of soybean and peanut.

Farmer workshops investigated key socio-economic issues related to adoption of the improved crop technologies - the major issue has been the increasing cost of farm labour which has increased at a rate of 20%/year during the life of the project. Village workshops developed partial budgets for return on investment for alternative technologies such as the application of nitrogen fertilizer to maize and inoculation of legume seeds with rhizobium. Further partial budgets were developed for weeding of crops - hand weeding versus chemical sprays.

Two data collection surveys were performed in the early wet season in Samlout and in Pailin in late 2010 to broaden the project's understanding of the value chain. An alternative approach was taken that encompassed the traditional need for ‘tangible’ quantitative data from farmers and traders, combined with collection of 'intangible' relationship information. A comprehensive survey was designed to illicit information pertaining to the supply of credit, crop inputs, storage and transport arrangements, typically required for a value chain assessment. The survey also collected information which can be used to develop a greater understanding of the social networks that exist within the business transactions that occur during the sale of commodities.

A workshop introducing the concept of using SMS as a business tool was held in Pailin, January 2011. Preliminary responses from the participants were positive and testing during the workshop indicated users were seeking alternative sources for pricing. The workshop tested two SMS delivery mediums. One developed within the project using an FrontlineSMS which is an open-source platform. The other was through a partnership with a Cambodian technology company called 010XPRESS which is independently developing an SMS information service. Workshop highlighted some key challenges specific to Cambodia, (1) limited availability of Khmer scripts on basic phones, (2) limited user understanding and daily use of SMS technology (3) young people driving the future use of the technology.

Technologies and improved practices developed in the project were effectively 'rolled out' to households beyond the project focus villages. The project put in place a strategy to extend impacts more widely through provincial government offices, other NGOs, the education sector and the private sector. Each have their unique strengths in reaching farming households.

3 Background

3.1.1 Context and rationale

ACIAR supports research that leads to increased agricultural productivity and stronger engagement in markets to assist in meeting economic growth and poverty reduction objectives. This is consistent with the Strategy for Agriculture and Water which was developed from Cambodia's National Strategic Development Plan. This strategy supports applied R&D that underpins agricultural diversification, particularly into non-rice field and horticultural crops. ACIAR has also placed greater emphasis on research to underpin the development of suitable supply chains. The ACIAR program also has a strong emphasis on building Cambodian R&D capacity and encourages the development of collaborative linkages between Cambodian organisations.

ASEM/2006/130 addressed Subprogram 2 of ACIAR's research priorities for Cambodia: Income generation and better nutrition through agricultural diversification (Non-rice field crops). In particular:

- Assessment of annual crops that support agro-industry, particularly maize, soybean and cassava, with less emphasis on peanut, mungbean and sesame;
- Improvement in returns from field crop marketing to value-chain participants by:
  - establishing the advantages and disadvantages of different farmer group institutional models and trading power relationships along the value chain;
  - identifying the effectiveness of different formal processes for interaction between value-chain members;
  - understanding customer requirements to match quality, volume and timing needs of markets with production cycles.

3.1.2 Key issues addressed

The production and natural resource problem targeted by the project was the potential for declining crop yields and land degradation in the north-western districts of Cambodia adjacent to the Thai border. The field work that was carried out in the Municipality of Pailin and the district of Samlout in Battambang province is applicable to a wider target zone which includes other districts in Battambang and the province of Banteay Mean Chey. Production of crops such as maize and soybean have rapidly expanded since re-integration of the former Khmer Rouge began in 1996 (Anon 2004). The area is mountainous and most of the cultivated areas have rich soil of volcanic or limestone origin. However, in the space of 10 years, crop yields are now declining and soils are being eroded and degraded by excessive cultivation and burning.

Because of the relative remoteness of these new cropping areas, the need was recognised to develop integrated and cooperative relationships between farmers and the downstream enterprises, including the grain drying facilities, middlemen and wholesalers (Roberts 2006). Win-win opportunities were identified to:

- improve profits and incomes for both the enterprises and the farmers;
- improve communication so that farmers know the value of their crops, quality standards and market demands;
- nurture farmer organisations that can help to counterbalance the power of organised buyers, middlemen, and large-scale processors; and
- provide more information, transparency and competition in the marketing chain.

3.1.3 Justification

The beneficiaries of the project in Cambodia were identified as approximately 153,400 people living in the broader target zone. Many of these people have moved from landscarce provinces to this relatively land-abundant area. Out of all provinces and municipalities in Cambodia, Pailin has the highest proportion of migrants. 77% of the population are recent arrivals, mostly from outside of the province or country. Therefore, there is a significant opportunity to assist these farmers in adapting their imported cropping practices to the local agro-ecological conditions to halt the decline in productivity. As well as farmers, the beneficiaries include all of the participants in the value-chain.

The problem targeted in north-western NSW is lack of adoption of no-tillage and conservation farming practices. Only 50% of farmers have adopted no-tillage cropping systems. Adoption of these practices is seen as key strategies for adaptation to climate variability and climate change. The focus crops in Australia were sorghum, maize and sunflower.

The area under maize production in Battambang and Pailin increased threefold from around 50,000 to 150,000 ha between 2005 and 2009. Total production has increased four-fold from around 175,000 to 725,000 tonnes during this period. The area of soybean appears to have declined from 65,000 to around 48,000 ha with yields remaining around 1.5 t/ha.

An evaluation of the whole value chain for upland crops was seen as a way to improve economic outcomes. Typically a reduction of 10-15% in marketing costs is possible from such work. A reduction of 10% in marketing costs could increase social welfare by US$2.5 million for maize and US$800,000 per annum for soybean in Battambang and Pailin.

The relevant production system in Australia is the north-eastern summer rainfall grain belt which extends across approximately 3.6 million hectares. The average annual value of production of crops in this region is over $2 billion.

The researchable issues on-farm in Cambodia included the need to:

- Investigate the objectives at the farm and village levels to determine social and economic context and what changes farmers are willing to consider in their crop production processes;
- Investigate potential profit improvements from alternative farm management methods and technologies;
- Evaluate potential improved technologies and practices based on previous farm trials and village workshop discussions, for instance;
  - Better varieties and alternative crop species;
  - Maintenance of soil fertility – rhizobium, rotations, fertiliser;
  - Management of pests and diseases; and
- Review and assess project impact, and plan for further innovation and improvement in the next cropping cycle.

The researchable issues off-farm included the need for innovation and improvement in:

- Post-harvest management (storage, handling, transportation, processing);
- Communications between different levels of the supply chain using SMS technology developed as a pilot project in ASEM 2003/012;
- Value chain relationships (eg buyer-seller and seller-seller).

In north-western NSW, the researchable issue was the lack of adoption of no-tillage and conservation farming practices where the adoption rate has been only 50%. No-tillage and associated response-cropping strategies reduce the risk of growing crops in a variable climate. Further development of these strategies especially summer crop alternatives could also provide options for adaptation to climate change.

4 Objectives

4.1 Cambodia

The overarching aim of the project was to improve the functioning of the production – marketing system for maize and soybean in north-western Cambodia as a key to increasing cash income, sustainable growth and poverty reduction for smallholder farmers. The project will facilitate the sharing of knowledge and information between practitioners at all stages of the value chain.

Objective C1. To exploit the potential synergies and efficiencies that can be obtained by the production component informing the marketing component of the value chain, and vice versa

The predecessors to this project addressed production (ASEM/2000/109) and marketing issues (ASEM/2003/015) separately. This objective is therefore designed to ensure the integration of the production (on-farm) system with the marketing and value chain system (post farm gate) elements of the project. Activities will include:

- Development of a web-based information system to facilitate communication, sharing and exchange of information and create an online ‘community of practice’
- Mapping capacities, constraints and opportunities in the production-value chain;
- Whole of chain diagnosis to identify opportunities and synergies
- PAR with stakeholders to develop a research action plan;
- Implementation of the action plan for integrated value chain development;
- End of project workshop and final report.

Objective C2. To enhance the adoption of improved technologies and practices for production of upland crops by integrating agronomic, economic, environmental and social factors

The improved technologies and practices developed for upland crops in ASEM/2000/109, will be revised through PAR/CI&I and additional action research will be carried out where required. Activities will include:

- Providing advice and support to NGOs and PDAs for implementation of PAR and Farmer Field Schools (FFS)
- Implementation of on-farm trials, farmer field days and workshops to validate and adapt improved technologies;
- Quantifying the value of improved technologies and practices in economic terms to determine potential financial benefits and risks;
- Using adaptive management, use case studies to identify factors limiting the adoption of improved technologies;
- Collation and review of previous studies and current baseline practices (CARE) and identify knowledge gaps. Conduct village workshops to fill the gaps - discuss the trialability of new technologies in farmer fields;
- Evaluation of the economic impact of adoption of improved technologies and practices and conduct an economic impact assessment of adoption of the improved technologies and practices
- Production of education, training and extension publications.

Objective C3. To improve post-harvest management, communications along the supply chain and value chain integration for maize and soybean in north-western Cambodia.

This objective will involve mapping the marketing system (post-harvest processes, socio-economics, communications and institutions) to determine the main constraints and opportunities for value chain improvements. The objective is to facilitate a process of change management for implementation of best-bet opportunities. Activities to address objective C3 will include:

- PAR to improve product quality and reduce costs through post-harvest storage, handling, transport, processing;
- Benefit-cost analysis of alternative post-harvest technologies, transport infrastructure, buyer surveys, buyer-seller relationships;
- Development of improved communications between different levels of the supply chain using SMS technology.

4.2 Australia

In north-western New South Wales, the over-arching objective is to address lack of adoption of conservation farming practices, increase summer crop diversity and to develop strategies for adaptation of farming systems to climate change.

Objective A1. Conduct a bio-economic evaluation of the technologies and strategies to reduce the impact of climate variability and climate change on farm families

Activity: Use of simulation modelling techniques for summer crops to predict experimental outcomes for different types of seasons (climate), planting dates and crop maturities.

Objective A2. Adapt and develop whole-farm models for extension programs

Activity: Development of whole-farm models, and business -related extension materials to facilitate adoption of conservation farming practices in collaboration with farmers and extension agents.

Objective A3. Develop variety specific agronomy packages for durum wheat (irrigated), canola, chickpea, fababean and field peas in northern NSW.

Limited information is available on the adaptability of new crop species and varieties to new tillage and rotation systems in northern NSW. Activities will include:

- Coordinate on-farm trials/demonstrations to develop recommended management practises with researchers.
- Engagement of consultants, growers and grower alliances to update key messages from projects.
- Engagement of key decision makers at the farm level to enhance the adoption of sustainable tillage and crop rotation practices.

5 Methodology

5.1 Cambodia

5.1.1 Continuous improvement and innovation (CI&I)

The project employed the participatory approach used in the previous projects (ASEM/2000/109 and ASEM/2003/012). In ASEM/2000/109, researchers obtained baseline socio-economic information, monitored farmers' crops, conducted field experiments, introduced outside knowledge and technologies, and involved farmers in the evaluation of results. Similarly, ASEM/2003/012 used community-based decision-making participatory techniques which involved the various participants of the marketing system.

The research method is designed to address specific issues identified by local people, combined with outside knowledge provided by the researchers and the results are directly applied to the problems at hand. The Continuous Improvement and Innovation (CI&I) method was used to set timeframes and performance targets to ensure that improvements were sustained beyond the life of the project.

The CI&I method was implemented in the ACIAR project, LPS/1999/036 "Developing profitable beef business systems for previously disadvantaged farmers in South Africa". In this case, the project members grouped farmers into local teams and then matched each with support teams (with expertise in production, management and marketing). The producer and mentor teams came together to establish a plan that would lead to CI&I of the farmers' business systems.

CI&I is a spiral of steps composed of planning, action and an evaluation of the result of the action and can begin, for example, with the idea that an improvement or change in the farmers' practice can result in increased yield or quality of the crop. This idea may have come from the farmers' 'indigenous' knowledge, from external scientific knowledge or from results of previous experimentation in the area.

As each cycle is completed, improvements are made, targets and timeframes are set and the process begins again at a higher level thus creating a spiral of continuous improvement.

5.1.2 Electronic Marketing Communication System (EMCS)

Electronic Marketing Communication System (EMCS) using mobile phone Short Message Service (SMS) technologies is an enabling technology for capacity building opportunities, particularly as it allows the farming and marketing sectors to collectively monitor the value chain and co-operate to achieve incremental improvements. This project continued to implement the EMCS initiative. It attempted to refine the SMS technology; the types of information and communications to be incorporated and build capacity of value chain participants to use the technology. The SMS technology focused on the delivery of market and production information by:

- Linking with maize/ soybean value chain and market information systems workshops held with project stakeholders to build awareness of the system;
- Expanding the Information-on-demand components of the EMCS for marketing and production information;
- Developing a trainer-the-trainer model for using the EMCS;
- Collecting and consolidating data that can be used to map the EMCS system and its relationship to the value chain; and
- Ongoing evaluation and monitoring of EMCS use and future developments.

The Cambodia-Canada Agricultural Market Information Project (CAMIP) developed the Cambodian Agricultural Market Information System (CAMIS). Robert Fitzgerald worked closely with Pieter Ypma and Eric Sommeling from CAMIP initially to share ideas about the dissemination of market information and then around the development of the EMCS pilot project. CAMIS developed a web-accessible database (http://www.camis-kh.org/) that records market wholesale price information collected by The Agricultural Marketing Office of MAFF. By using the EMCS, the CAMIS project accesses price data from their website via SMS and they agreed to give the EMCS team access to this database. We expect CAMIP will eventually develop their own SMS server but we will continue to share ideas related to the use of SMS technologies.

5.1.3 Target zone and collaborators

The project concentrated its operations in the province of Battambang (Samlout) and the municipality of Pailin in collaboration with MJP, CARE and the PDAs in Battambang and Pailin. These organisations have strategies in place to engage with up to 3,000 farm families during the period 2008-11. Extension to additional districts in Battambang and to Banteay Mean Chey is possible through engagement of new extension providers (other PDAs and NGOs). The AusAID project CAVAC also focussed on value chains but in different provinces in Cambodia. Opportunities for collaboration with CAVAC were sought but CAVAC has confined itself to value chain issues in rice-based systems.

The project built on PRA methodology developed in the previous projects. Training was provided to extension collaborators on the implementation of experiments and on-farm trials. Training was also be provided on the identification of pests and diseases and on the implementation of IPM for upland crops. Cambodian researchers were provided with training to broaden their research capacity, opportunities for post-graduate training and to improve their scientific writing skills. The project also endeavoured to improve CARDI's capacity and credibility in provincial applied research. The project also endeavoured to assist CARDI's capacity to generate income through commercialisation of technologies such as the production of rhizobium inoculants for sale to farmers.

Collaboration with the MJP in Samlout and CARE Cambodia in Pailin was formalised. MJP benefited from hands-on training and supervision for implementing trials and for the recording of data and analysis of results. Two full-time staff members funded by the project were located with MJP. There is a significant co-funding advantage of collaboration with NGOs because they do not need to be paid to implement on-farm trials. Although CARE Cambodia were able to implement on-farm trials during 2007, CARDI were unable to provide adequate technical support with Phnom Penh-based staff. The new project has enabled CARE Cambodia to employ 3 full-time field officers.

Collaboration with MJP and CARE has enabled the improved on-farm technologies and practices to be rolled out to 1065 households in Samlout and 2,857 households in Pailin.

5.2 Australia

In Australia there is currently a major R&D focus on climate change. There are 3 elements: (a) developing predictive capacity (modelling); (b) enhancing ability to mitigate emissions and (c) developing capacity for adaptation. The threat of climate change has reinforced the need for farmers to adopt reduced tillage and residue retention cropping practices that preserve soil water and reduce soil temperatures. The project largely focused on modelling of adaptation options recognising that conservation farming practices developed for adaptation to a variable climate are also likely to provide capacity for adaptation to climate change. Since these no-tillage and conservation practices have only been adopted by 50% of farmers in north-western NSW, the focus of the project was on constraints to adoption of climate change adaptation strategies.

The aspects of the Australian component of the project were: (a) simulation modelling to identify response-cropping strategies that reduce the risks associated with climate variability and climate change; (b) use of whole-farm models and business management tools to enable farmers to evaluate options; and (c) use of social network analysis to identify opportunities to facilitate further adoption of conservation farming practices.

5.3 Project participants

Prof. Bob Martin (University of New England)

Bob Martin was project leader. He was Director of the Primary Industries Innovation Centre (PIIC) - a partnership between the UNE and NSW DPI from 2005-11 and was Director, Tamworth Agricultural Research Institute 1997 to 2007. Bob was Program Leader, Agricultural Systems (NSW Agriculture (1993-96) and Principal Officer Weed Science Branch (Agriculture WA – 1989-93). From 1971-89, Bob researched the distribution, ecology and control of weeds in pastures and field crops.

Dr Bob Farquharson (University of Melbourne)

Bob was a Research Scientist in economics with NSW DPI until 2008. He is now Senior Lecturer in Agricultural Resource Economics at the University of Melbourne. He conducts research into farming systems issues and technology evaluations. During the past four years Bob has:

- conducted evaluations of new technologies at the farm and industry level;
- investigated issues of crop prices and quality premiums for Cambodian farmers;
- identified new opportunities and directions for R&D to address production, economic, resource and environmental issues facing Cambodia's agricultural producers;
- helped in developing the scientific capacity of CARDI research staff.

Ms Fiona Scott (NSW DPI)

Fiona is an Economist at the Tamworth Agricultural Institute and commenced with the Department in October 1993. She conducts research and extension on the farm level financial consequences of alternative farming systems and resource conservation strategies. During the past four years, Fiona has contributed to achieving the outcome of increased adoption of profitable and sustainable farming systems in Cambodia by:

- conducting economic analysis with MJP, CARE and CARDI staff;
- assisting in the training of extension staff in economic analysis principles;
- conducting economic evaluations of new technologies at the farm and industry level;
- assisting in developing the scientific capacity of MJP, CARE and CARDI research staff.

Ms Stephanie Belfield (HMAg Pty Ltd)

Stephanie was District Agronomist, Moree East with NSW DPI until 2008 when she joined the agricultural consulting firm HMAg Pty Ltd in Moree. Stephanie is an extension officer but also conducts trials and extends results of research on a number of alternative crops to winter cereals in the context of providing farmers with options to make their rotations more sustainable and profitable. She is also experienced in writing publications, organising field walks and meetings. Stephanie's clients are producers of winter cereals, chickpeas, faba beans, canola, mustard and lupins. They also grow summer crops such as sorghum, maize, sunflowers, sesame, mungbeans, cowpeas and soybeans. Hence there is a strong overlap between Australian and Cambodian crops.

Prof. John Spriggs (University of Canberra)

John is foundation Professor in the Australian Institute for Sustainable Communities, University of Canberra. Immediately prior to this appointment, he was foundation Professor of Agribusiness at Charles Sturt University. He is a Senior Associate of the Australian Centre for Co-operative Research and Development. John's research interests include socio-economic change in local, national and international regions, agribusiness supply chain management, agribusiness marketing, and agricultural policy. His approach is from the perspective of new institutional economics and his methodology is participatory and trans-disciplinary, with considerations of hard and soft systems within a critical action research framework. He is currently involved in three major research projects: Improving the Marketing System for Fresh Produce of the Highlands of Papua New Guinea (principal investigator); Improving the Marketing System for Maize and Soybeans in Cambodia (principal investigator); Analysing the Effects of Globalization on Developing Countries (senior research associate).

Prof. Rob Fitzgerald (University of Canberra)

Robert is a senior research scientist in the Australian Institute for Sustainable Communities at the University of Canberra. He has over 17 years experience in the information and communications technology field (ICT) and has a strong record of research and publication, particularly around its application to development (ICT4D), learning and capacity-building. Robert is an expert in the development of web-based communities. He currently leads an ACIAR project using SMS and mobile technologies to develop a rural market information system. Robert will lead the development and application of SMS and mobile technologies to the marketing, production and extension components of the project. With John Spriggs and Andrew Higgins, he will work on the integrated development and value chain analysis components of the project.

Mr Stuart Brown (CSIRO)

Stuart has had 13 years experience with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. These skills include whole farm planning; value chain data collection and analysis; crop and pasture agronomy; ecological research in highly modified landscapes; detailed knowledge and implementation of tropical forages technologies in farming systems and expertise in agricultural information systems. He also has expertise in information systems and implementation of large scale database projects. Stuart lead the value chain component of the project from December 2009. He has also developed substantial linkages between organisations and research institutions to forge greater collaboration within the small holder agricultural sector in Cambodia.

Ms Chan Phaloeun (CARDI)

Phaloeun has had professional working experience for 20 years. In 1987, Phaloeun completed a Masters of Science, Agronomy degree at the Patrice Lumumba University, Moscow. She has had professional experience in research and agency development. Currently, she serves as Deputy Director of CARDI and has been responsible to the Director of CARDI for the implementation of the successful ACIAR project ASEM/2000/109. She has responsibility within CARDI for making its research program more responsive to the needs of stakeholders. She will be responsible for overseeing the project and supervising CARDI staff.

Dr El Sotheary (CARDI)

Sotheary has recently completed her PhD studies at the University of Queensland, Gatton. She has been involved in the evaluation of contemporary participatory approaches to research and extension in relation to new community-based approaches for rodent management in rainfed rice systems. Technologies such as the Trap Barrier System (TBS) were evaluated in a project called FARMERS (Farmer-based Adaptive

Rodent Management, Extension and Research System), which commenced in 2001. The project was based in Kampong Cham. One of the central problematic issues remaining is whether or not the TBS is actually a feasible option for a farming community in Cambodia. Sotheary has evaluated rodent control techniques using a systems modelling approach employing Bayesian Belief Networks (BBN) to capture and integrate farmers' knowledge of the critical factors influencing the efficacy of optional techniques.

Mr Lex Freeman (MJP)

Lex has over 30 years experience in capacity building projects in countries such as Papua New Guinea, Laos and Cambodia. Prior to joining MJP, Lex was based in Battambang with the AusAid Cambodia Australia Agricultural Extension Project (CAAEP) a capacity building project which set up the Department of Agricultural Extension. Lex is experienced in PRA methodology and Agro-Ecosystems Analysis to enable communities to do their own development planning. Agro-Ecosystems Analysis is an agro-ecological needs assessment methodology of great utility. Lex has experience in activity monitoring, aggregation of data, and monitoring the effectiveness of adoption and diffusion of innovations. CAAEP pioneered the innovative Technology Implementation Procedures training program. The successful engagement of ASEM/200/109 with extension collaborators was greatly helped by Lex and his CAAEP colleagues with their advice based on experience and local knowledge.

Mr Joseph Kodamanchaly (CARE)

Joseph was the Rural Development Program Coordinator for CARE Cambodia. In collaboration with FAO, Joseph has developed and published the Guidelines for Participatory Village Planning for the National Programme for Food Security and Poverty Reduction Cambodia in 2005. These guidelines are for the use of Village Planning Workshop Facilitation Team members working with the National Programme for Food Security and Poverty (FSPR) in Cambodia. At the village level the programme operates mainly through: FFSs and field trials; Small Savings and Credit Groups of FFS participants; and Community Micro Projects relevant to Food Security.

6 Achievements against activities and outputs/milestones

Objective C1: To exploit the potential synergies and efficiencies that can be obtained by the production component informing the marketing component of the value chain, and vice versa.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Development of a web-based information system to facilitate communication, sharing and exchange of information and create an online 'community of practice'	'Google group' of project participants activated	Year 1, m5	Google group setup and fully operational with 38 registered users.
		Interactive web site provider identified and web address obtained Interactive web site fully operational	Year 1, m12 Year 2, m1	Established two websites for the project. An interactive wiki website based on pbwiki (https://ccpmp.pbworks.com/) and a wordpress site (http://ccpmp.info). The wiki has been used by project researchers to upload and share project documentation and reports. A number of online communities of practice were established in the areas of socio-economics and SMS technology to provide wider access to resources. While there are only 13 registered editors many pages are publically accessible. Twenty-eight pages have been created (and revised) and 94 files have been uploaded.

1.2	Mapping capacities, constraints and opportunities at all points in the production-value chain	Capacities, constraints and opportunities documented Research methodologies defined Synergies and interactions identified	Year 1, m6	As part of this overarching objective, an opportunity arose in early 2009 to develop an integrated production and marketing pilot project with NAMA in response to a request for certified seed for export to Taiwan by an Australian company (APS). This request provided an opportunity not only to develop an integrated development pilot project for the region, but also it was hoped to provide a good platform for NAMA developing as a production-marketing-communications hub for upland crops in northwest Cambodia. This initiative involved team members from both the production and marketing /value chain teams working with NAMA and APS. Ultimately, the initiative foundered because we were unable to bridge the gap in trust between NAMA and APS. However, we learned significant lessons as part of this initiative. An opportunity was identified to work with NAMA members to develop an export oriented website that would promote the activities and capacities of the NAMA group. A prototype was delivered in September 2010 (http://talkingtactics.businesscatalyst.com/cms) and further work is on-going. In terms of the value chain, constraints and opportunities have been mapped through a series of workshops and surveys throughout the project. Early survey work and a baseline data capturing workshop developed a comprehensive value chain map which highlighted the flows of exchanges and interactions between actors in the value chain. Based on this data, key constraints for the actors at the lower end of the value chain were identified. From this, constraints and opportunities were discussed at subsequent workshops. These opportunities consisted of points of intervention priorities such as the establishment of a farmers association and grain trader association. Grain storage financial modelling was undertaken to highlight the potential value adding opportunities for grain traders and farmers alike.
1.3	Whole-of-chain diagnosis to identify opportunities and synergies	Whole-of-chain diagnosis completed Opportunities for synergies and interactions identified Action plan for integration completed	Year 1, m6	All four components of the project have made efforts to build synergies during the year through joint meetings, conference calls and the establishment of a project wiki for communication. There is a good level of mutual respect and camaraderie and a determination to carry forward the efforts to work together in the second year (e.g. through joint involvement in village workshops). Throughout the course of the value chain study, reflective analysis was used to identify ways to interconnect other aspects of the project with the value chain. The project has come to understand that all parts of the project share a connection via a social network of interactions within the production, marketing and sale of the commodities. On the basis of this concept of interconnectedness, plans were developed to assess the relationships and information flows throughout the “value network”.

1.4	PAR with stakeholders to develop a research action plan	Action plan for integrated value chain development completed	At various times between Year 1, m7 and Year 2, m6	Action plan developed that involved: (a) background paper on NAMA, (b) held two participatory workshops with NAMA members to explore their issues and potential actions. Exploring the possibility of working with CARE-Cambodia to develop a strategic plan for developing farmer associations or cooperatives in the second year of the project. Integrated action plan developed for project team - three-pronged approach (micro level, meso level and macro level) to integrated development. As part of this three-pronged approach workshops were held dealing directly with the key actors identified in the value chain. The grain traders (or middlemen) are the key actors that help facilitate the sale and movement of grain in the network. Their key constraints were identified and solutions posed at two workshops. A concrete set of outcome from this approach has been the development of plans to establish a grain trader association and a networking workshop between the farmer association and major grain traders and silos in the Pailin region.
1.5	Implementation of the action plan for integrated value chain development	Action plan implemented through meetings and on-line communication	At various times between Year 2, m7 and Year 3, m6	The project team use the PAR cycle of continuous improvement to implement project activities and to identify required changes in direction. For example the addition of herbicide trials and demonstrations was in response to farmers' needs. Further evidence of the implementation of the action plan has been the development of a comprehensive survey for farmers and middlemen for the early and main wet season 2010. Limitations were identified in the information gathered through two previous surveys in terms of understanding the flows of information and the social and business relationship throughout the network. A social network analysis along with traditional statistical analysis will be used to garner information about the underlying patterns within the grain sector of Pailin and Samlout.
1.6	End of project workshop and final report	Final report on the Model of Sustainable Integrated Value Chain Development	Year 3, 12	A final external review of the project was conducted in October 2010. This review included formal presentations of project outputs and achievements. The project was granted an extension to December 2011 and a final report was completed in January 2013.

Objective C2: To enhance the adoption of improved technologies and practices for production of upland crops by integrating agronomic, economic, environmental and social factors.

No.	Activity	Outputs/ milestones	Completion date	Comments

2.1	Providing advice and support to NGOs and PDAs for implementation of PAR and Farmer Field Schools (FFS)	New extension collaborators trained (PDA, NGO) trained each time	Years 1, 2, 3 m2, 6	Extension collaborators (MJP, CARE, PDA) participated in field days at trial/demo sites (Jun, Oct 2009). Samlout School Teachers and key farmers in Samlout and Pailin provided with training in IPM (Oct 2009) and rhizobium inoculation (Feb 2010). MJP and CARE project staff provided with training in experimental design, data management, statistical analysis and Gross Margin analysis (Jan 2009, 2010 and 2011). MJP and CARE project staff provided with assistance in preparing Field Log Books for the trial and demo program (2008, 2009, 2010 and 2011).
2.2	Implementation of on-farm trials, farmer field days and workshops to validate and adapt improved technologies	On-farm trials implemented Field days held and farmer feed-back obtained	Years 1, 2, 3 m3, 7 Years 1, 2, 3 m6, 9	Participatory Action Research carried out with eight focus village clusters established in Samlout (4) and Pailin (4) in 2009 and continued in 2010 and 2011. Trial and demonstration program commenced in 2008 and continued through 2009, 2010 and 2011: MJP Samlout trials and demos 2008-2011: Maize nitrogen nutrition (10); Maize varietal evaluation (1); Rhizobium inoculation (10); Legume varietal evaluation (14) Crop rotations/intercrop (7) Weed management (14) CARE Pailin trials and demos 2008-2010 Nitrogen nutrition (4); Rhizobium inoculation 4); Legume varietal evaluation (1) Crop rotations/intercrop (7) Weed management (6) Trials and demonstrations were conducted in both Early Wet Season and Late Wet Season. Farmers participated in the layout, planting and maintenance of the trials. Field days were held at all sites at crop maturity and at harvest. Farmers participated in workshops to discuss the results and to provide feedback. Farmer feedback resulted in changes in direction in research for example from nitrogen nutrition to weed management in maize.
2.3	Quantifying the value of improved technologies and practices in economic terms to determine potential financial	Crop budgets benchmarked for EWS, MWS crops and used in village workshops	Year 1, 2, 3 m6, 9	All significant production results were analysed using gross margin analysis for 2008, 2009, 2010 and 2011 with assistance from Fiona Scott. This included nitrogen nutrition of maize and the rhizobium x nitrogen demonstrations for soybeans, mungbean and peanuts.

	benefits and risks	Crop GMs updated: yield and price distributions and correlation, @RISK analysis (ex ante and ex post)	Years 1, 2, 3 m6,9	Village workshops were conducted at two times each year (2008, 2009, 2010) for 4 villages in each of the Pailin and Samlout districts. Gross margin budgets of farmer crop activities were developed in village workshops in June 2009. Forty-three budgets of EWS and MWS crops were compiled. These crop budgets provide an idea of actual crop performance and income for upland farms. Gross margin surveys of more than 120 farmers crops (maize, soybean, peanut and cassava) were carried out in 2010 and 2011 in Samlout.
		Partial budgets, ROI calculations (ex ante and ex post) completed, data on uptake collected	Years 1, 2, 3 m6, 9	In June 2009 the village workshops developed partial budgets for return on investment for the application of Nitrogen fertilizer to maize and inoculation of legume seeds with rhizobium. In October 2009 further partial budgets were developed for weeding of crops - hand weeding versus chemical sprays.
2.4	Using adaptive management, use case studies to identify factors limiting the adoption of improved technologies;	Stakeholder workshop, farmer trials, field days, field data collection completed	Year 1, m2, 4, 6, 10, 11	Farmer trials field days were conducted (see Objectives 2.1 and 2.2). Economic evaluations of rhizobium (based on trial yields and expected prices) showed that this could be a very appealing crop technology (in terms of return on investment) to these upland farmers. Rhizobium is unavailable and it is currently being sourced from the Suranaree University of Technology (SUT) in Thailand. Farmers in Samlout and Pailin were provided with training and rhizobium inoculum on their own farms in EWS and MWS 2010. The University of Battambang (UBB) is investigating production of rhizobium inoculants for commercial sale. *This will be possible by having a suitable person trained in rhizobium culture techniques at the Suranaree University of Technology (SUT) at Nakhon Ratchasima, Thailand.* In 2010, farmer workshops were conducted to identify the factors limiting the adoption of improved technologies. Farmers were asked to score the technologies for Relative advantage, Complexity, Trialability and Observability. Varieties and to a lesser extent selective herbicides were given high scores. The more complex technologies such as rhizobium and IPM received low scores and will require further PAR to achieve full adoption.

2.5	Collation and review of previous studies and current baseline practices (CARE) and identify knowledge gaps. Conduct village workshops to fill the gaps - discuss the trialability of new technologies in farmer fields	Baseline social and demographic information completed	Year 1 m6, 9	Baseline reports from CARE and from MJP have been reviewed and showed that farmers were very poor with small farm sizes. The average age of farmers in Samlout and Pailin is around 44 with the average farm area of 5.4 ha in Pailin and 2.7 ha in Samlout. Khmer Rouge fighting ceased in 1998 and as a result the average number of years farming is around 7. Further baseline information was collected in the village workshops conducted in June and October 2009. This information confirmed that farmers have small farm areas, low levels of education, large families and relatively low yields. They have very few financial reserves and pay high interest rates when borrowing money to plant crops. There is a substantial proportion of female farmers in the villages of our study.

		Impact of adoption of new technologies on equity at the household, gender and community level determined	Years 1, 2, 3 m6,9	Workshops have investigated the likely returns to upland farmers of rhizobium inoculation and nitrogen fertilization of maize. Questions of hand weeding of crops versus use of chemicals for control have been analysed. Other investigations were of the cost of credit to farmers, their sources of crop seeds, and an assessment of typical farm family income and expenditure patterns. Partial budgets were used in workshops to investigate potential financial gains from using less farm labour and more herbicide control of weeds in crops. A separate analysis of trends in the price of farm labour confirmed the changed incentives for farmers when considering methods to reduce crop weeds. Both CARE and MJP target poor and vulnerable households for interventions and funding from outside the ACIAR project is used to provide incentives to farmers to adopt improved technologies developed in the project. Both CARE and MJP provide cash and seed credit and in 2009 CARE provided $110,658 in cash and seed credit to encourage adoption of improved technologies. Roll-out of technologies through CARE/MJP Farmer Field Schools in 2009 included the: CARE: Beneficiary population 3,398 families. Seed credit provided to 1,141 families in 21 villages to encourage adoption of improved technologies in maize. Mungbean seed provided to 447 families in 12 target villages, peanut seed provided to 19 families in 3 villages, and soybean seed to 9 families in 2 villages through establishing seed credit. MJP: Beneficiary population 343 out of 1,076 families. TIP successfully implemented for improved practice in maize, peanut, soybean, sesame with increased crop yields and GMs.

		Feedback obtained from on-farm trial and experimental team, so that the improved technologies and practices can be refined.	Years 1, 2, 3 m6,9	Feedback on refinement of improved technologies was obtained from (a) farmer field days/workshops; (b) observation and analysis by project staff. Feedback resulted in (a) identification of problems such as unavailability of inputs (eg rhizobium) and problems with seed storage – particularly soybean and (b) changes in research priorities such as from nitrogen nutrition to weed management in maize. With assistance from Barbara King (Melbourne University) we have commenced using Social Network Analysis (SNA) to gain a better understanding of information and knowledge flows within the farming communities. Two pilot studies were conducted (1) on farmers' source of information on the use of herbicides and (2) to identify the key actors in the farmer/grain trader network.
2.6	Evaluation of the economic impact of adoption of improved technologies and practices and conduct an economic impact assessment of adoption of the improved technologies and practices	Baseline surveys to show starting point for comparison analysed	Year 1, m2 Year 3, m11	Information from the CARE and MJP baseline studies, and from the December 2008 and 2009 workshops conducted by Bob Farquharson and the CARDI socio-economic team, shows the base case. Discussions of the existing (base) cases are included in Farquharson et al. (2010) A paper outlining an approach to economic evaluation of new technologies at the village level was presented at the AARES conference (Spriggs et al. 2010).
		Case studies of areas sown using improved technologies and practices and new GM budgets completed	Year 2, 3 m6,9	Plans have been developed to collect relevant data and conduct case studies (e.g. see Chan et al. 2010). Examples of economic evaluations of technologies are in Chea et al. (2010) and Farquharson et al. (2010). It is expected that Social Network Analysis (SNA) will be used as one of the tools of evaluation. On-farm demonstrations have been conducted and Gross Margin budgets based on the trial results have been developed by Fiona Scott in conjunction with the CARE/MJP project officers. In June 2010 82 farmers from Pailin and 72 from Samlout were engaged in the village workshops.
		Modelling & analysis of data on uptake of improved technologies and practices, benefit cost analysis of the project completed	Years 1, 2, 3 m6,9	Two papers on evaluation (Chea et al. 2010 and Spriggs et al. 2010) have been prepared outlining an approach to project evaluation. An impact pathway model of project evaluation has been developed as part of the project assessment process.

2.7	Production of education, training and extension publications	FFS curricula prepared for: IPM; improved production technologies and marketing strategies.	Year 4, m3	Extension publications for improved production technologies for upland crops in Cambodia are being produced in Khmer language. These are distributed to MAFF and PDA offices across Cambodia as well as to universities, colleges and relevant NGOs and individuals. The current distribution is over 1000 copies including multiple copies to institutions. Publications include: A guide to upland cropping in Cambodia: soybean (ACIAR MN 146) Insects of upland crops in Cambodia (ACIAR MN143). Weeds of upland crops in Cambodia (ACIAR MN141: English, Khmer). A guide to upland cropping in Cambodia: maize (ACIAR MN140: English, Khmer) Jorani and the green vegetable bugs (ACIAR MN137: English, Khmer, Lao). Farmer Field School Flip Charts (Khmer): Rhizobium inoculation, IPM Life-skills units for primary schools: IPM Farmer FactSheets (16 subjects) published in Khmer language in collaboration with UBB.

Objective C3: To improve post-harvest management, communications along the supply chain and value chain integration for maize and soybean in north-western Cambodia.

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	PAR to improve product quality and reduce costs through post-harvest storage, handling, transport, processing	Mapping of marketing system complete and main constraints & opportunities identified	Year 1, m5, 8	The value chain mapping exercise has been completed and the main opportunities for improvement have been identified. These opportunities include a farmers association; grain trader association and storage facilities. A grain trader workshop was held in March 2010 to raise awareness of grain storage at the grain trader level in the value chain. An enthusiastic response at the workshop has progressed to planning and budgeting for an association creation.
		Action plans developed and communicated to wider Cambodia chain participants & government	Year 1, m8	Work is continuing along the action plan developed in the previous year. EWS and MWS survey has been completed for 2009 and is currently being analysed and combined with the 2008 data to contribute to a greater understanding of the relationships and market in Pailin. A workshop has been held to address some of the issues identified by the grain traders as impediments for their businesses. Close cooperation exists between the project team (CARE Pailin) PDA and DoC through joint planning activities in relation to the farmers association and the grain trader association.

3.2	Benefit-cost analysis of alternative post-harvest technologies, buyer surveys, buyer-seller relationships;	Draft modelling and economic analysis conducted for marketing system opportunities & technologies and communicated to Cambodian chain participants	Year 1, m8, 10 Year 2 , m2	The analysis of post harvest technologies in Pailin commenced in the second half of 2009. In the first year of the project, an increased emphasis and timeframe was allocated to mapping out the supply chains for the CARE clusters. Information was gathered from at two EWS and MWS seasons to get a temporal understanding of the supply chain mapping, which will increase the robustness of any future analysis undertaken. Discussions between the socioeconomic and value chain teams provided a template for economic analysis for the value chain (post harvest) activities in Pailin. A literature review was conducted and discussions held on the best approach. (1) This included the aspects/measurement of marketing margins at each stage and (2) issues of pricing efficiency (i.e. if a price changes at the top of the chain is this transmitted down to the lower levels). Discussions also considered the suitable supply chain goals for Pailin, which go beyond the traditional “lean” thinking to address potentially more attractive goals in agility and resilience.
		Modelling & economic analysis refined through action research, and change management plan initiated for best bet opportunities	Year 1, m2, 7	
		Strategies for overcoming barriers to adoption implemented and piloting commenced and monitored	Year 2, m10 Year 3, m3	Julien Brewster, an AYAD volunteer commenced a 12 month assignment with MJP in October 2010. Julien’s assignment focussed on developing pathways to adoption of improved technologies and management practices. The priority technologies to be progressed were rhizobium inoculation and IPM. The University of Battambang is interested in small scale commercial production of rhizobium inoculants in collaboration with SUT.

		Action plans developed for dissemination to upland crop areas in Cambodia. Industry communication completed	Year 2, m6 Year 3, m8	The plan for dissemination of project technologies across Cambodia involves making connections with and between four channels which have complementary strengths: Public extension agencies (information warehouse); NGOs (community engagement); Private sector (technology transfer); Education (future generations). Dissemination of project publications has commenced to a distribution list of over 1000 recipients. The Khmer version of the maize book has been distributed and circulation of the weeds book is currently underway. Project Best Practice Manuals are being distributed with CARE/MJP seed credit programs to farmers and it expected that this could be extended to other NGOs. Engagement with the private sector has commenced with SNA analysis of players in the input supply chain. Pesticide suppliers interviewed so far are willing to include Khmer language application instructions and IPM guidelines with pesticide products sold. In addition, silos and other providers of seed credit are likely to be engaged in dissemination of project technologies. A pilot 'life skills' program on IPM for primary schools was successfully implemented in Samlout in 2010. The effectiveness is currently being evaluated.
3.3	Development of improved communications between different levels of the supply chain using SMS technology	Linking with VC & MIS workshops held with project researchers, collaborators, and stakeholders in Cambodia (Feb, Aug 08) to build awareness of SMS objective and current CCPMPIS developments Development of trainer-the-trainer model (TOT)	Year 1, m2, 8	Workshops held in Cambodia (August 2008 & January 2009) raised awareness of the role that ICT and mobile technologies in particular (e.g. SMS) can play in the VC for the sharing & exchange of information and the development of production/marketing communities of practice. Both MJP and CARE have a TOT/FFS model whereby project technologies are rolled out to the full MJP/CARE target groups.

		Data collected, consolidated and used to map the CCPMPIS system and validated by project team	Year 1, m9, 12	In February 2009, after initial testing and evaluation, a basic model of an SMS communication system (CCPMPIS) was developed that adopted the open-source application FrontlineSMS A decision was taken to link to the CAMIS web-based market information database to extract price information The concept of the CCPMPIS was expanded to incorporate multiple servers located in different regions that could operate as field communication systems. Worked with the newly formed NAMA to develop the SMS Field Communication System to install a server in Pailin (February 2009) with particular focus on the provision of information (rated top priority by members) and the exchange and sharing of silo association price and market information. In June 2009 we further refined the systems and NAMA is focusing on NAMA broadcast messages to members, price Information and input costs. *NAMA SMS server taken offline while a new scaling facility is constructed (September 2010). The server* had been *used regularly by 5 traders and one administrator has been trained and is confident in its operation.* Some farmers still report a preference for voice calls over SMS. Discussions were held with MJP in Battambang (February 2009) about the establishment of a server run by MJP to provide access to basic market information and health alerts.

		Workshops held in Cambodia to finetune CCPMPIS and apply it to identify system limitations and priority MIS opportunities Ongoing evaluation and monitoring of CCPMPIS use	Year 2, m2, 8 Year 3, m8	Farmer field day conducted in conjunction with socio-economic team surveyed farmers about their use of mobile and information needs. Mobile phone ownership reported at 40%. Farmers showed keen interest in S and we provided simple demonstrations of the service. (June 2009). Redeveloped the CCPMPIS taking into account the farmers needs. A prototype system was completed in January 2010, using a more modular architecture and popular open source software solutions. Field research done in February 2010 resulted in a revised focus for the system towards mapping and disseminating information about market players relevant to users. A FrontlineSMS server was hosted at the Royal University of Phnom Penh (RUPP) however following some ongoing technical problems that required more hands-on monitoring, the server was moved to Battambang to be managed by the web developer. Launched (June 2010) the redeveloped CCPMPIS web service that provides the data for the SMS server (http://ccpmp.heroku.com/). Currently populating the web database with farmer and trader contact information generated from social network analysis surveys (October 2010). Analysis of a farmer survey from the Samlout area (n=182) showed mobile phone ownership had increased to 80% with 55% reporting they used their phone to located farm information (October 2010). Plans to further develop the CCPMPIS model towards a hubs and spokes model introducing the role of an information broker (i.e. middle man) into the VC. Develop the train-the-trainer model around the iBooth concept and this new role of information broker (December 2010-January 2011).

Objective A1: Conduct a bio-economic evaluation of the technologies and strategies to reduce the impact of climate variability and climate change on farm families.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Use of simulation modelling techniques for summer crops to predict experimental outcomes for different types of seasons (climate), planting dates and crop maturities	Model/modellers identified	Year 1, m6	De Li Liu (NSW DPI) was brought into project to provide downscaled climate scenarios for NW NSW. Bruce Haigh conducted APSIM modelling of sorghum and maize options for crop production. Extension specialists were consulted on farmer preferences for climate change adaptation strategies for sorghum and maize. These preferences were then used as the basis for comparison in the subsequent papers and presentations listed below.

		Simulation runs conducted	Year 2, m2	Down-scaled future climate scenarios were completed for sorghum at Quirindi and Moree. APSIM simulation runs were completed for farming systems options for sorghum and maize. Economic analysis of farmer preferences were completed and submitted for presentation/publication at the Australian Summer Grains Conference June 2010, the Australian Agricultural and Resource Economics Society, Melbourne, Feb 2011 and the NCRGGR Rural Climate Change Solutions Symposium, Armidale, May 2011.
		Stochastic programming analysis with State Contingent Theory (SCT) completed	Year 2, m8	The APSIM runs have been completed for sorghum and maize and the economic analysis has commenced. @Risk has been used to compare the variability of the sorghum and maize systems. Given we were only able to model sorghum and maize, we need to model winter crops in the next project to complete the farming system before going to more advanced techniques such as state contingent programming.
		Economics Research Report, AARES conference, journal paper.	Year 4, m3	Economic analysis of farmer preferences were completed and submitted for presentation/publication at the Australian Agricultural and Resource Economics Society, Melbourne, Feb 2011. Journal paper in draft form for the sorghum and maize runs as of June 2011, aiming for submission to the journal Agricultural Systems.

Objective A2: Adapt and develop whole-farm models for extension programs…

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Development of whole-farm models, and business -related extension materials to facilitate adoption of conservation farming practices in collaboration with farmers and extension agents	Farm enterprise data collected from 6 agro-ecological zones	Year 1, m6	Zones determined - Western Clay, Western Red, Liverpool Plains, Inner East, Inner West and North-east slopes. Data from 2006 ABS Agricultural Census and 2007-08 Agricultural Survey obtained on adoption rates of conservation tillage. Cash flow budget built which can compare; - conventional and zero-till or - zero till and controlled traffic or - conventional and zero till/controlled traffic.
		Whole-farm models developed	Year 1, m12	Whole farm model for Western Clay region set up to compare zero and reduced till.
		Models validated through 6 regional workshops; key issues analysed	Year 2, m6	Focus moved from social network analysis workshops in 2.2 to surveys. Hence workshops were unable to be undertaken.

		Economics Research Report, AARES conference paper, Primefact	Year 3, m2	A summary paper will be prepared on cash-flow scenarios for : - conventional and zero-till or - zero till and controlled traffic or - conventional and zero till/controlled traffic

Objective A3: Determine the social networks that influence farm practice change with a focus on adoption of conservation farming practices…

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	A survey of farm management teams from 2 study groups (adopters and non-adopters) in at least 2 North West NSW locations	Separate interviews of farm family members completed. Social network analysis for farm family members completed	Year 1, m7	This work was delayed by the resignation of project officer, Shauna Dewhurst from NSW DPI. The work has recommenced through UNE by linking it to the DAFF Soil Carbon Research Project. S*tudy groups are being selected from farms sampled in the DAFF National* Soil *Carbon Research Program where groups of 25 adopters / 25 non-adopters of conservation farming practices* have *been selected for a range of soil-landuse combinations.* The survey of 88 cropping paddocks was completed in Dec 2010-May 2011. Data has been collated and is being analysed by a DPI biometrician.
3.2	Identification of extension and training strategies to harness key social influences to accelerate farm practice change.	Extension and training methods identified	Years 1, 2, 3 m6,10	*Extension and training strategies were be based on the results of the social network analysis.* It is expected that this objective will be achieved by April 2011.
3.3	Engagement of key decision makers at the farm level to enhance the adoption of no-tillage and sustainable farming practices	Alternative extension methods and educational tools developed to enhance adoption of no-tillage and sustainable farming practices.	Year 4, m3	It is expected that this objective will be achieved on time. The improved extension methods and educational tools will be submitted to NSW DPI for implementation through their network of extensionists.

7 Key results and discussion

7.1 On-farm trials and demonstration of improved practices for sustainable crop production

Summary

Production of rainfed crops such as maize and soybean have rapidly expanded in North-Western Cambodia since re-integration of the former Khmer Rouge began in 1996. The region has a monsoonal climate with a rainy season between May and October and a distinct dry season between November and March. At Battambang, the annual climatic averages are: rainfall, 1,263; temperature, 28.0^{o}C; and relative humidity, 80%. The area is mountainous and most of the cultivated areas have rich soil of volcanic or limestone origin. However, sustainable crop production is threatened by excessive cultivation and burning. The main crops grown in the upland areas of the region are maize (red corn), soybean, mungbean, sesame and cassava.

Average farmer yields (2005-2009) for maize, mungbean, peanut and soybean in Battambang/Pailin were 4.289, 0.655, 1.634 and 1.273 t/ha respectively or around 40% of the expected regional yield potential for maize, mungbean and soybean and 27% for peanut. Experiments and demonstrations were carried out in farmers' fields from 2007 to 2011 to evaluate improved varieties, cultural practices, nitrogen nutrition of maize and rhizobium inoculation of legumes. Under experimental conditions, all crop species were shown to be capable of exceeding the predicted yield potentials of 10, 6, 3 and 2 t/ha for maize, peanut, soybean and mungbean respectively.

Maize responses to nitrogenous fertiliser varied between sites and it was concluded that the response could be masked by other factors such as soil constraints and poor weed control. The farmer practice of replanting the F2 seed of single-cross maize varieties such as CP888 could also be contributing to lower yields. There is a need to continue on-farm demonstrations of improved practices for maize production. New maize hybrids from seed companies Advanta-Pacific, Dupont-Pioneer and Seed Asia are now available in Cambodia. 28 hybrids were evaluated at Samlout in 2011 with several new varieties significantly out-yielding the traditional CP888 from Charoen Pokphand.

The results of varietal evaluation for soybean were inconclusive and this was attributed to loss of seed viability due to lack of appropriate seed storage facilities. The average temperature and humidity at Battambang is 28^{o}C and 80% respectively and it is has been shown in other studies that soybean seed stored under these conditions will quickly lose viability. Further evaluation of ICRISAT peanut varieties for disease and drought tolerance could be justified. Despite the high yield potential and price, few farmers in Pailin and Samlout grow peanuts because of the high cost of production and difficulty with harvest and drying. Mungbean yields in excess of 2 t/ha appear to be achievable with rhizobium inoculation and good agronomic practices. There appears to be scope for further gains to be made with improved varieties from Australia such as ATF 3944 which has been commercially released as CMB 3 by CARDI.

On-farm demonstrations in MWS 2010 confirmed that rhizobial inoculation can increase the yields of legume crops (mungbean, peanut and soybean) by 10-15%. Because of the low cost of the inoculum, these yield increases translate to a significant increase in profit. Gross margin for soybean was increased by $32 and peanut by $280/ha. Farmers would readily adopt rhizobial inoculation if the inoculants were available. Options for inoculant supply are: (a) establishment of a rhizobium culture laboratory in Cambodia; (b) encouraging the private sector (eg silo input suppliers) to import and provide short-term storage and distribution of inoculants to farmer clients.

Introduction

North-West Cambodia has seen rapid expansion of rainfed upland cropping as a result of large-scale land clearing since the end of the Khmer Rouge civil war in 1998. Unfortunately this development has been associated with excessive cultivation and burning of crop residue which has led to rapid soil fertility decline and soil erosion. ACIAR research to address these problems commenced in 2003.

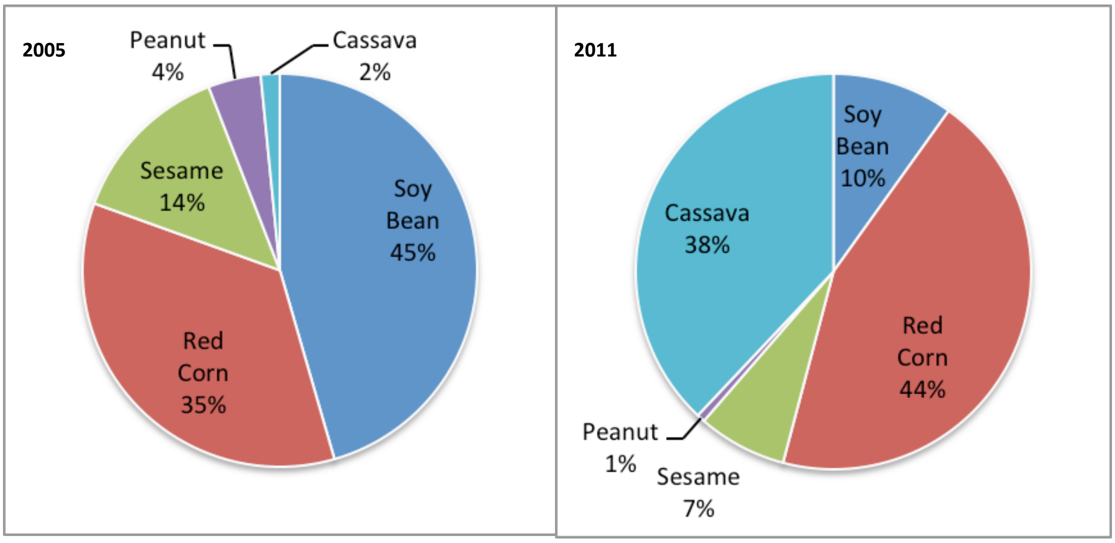

Figure 1. Cropping trends in Battambang Province based on area of production.

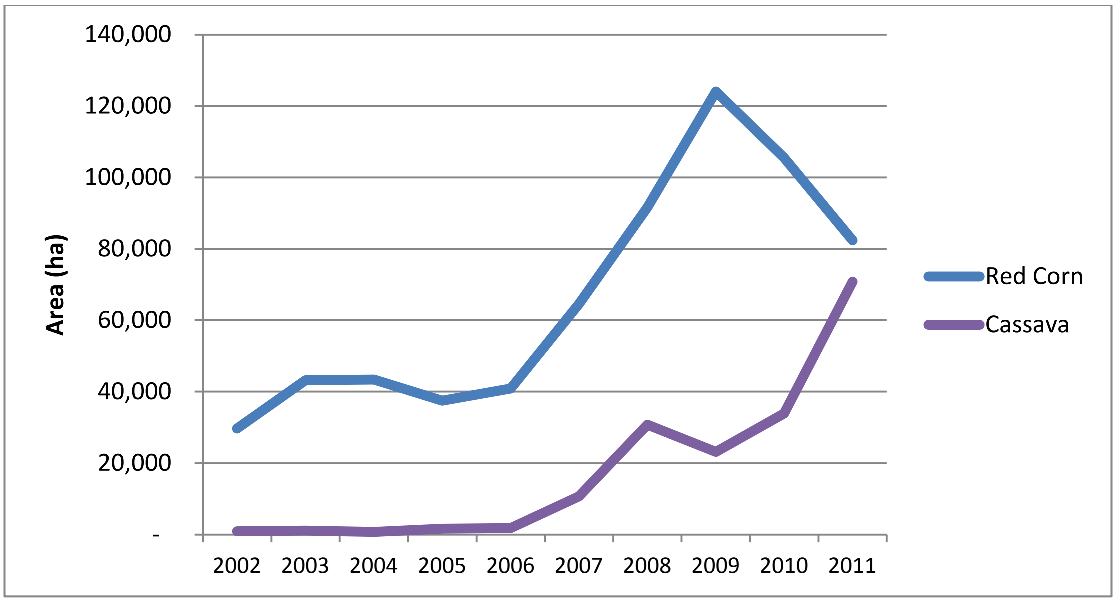

Figure 2. Trends in the area of red corn and cassava in Battambang Province.

The expansion of maize and cassava, which began in 2006, has also led to a loss of crop diversity (Figure 1, Figure 2). The expansion of area under maize appears to have peaked in 2009 and is being replaced by cassava. Maize yields are declining as soil fertility declines and this might be one of the reasons why farmers have begun to increase the area of cassava at the expense of maize since 2009 (Figure 2). The expansion of cassava could also be due to the need for less labour and opportunity for household members to earn off-farm income.

Options to increase crop yields

Options to increase yields include: better varieties, certified seed, improved agronomic practices, better weed and pest control, fertiliser application, legume rotations. Chan *et al*. (2009) identified potential constraints to increasing yields of upland crops in Cambodia. These included:

- Cost or availability of crop inputs such as rhizobium, certified seed, fertiliser;
- Availability of suitable varieties with suitable duration, drought tolerance and resistance to diseases and pests;
- Crop rotations and crop residue management to maintain soil fertility and to reduce the impact of diseases and pests;
- Risk management strategies to minimise the impact of climate variability, drought and natural disasters;
- Farmers' beliefs and understanding of soil fertility and the role of fertilisers, especially for non-legume crops such as maize.

The average yields for maize, mungbean, peanut and soybean, and in Battambang/Pailin during the period between 2005 and 2009 were 4.289, 0.655, 1.634 and 1.273 t/ha respectively. These are around 40% of the estimated yield potential for maize, mungbean and soybean in the region (Holland pers. comm.) (Figure 3). However, peanut yields were only 27% of the expected potential yield. Potential production constraints could be grouped as:

- Biological: species or variety; poor management of weeds, diseases, insect pests;
- Physical/chemical: soil/water problems, soil fertility;
- Social: traditions & attitudes; knowledge;
- Economic: cost of inputs, cost of credit, cost of labour.

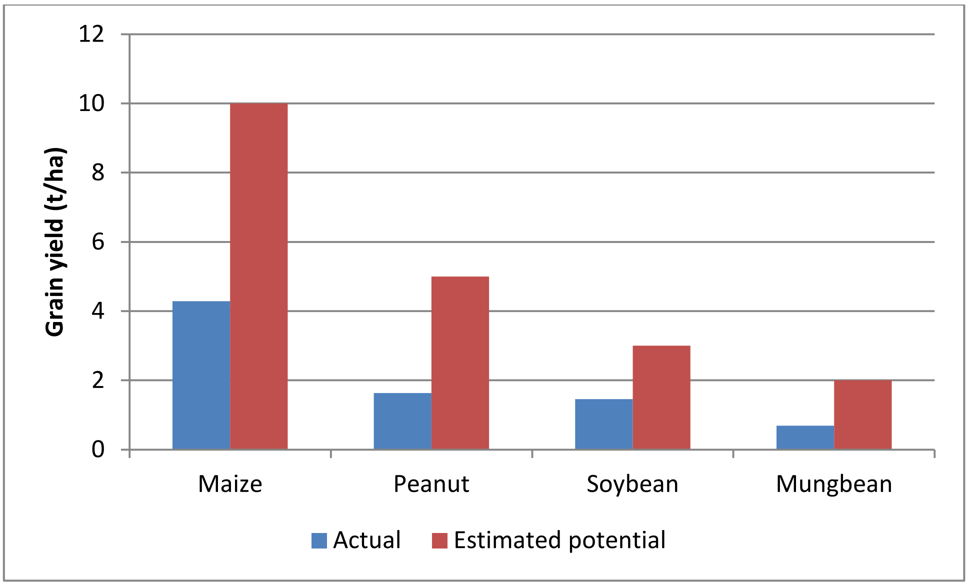

Figure 3. Actual and potential yields for upland crops in Cambodia.

7.1.1 Materials and methods

Climate and soils

Experiments and demonstrations were carried out in farmers' fields in the district of Samlout in Battambang province and in the Municipality of Pailin in North-Western Cambodia from 2007 to 2011 (Figure 4).

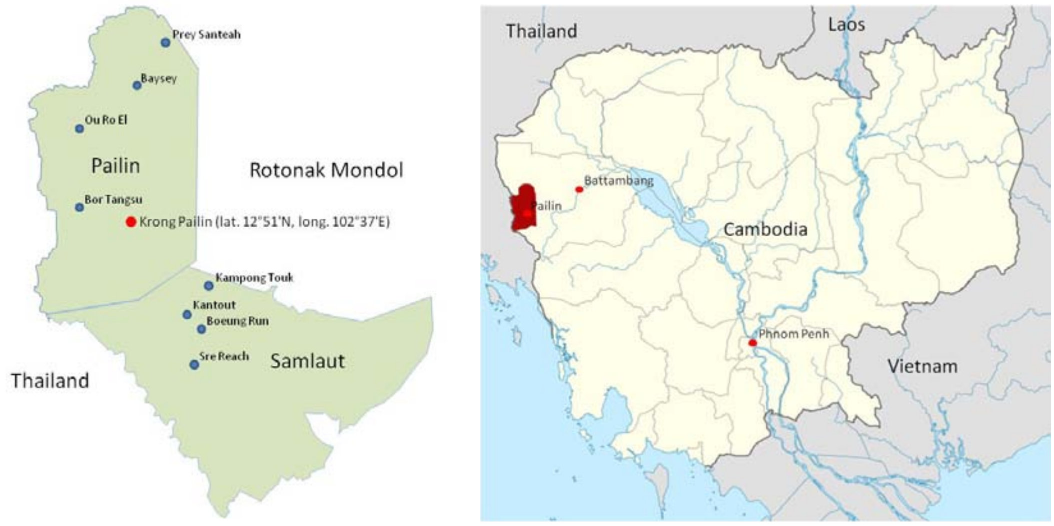

Figure 4. Location of experimental sites.

Experiments and demonstrations were carried out in village clusters: four in Pailin (Bor Tangsu, Ou Ro El, Baysey and Prey Santeah) and four in Samlout (Sre Reach, Boeung Run, Kantout and Kampong Touk) (Figure 4).

The region has a monsoonal climate with a rainy season between May and October and a distinct dry season between November and March. The average annual rainfall at Battambang (1982-2008) is 1,263 mm (Figure 5). Rainfall steadily increases from February through to a peak in October. The average temperature at Battambang is 28.0^{o}C. April is the warmest month with an average maximum temperature of 36.1^{o}C and December the coolest with an average minimum temperature of 19.7^{o}C. Average relative humidity at Battambang is 80% rising to 86% in September-October and falling to 72% in March.

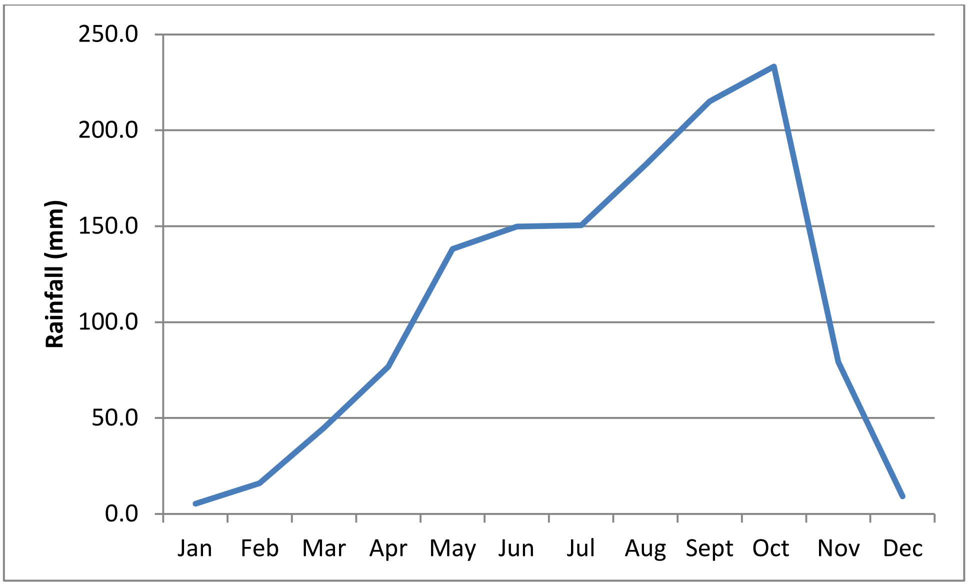

Figure 5. Average monthly rainfall at Battambang (1982 – 2008).

The period from March to June is known at the early wet season (EWS) and the period from July to October, the main wet season (MWS). The main crops grown in the EWS include sesame, mungbean, and maize, while the main crops grown in the MWS are maize and soybean.

The main soils where upland crops are grown in Samlout and Pailin are known as Kampong Siem (Vertosol) and Labanseak (Ferosol) (White *et al*. (1997). The Kampong Siem soils are black self-mulching clays and the Labanseak are red friable clay-loams.

Martin *et al.* (2005) reported analyses for 25 ferosols and 25 vertosols in adjacent Ratanal Mondul district (Table 1). On average, the vertosols are higher in organic carbon and total nitrogen and have higher pH than the ferosols (Table 1).

Table 1. Organic carbon, total nitrogen and pH of ferosols and vertosols in Ratanak Mondul district Battambang.

Soil	Organic carbon (%)	Total nitrogen (%)	pH (water)
Ferosol	2.07 (1.36-3.81)	0.176 (0.115-0.258)	5.5 (5.0-6.0)
Vertosol	2.46 (1.45-4.50)	0.181 (0.105-0.342)	6.5 (5.0-8.0)

Experiments and demonstrations in 2007

Preliminary on-farm experiments and demonstrations were carried out during the MWS in Samlout in 2007. The design and layout of the demonstrations was described by Martin and Belfield (2007). The demonstrations included evaluation of soybean varieties (3 sites) and improved practices for soybean (2 sites), mungbean (Boeung Run, Samlout, Sre Reach), peanut (1 site) and maize (2 sites). The sites were sown between the 18th and 27th July.

Seven soybean varieties were tested including B3039 (seed kept by farmer), B3039 (seed from Bos Knor research station Kampong Cham), Asca (CIRAD), DT84 (Bos Knor), Chang Mai 60 (Thailand), Chakkrabandhu#1 (Thailand) and an un-named variety (Pailin market).

Demonstration trials for improved practices were not replicated but repeated in 2-3 different villages to maximise the exposure to farmers. Individual plots were 7*10m. There were six treatments in the maize demonstration and seven for the legumes (Table 2).

Table 2. Treatments applied for demonstration of improved practices.

Maize	Soybean, Mungbean, Peanut
Farmer Practice (FP)	Farmer Practice (FP)
Improved Variety (IV)	Improved Variety (IV)
IV + Basal Fertiliser (BF)	IV + Basal Fertiliser (BF)
IV + BF + Nitrogen Topdressing (NT)	IV + BF + Nitrogen Topdressing (NT)
IV + BF + NT + Zero Tillage (ZT)	IV + BF + Rhizobium Inoculation (RI)
IV + BF + NT + ZT + Straw Mulching (SM).	IV + BF + RI + Zero Tillage (ZT)
	IV + BF + RI + ZT + Straw Mulching (SM).

The experimental fields were ploughed a first time to a depth of 15–20 cm deep, followed by a second ploughing to a depth of 8–10 cm and harrowed just before planting. Row spacing for mungbean, peanut and soybean was 40 cm with 30 cm between hills. Mungbean and soybean were thinned to three plants per hill and maize and peanut to two plants per hill at approximately ten days after sowing. Maize was planted in 70 cm rows with 50 cm between hills.

A basal fertiliser application of DAP (18:20 N:P) was applied at 100 kg/ha. Fertiliser was applied in the seed furrow or seed hole at planting and placed below the seed. The rate of urea applied in demonstrations of improved practices was 87 kg/ha to achieve a rate of 40 kg N/ha.

Data recorded for the soybean variety evaluation included germination (%), emergence (%), days to maturity, grain yield (t/ha) and 100 seed weight (g). Balanced analyses of variance were carried for emergence, grain yield and days to maturity using IRRISTAT v5 (IRRI, 1998-2005) with sites as replicates.

Experiments and demonstrations in 2008

Nitrogen nutrition of maize. Experiments were carried out in Samlout and Pailin in 2008 to determine the effect of topdressing with urea on the yield of maize. The experiments failed at Samlout but were successfully completed at four sites in Pailin. The rates of urea applied were 25, 50, 75 and 100 kg/ha (11.5, 23.0, 34.5 and 46 kg N/ha). There were three replicates of each application rate at each site. A balanced analysis of variance, combined across sites, was carried out for grain yield using IRRISTAT v5 (IRRI, 1998-2005).

Rhizobium inoculation of legumes in 2008. Rhizobium inoculation of mungbean, peanut and soybean was compared to application of urea at 87 kg/ha (40 kg N/ha) and untreated control at two sites in Samlout district (Kantout) and four in Pailin (Bor Tangsu, Ou Ro El, Spung and Prey Santeah). Nodulaid™ peat-based rhizobium inoculant was added to the seed immediately before planting at the rate of 5 g in 15 ml water per kg of seed. Rhizobium strains used were Group I for mungbean, Group P for Peanut and Group H for soybean. A balanced analysis of variance, combined across sites, was carried out for grain yield using IRRISTAT v5 (IRRI, 1998-2005).

Soybean varietal evaluation. Thirty soybean varieties were obtained from a collection previously evaluated in Kampong Cham province (Stephane Boulakia pers. comm.). The varieties were predominantly of Brazilian origin and included: 98 C 81,Asca, B3039, Carrera, CD 204, CD 211, CD 217, Conquista, DT 84, Emgopa 316, Flora, Jatai, Kaiabi, Monsoy 6101, Monsoy 8550, Monsoy 8866, Monsoy 8870, Monsoy 9030, Mutum, Nina, Perdiz, Pintado, Rosa, Sambaiba, Santa Cruz, Sbank Lauk, Siriema, Splendor, Tabarana and Tucunare. The experiment was unreplicated and not analysed.

Experiments and demonstrations in 2009

Nitrogen nutrition of maize. Experiments were carried out at Samlout only in 2009. The plots were 2.6 * 6.0 m with 70 cm rows and plants spaced at 25 cm within rows (1 plant per hill). There were ten treatments in a factorial arrangement of urea applied at sowing (nil and 50 kg urea/ha (23 kg N/ha) and urea topdressed 10-20 days after sowing at rates of nil, 50, 100, 200 and 400 kg/ha (nil, 23, 46, 92 184 kg N/ha). The experiment was laid out as a randomised complete block with three replicates. A combined balanced analysis of variance was carried out across sites for grain yield using IRRISTAT v5 (IRRI, 1998-2005). In 2009 at Pailin, the field program focussed on on-farm demonstration involving comparison of farmer practice with improved practice on 10 farms. Improved practices included:

- Reducing the seeding rate from 18 – 20 kg/ha (60*40 cm seed spacing) to 66 kg/ha (70*50 cm spacing);
- Planting of certified hybrid seed such as Pioneer 30 K 95, 30 B 80, or CP 888;
- Improved weed management including more hand-weeding and application of herbicide.

Rhizobium inoculation of legumes. Experiments were carried out at Samlout only in 2009. The plots were 20.*6.0 m with 40 cm rows, 30 cm spacing between hills and three seeds per hill. The experiment was of split-plot design with species (mungbean, peanut and soybean) as main plots and three rhizobium treatments (nil, plus rhizobium inoculation and urea at 40 kg N/ha) as sub-plots.

Experiments and demonstrations in 2010

Field experiments and demonstrations were carried out at Samlout during the main wet season (MWS) 2010 to investigate the following:

1. Maize- legume intercropping systems (3 sites);
2. Herbicide options for weed control in soybean (2 sites);
3. Herbicide options for weed control in maize (2 sites);

4. Timing of atrazine applications in maize (3 sites);
5. Demonstration of best- practice for growing maize (3 sites);
6. Demonstration of rhizobium liquid inoculants (28 sites).

Below average rainfall was received in Samlout during 2010. The average monthly main wet season rainfall for five experimental sites in Samlaut was 431 mm. This was only 60% of the average for 2006- 09 at the MJP Field Headquarters. MWS rainfall also varied between sites from 426 mm at Sre Reach to 500 mm at Kantout. The main difference between the 2010 MWS rainfall and the long- term average at MJP FHQ was the lack of rain in August particularly at Kampong Touk.

Experiments and demonstrations in 2011

Field activities conducted in 2011 included:

1. Evaluation of maize hybrids.
2. Benchmarking farmer maize fields to identify factors associated with crop yields.
3. Gross margin survey of cassava, maize and soybean fields in collaboration with with the University of Battambang.
4. Economics of weed management in Pailin.

7.1.2 Results

Results in 2008-2009

Maize

In the MWS 2008, maize experiments were successfully completed at four sites in Pailin. The average kernel yields differed significantly between sites and average site yields ranged from 4.44 to 8.36 t/ha (Table 3). The effect of urea application was significant with kernel yields increasing up to the rate of 34.5 kg N/ha, a 14% increase compared to applications of 11.5 kg N/ha (Table 3).

Table 3. Effect of urea topdressing on kernel yield of maize at four sites in Pailin in 2008.

Rate (kg N/ha)	Bor Tangsu	Ou Ro El	Spung	Prey Santeah	Average*
11.5	6.84	7.78	5.59	4.34	6.14
23.0	7.64	8.20	5.86	4.06	6.44
34.5	7.33	8.83	6.84	4.98	7.00
46.0	7.08	8.61	6.48	4.38	6.64
Average	7.23	8.36	6.19	4.44	6.55

*SE (n=12) = 0.14, 5% LSD = 0.41, CV = 7.5%.

In 2009, nitrogen fertiliser experiments were carried out at four sites in Samlout. The design included five topdressing rates (Table 4) with and without a basal dressing of 50 kg N/ha. The average kernel yield across the sites was 8.00 t/ha. Basal application of urea increased kernel yield by 5% from 7.80 to 8.20 t/ha.

Table 4. Effect of urea topdressing on kernel yield of maize at four sites in Samlout in 2009.

N (kg/ha)	Kampong Touk	Kantout	Samlout	Sre Reach	Average*
0	6.26	8.04	6.89	5.89	6.77
23	7.62	8.85	8.29	6.33	7.77
46	7.65	8.24	9.50	6.94	8.08
92	8.22	8.61	10.42	6.99	8.56
184	9.16	9.34	10.05	6.71	8.81
Average	7.78	8.62	9.03	6.57	8.00

*SE (n = 6) = 0.37, 5%LSD = 1.04, CV = 11.3%.

Maize responded significantly to topdressings of urea up to 184 kg N/ha. However, the responses also varied significantly between sites. The largest responses were obtained at the Samlout site with a maximum yield of 10.42 t/ha being obtained with application of urea at a rate of 92 kg N/ha.

An economic analysis of Urea application was done on the average yield for the Samlout experiments (Table 4) where 2012 prices and costs were used. The maize price was assumed to be $165/t, the cost of Urea $0.63/kg and application cost of $56.25/ha. This analysis shows that it is economically feasible to apply Urea to maize at up to 200 kg/ha. Currently farmers are reluctant to apply fertilizer for several possible reasons:

1. Cost of credit to buy the fertilizer;
2. Believe their soil is still gigh fertility;
3. Believe that fertilizer harms soil microorganisms (myth promoted by NGO?).

Table 5. Economic analysis of Urea application to maize in Samlout.

Urea (kg/ha)	Yield (t/ha)	Income	Variable Costs	Gross Margin	Marginal Costs	Marginal GM	MRR
0	6.77	$1,117.05	$563.80	$553.25			
50	7.77	$1,282.05	$651.30	$630.75	87.5	77.5	89%
100	8.08	$1,333.20	$682.55	$650.65	118.75	97.4	82%
200	8.56	$1,412.40	$745.05	$667.35	181.25	114.1	27%
400	8.81	$1,453.65	$870.05	$583.60	306.25	30.35	-67%

Improved practice on the 10 demonstration farms at Pailin resulted in highly significant (84%) higher average yield of 6.76 t/ha compared to 3.67 t/ha for farmer practice.

Soybean

Varietal evaluation. Seven soybean varieties were evaluated at three sites in Samlout in the MWS of 2007 (Table 6). The average yield was 2.06 t/ha. Yields varied significantly between sites, ranging from 1.65 through 1.96 to 2.56 t/ha. The local variety and un-certified seed obtained from the Pailin market gave the lowest yields. Only Asca gave significantly higher yields than the farmer's seed (Table 6). B3039, the same variety as farmer's seed was the second highest yielding variety. Asca is a selection from B3039 (Boulakia pers. comm.).

Table 6. Evaluation of soybean varieties at Samlout in the MWS 2007.

Variety	Local	Market	Chak#1	DT84	CM60	B3039	Asca	5% lsd
Yield (t/ha)[1]	1.70	1.52	2.10	2.10	2.16	2.27	2.53	0.59
Emergence (%)	-	44	70	71	76	94	93	21.2
Days to maturity	-	93	106	87	94	92	93	5.8

Poor seed quality, especially of the uncertified seed obtained from the Pailin market resulted in seedling emergence as low as 44% and may have resulted in an underestimation of yield for some varieties (Table 6). DT84 matured in 87 days and Chakkrabandhu#1 in 106 days. All other varieties matured in 92-94 days (Table 6).

Improved practices did not significantly affect the yields of mungbean, soybean or peanut at Samlout in 2007. However, nitrogen topdressing increased soybean yield by 6% and rhizobium inoculation by 11%.

In 2008, 30 soybean varieties (Boulakia pers. comm.) were evaluated at Samlout. The average yield was 2.02 t/ha. None of the varieties exceeded the yield of B3039, the variety currently used by farmers in the area.

In 2009, it was planned to evaluate the following 10 soybean varieties:

- 72LH-08, KKU-30, KKU-35, Sor chor and V-1069 (obtained from Thailand by Mr Ung Sopheap);
- ASCA, B3039, CD-204 and DT84 (the best of the Boulakia collection evaluated in 2008);
- Chang Mai 60 obtained from Pailin market.

The experiment failed completely in Samlout and in Pailin analysable data were obtained for five varieties only (Table 7). The other five varieties failed due to poor seed quality. The highest yielding variety was 72LH-08 from Thailand.

Table 7. Evaluation of soybean varieties at Pailin in the MWS 2009.

Variety	Sor Chor	ASCA	V-1069	KKU-35	72LH-08
Yield (t/ha)	1.11	1.11	1.19	1.36	1.60

SE = 0.10 (n = 3), 5%LSD = 0.34, CV = 14.1%.

Rhizobium inoculation. In 2008, the soybean treatments in Pailin failed due to poor quality seed. At Samlout, rhizobium inoculation did not significantly increase soybean yield. The average yields at the sites were 2.69 and 1.06 t/ha respectively. At the lower yielding site, urea application increased the yield from 0.89 to 1.39 t/ha. This suggests that the rhizobium inoculation might have failed at this site.

In 2009, rhizobium inoculation of soybean was compared to application of urea (40 kg N/ha) at four sites in Samlout district: Kampong Touk, Kantout, Samlout and Sre Reach (Table 8). There was no significant response in soybean yield to either rhizobium inoculation or application of urea. The yields varied significantly between sites, ranging from 1.43 to 2.60 t/ha.

Table 8. Soybean response to rhizobium inoculation and application of urea at Samlout in the MWS 2009.

Treatment	Kampong Touk	Kantout	Samlout	Sre Reach	Average
Nil	1.40	1.80	2.82	1.97	2.00
Plus rhizobium	1.44	1.82	2.75	2.00	2.00
Plus urea	1.45	1.76	2.21	2.24	1.91
Average*	1.43	1.79	2.60	2.07	1.97

SE = 0.09 (n = 9), 5%LSD = 0.26, CV = 13.4%.

Soybean yields varied widely between experiments carried out between 2007 and 2009 at Samlout with occasional treatments approaching the 3.00 t/ha expected yield potential. Most experiments with soybean failed at Pailin due to poor seed quality.

Peanut

Table 9. Evaluation of peanut varieties for disease resistance, drought tolerance and short duration at Samlout in 2008.

	Average yield (t/ha)	Local variety (t/ha)	Highest yield (t/ha)	Potential increase (%)
Foliar disease	3.68	3.41	5.56	63
Drought	4.69	5.19	6.31	22
Short duration	4.82	6.19	6.19	0
Average	4.40	4.93	6.02	-

Trial kits were obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to evaluate peanut varieties for foliar disease resistance, drought resistance and short duration. There were 15 varieties in each kit and these were compared with the local variety in 2008. Three ICRISAT varieties were significantly better than local variety for resistance to foliar disease but no ICRISAT short duration or drought tolerance varieties were significantly better than the local variety. The best variety for foliar disease resistance yielded 63% more than the local variety and the best variety for drought resistance yielded 22% more than local variety (Table 9). Therefore further varietal evaluation for peanut for disease and drought tolerance could be justified.

In 2008, rhizobium inoculation of peanut was compared to application of urea (40 kg N/ha) at two sites in Samlout district (Kantout) and four in Pailin (Bor Tangsu, Ou Ro El, Spung, Prey Santeah) (Table 10). Rhizobium inoculation significantly increased average yield of peanut by 20% compared to an average increase of 10% for urea.

Table 10. Peanut response to rhizobium inoculation and application of urea at Samlout and Pailin in MWS 2008.

Treatment	Kantout	Kantout	Bor Tangsu	Ou Ro El	Spung	Prey Santeah	Average*
Nil	1.96	4.76	3.63	5.28	3.20	4.00	3.80
Plus rhizobium	3.29	5.64	3.93	6.24	3.78	4.64	4.59
Plus urea	2.67	5.78	2.72	6.72	3.20	4.16	4.21
Average	2.64	5.39	3.43	6.08	3.39	4.27	4.20

*SE = 0.18 (n = 6), 5% LSD = 0.57, CV = 10.6%.

In 2009, results were obtained for peanut rhizobium experiments at three locations in Samlout: Kampong Touk, Kantout and Sre Reach. Average yields were 0.54, 0.75 and 0.94 t/ha at Kampong Touk, Kantout and Sre Reach respectively. The low yields were attributed to poor quality seed and poor establishment. There was no significant response to rhizobium inoculation or to urea.

The yield potential for peanut in Battambang/Pailin is estimated at 6 t/ha while the regional average is 1.63 t/ha. The average yields in trials ranged from 1.96 to 6.72 t/ha in 2008. Yields of up to 6.0 t/ha therefore appear to be achievable with improved varieties and rhizobium inoculation.

Mungbean

In 2008, rhizobium inoculation of mungbean was compared to application of urea (40 kg N/ha) at two sites in Samlout district (Kantout) and four in Pailin (Bor Tangsu, Ou Ro El, Spung, Prey Santeah) (Table 11). Rhizobium inoculation significantly increased average yield of mungbean by 29% compared to an average increase of 9% for urea which was not significantly different from the nil treatment. Mungbean yields averaged 1.50 t/ha but varied significantly between sites with one site yielding well over the estimated potential for the region of 2.00 t/ha.

Table 11. Mungbean response to rhizobium inoculation and application of urea at Samlout and Pailin in MWS 2008.

Treatment	Kantout	Kantout	Bor Tangsu	Ou Ro El	Spung	Prey Santeah	Average*
Nil	2.06	2.44	0.99	0.83	0.07	1.56	1.33
Plus rhizobium	2.08	3.22	1.06	1.08	0.77	2.12	1.72
Plus urea	1.83	2.36	1.00	0.97	0.69	1.84	1.45
Average	1.99	2.68	1.01	0.96	0.51	1.84	1.50

*SE = 0.13 (n = 6), 5% LSD = 0.28, CV = 14.6%.

In 2009, results were obtained for mungbean rhizobium experiments at four locations: Kampong Touk, Kantout, Samlout and Sre Reach. Yields did not differ significantly between sites and the average yield was 1.75 t/ha. Application of urea significantly increased yield by 22% from 1.63 to 1.99 t/ha. It is suspected that the rhizobium inoculant failed as a result of long-term storage at room temperature.

In summary, mungbean yields in excess of 2 t/ha can be achieved with good agronomic practices and inoculation with rhizobium.

7.1.3 Discussion of 2008-2009 results

Nitrogen nutrition of maize

The response to application of nitrogenous fertiliser varied between sites but the lowest yielding sites did not give the largest responses to urea. This indicates that other factors such as soil constraints or weed management might have been involved. Overall the results of experiments and demonstrations suggested that the expected yield potential of 10 t/ha for maize (on cob) in Battambang/Pailin is achievable by farmers if they adopt improved practices such as: using fresh certified hybrid seed; implementing good agronomic practice including correct seeding rate; prevention of weed competition with the crop; and application of nitrogenous fertiliser if required.

On-farm demonstrations in Pailin in 2009 showed that improved practices could increase maize yield from 3.67 to 6.76 t/ha. A common farmer practice in Pailin and Samlout is to replant the F2 seed of hybrid maize varieties such as CP888. This could be a significant cause of reduced yields as the yield reduction from replanting single-cross hybrids such as CP888 could result in yield reductions of 35-40% (Morris 1998). Further work is required to separate the factors in on-farm demonstrations. This could be achieved by adopting the demonstration design shown in Table 3 where the improved practices are added step-wise.

Potential to increase yields of legume crops

Soybean. Soybean yields varied widely between experiments carried out between 2007 and 2009 at Samlout with occasional treatments approaching the 3.00 t/ha expected yield potential. Most experiments with soybean failed at Pailin due to poor seed quality. It is suggested that further work is required to overcome constraints to increased soybean yields. Results of variety evaluation experiments have been inconclusive and further work is required to evaluate varieties without the confounding effect of variable and poor seed quality. The loss of soybean seed viability in the tropics has been shown to be directly related to seed moisture content (Ndimande *et al.* 1981). The average temperature and humidity at Battambang is 28^{o}C and 80% respectively and it is therefore likely that soybean seed stored under these conditions will quickly lose viability.

Peanut. The yield potential for peanut in Battambang/Pailin is estimated at 6 t/ha while the regional average is 1.63 t/ha. The average yields in trials ranged from 1.96 to 6.72 t/ha in 2008. Yields of up to 6.0 t/ha therefore appear to be achievable with improved varieties and rhizobium inoculation. Further evaluation of ICRISAT peanut varieties for disease and drought tolerance could be justified. Gross margins of more than $2,500/ha have been recorded in these experiments (Fiona Scott pers. comm.). Despite this the area of peanuts grown in the region is very small. Farmers do not grow peanut in large areas because of the high cost of production and difficulty with harvest and drying. The price for peanut at Pailin in August 2010 was $1,500/t so therefore efforts to overcome the constraints to production of peanut appear to be justified.

Mungbean. The experiments and demonstrations showed that mungbean yields in excess of 2 t/ha can be achieved with good agronomic practices and inoculation with rhizobium. Improved varieties of mungbean were evaluated in a previous study (Pin Tara pers. comm.). The most promising variety was ATF 3944 which was included in on-farm demonstrations in Kampong Cham and Battambang in the MWS 2006 and EWS 2007. The average yield of ATF 3944 was 0.795 t/ha which was significantly greater ($p<0.01$) than that of the local variety (0.481 t/ha). Ouk *et al*. (2009) also obtained significantly higher yields for ATF 3944 and this variety will now be released for commercial production in Cambodia.

Rhizobium inoculation of legumes

Pin *et al.* (2009) reported on the results of a series of 28 experiments carried out in Kampong Cham and Battambang provinces where rhizobium inoculation increased average mungbean yield by 7%, peanut by 15% and soybean by 12%. The results of the present study were quite different. There were no significant responses by soybean to inoculation. Good responses were obtained for mungbean (29%) and peanut (20%) in 2008 but no responses were recorded in 2009. There could be several reasons for the lack of response to rhizobium inoculation in this study despite the presence of apparently healthy root nodules. High levels of soil nitrate are known to inhibit N_2 fixation by soybean (Herridge and Betts, 1988) and this could have been a factor on the recently cleared and fertile soils at Samlout and Pailin. It is also known that the presence of resident populations of ineffective rhizobia can reduce the successful nodulation by superior rhizobial strains for soybean (Devine 1984).

Results in 2010

Maize-legume intercropping systems

MBILI, a successful intercropping configuration in Africa, was compared to conventional intercropping for maize and legumes (mungbean, peanut and soybean). In MBILI, maize rows are spaced as 50 cm pairs 100 cm apart with two rows of legume at 33.3 cm row spacing in the resultant wider inter- row space. Previous experiments in Kampong Cham and Ratanak Mondol in ASEM/200/109 showed that the legumes could not compete with the maize. It was thought that the MBILI configuration would allow more light to reach the legumes and improve the yield so we conducted further intercropping experiments to test the idea under local conditions.

Maize cob yields ranged from 4.484 t/ha at Sre Reach to 8.398 at Kantout. Legume kernel yields were very low: mungbean (0.160 t/ha); peanut (0.262 t/ha; soybean (0.268 t/ha). The MBILI configuration did not increase the legume yields compared to conventional intercrop and it was concluded that intercropping maize and legumes is not feasible in Samlout. The main reasons were:

1. The legume crops were not able to compete with the maize for light;
2. Intercropping appeared to increase the severity of insect pest attack on the legumes;
3. Intercropping requires more time and labour to control weeds and to harvest the crop;
4. The selective herbicides farmers now use to control weeds in maize and legume crops cannot be used in the intercrop system.

Herbicide options for weed control in soybean

As a result of the rising cost of labour, more than 80% of farmers now use selective herbicides for in-crop weed control in soybean. Since farmers have been using the herbicides at a wide range of application times, it was decided to carry out an experiment to determine the effect of late application timing on the efficacy of the herbicides for weed control and for damage to the crop.

Farmers typically use a tank mix of Fomesafen and Quizalofop for post- emergence selective weed control in soybean. Fomesafen controls broadleaved weeds and Quizalofop controls grass weeds. The soybean kernel yield at Kampong Touk was 3.014 t/ha and 2.478 t/ha at Samlout. However, none of the herbicide- hand weeding combinations significantly increased soybean yield compared to the non- weeded control. The ability of soybean to compete strongly with weeds could be a reason for this. It appears that the farmer practice of delayed application of herbicide has no negative impact on soybean yield. Further experiments are justified to determine the critical weed thresholds and effect of time of removal of weeds on soybean yields. If no labour for hand weeding was available, in this instance, applying herbicide instead was no guarantee of higher profitability. Further work is required; including weed population observations, to ascertain if this would be the case. Soybean is capable of competing well with weeds, however, there may be an economic threshold of weed population in soybean where it would be worth applying a herbicide instead of taking no in- crop weed control measures.

Atrazine and 2,4D options for weed control in maize

Atrazine and 2,4- D are the only two herbicides currently available for selective weed control in maize in the region. Atrazine is more effective for the control of grass weeds and 2,4- D is more effective for the control of broad- leaved weeds. Therefore the two herbicides are normally applied together as a tank mixture for weed control in maize. We have observed that farmers might need some help in determining the appropriate use and timing of application of herbicides in maize. In particular, we have observed damage to maize from late application of 2,4- D. Maize cob yields ranged from 4.294 to 10.339 t/ha at sites in this experiment. Maize yield with nil weed control was 4.715 t/ha. The highest yielding treatments were atrazine followed by nil hand weeding (5.289 t/ha) and atrazine plus 2,4- D followed by nil hand weeding (5.355 t/ha). This finding supports the farmer practice of using selective herbicides to replace hand- weeding in maize. Of all the hand weeding options, hand weeding once early with no other weed control measure was the most profitable.

Rate and timing of atrazine for weed control in maize

According to the label, post- planting, post emergence atrazine 80% should be applied at 1.5 kg/ha at the 2- 3 leaf stage of maize, preferably after secondary root development has been initiated. Therefore the ideal time for application of would be at the 3 leaf stage of maize. Farmers often apply atrazine after this stage and this experiment was designed to determine if late application reduced the effectiveness of the herbicide for weed control or caused damage to the crop. The average maize cob yield in the maize atrazine experiment was 2.856 t/ha but there were no significant differences between the atrazine treatments. Therefore the farmer practice of late application of atrazine did not seem to adversely affect maize yield. The economic analysis showed that the timing of atrazine application had no impact on the profitability, and based on this trial, farmers would be able to choose from any of the six application options. Most farmers ranked split applications of atrazine as the best treatment but some would not adopt because of the extra costs of doing this.

Demonstration of improved practices for growing maize

Farmers in Samlout generally use hybrid maize varieties such as CP 888. However, they plant maize at higher than recommended plant populations, apply herbicides later than label recommendations and use no fertiliser. This demonstration was designed to test the effect of sequential addition of improved practices for improvement of maize yield and profitability. The combined improved practice treatments gave significantly higher maize cob yields compared to farmer practice. Also the full improved practice package gave the highest cob yield and was significantly better than the farmer practice. The improved practice maize yield (7.552 t/ha) was significantly greater than farmer - practice (4.677 t/ha). All of the improved practices were significantly more profitable than typical farmer practice. However, farmers gave the full improved practice treatment the lowest score because it required higher input costs compared to other treatments. Moreover, farmers think that their soil still has high fertility; so, they did not need to apply fertiliser yet. These conflicting results suggest that there is need for further demonstrations to convince farmers of the advantages of adopting improved practices for maize production.

Demonstration of rhizobium liquid inoculants

Previous research has demonstrated that rhizobial inoculation can replace nitrogen fertiliser for mungbean, peanut and soybean at a much reduced cost and reduced environmental impact. Pin et al (2009) obtained significant increases in grain yields of mungbean (7%), peanut (15%) and soybean (12%) were obtained by rhizobial inoculation and the response was equal to (soybean) or better than (mungbean, peanut) application of 40 kg N/ha. Inoculation increased the number of nodules per plant by 23% for mungbean, 39% for peanut and 66% for soybean. Rhizobial inoculation was included in on- farm demonstrations of improved technologies in collaboration with Provincial Department of Agriculture staff as well as non- government organisations. Early results indicate that farmers are interested in inoculation but lack understanding and the ability to adopt the technology. The purpose of this demonstration was to give farmers "hands- on" experience and practice in rhizobial inoculation. Rhizobium inoculation increased the average soybean kernel yield by 15% to 3.379 t/ha and the kernel yield of peanut by 12% to 3.920 t/ha. These increases in yield did not translate to a significant increase in profit. Despite the small increases, farmers have indicated they would use inoculants if they were available. There is a need to explore options for the supply of rhizobium inoculants to farmers in Cambodia.

Survey of farmer Gross Margins for maize, soybean and peanut

Gross Margin data were collected from farmers for 20 maize, 15 soybean and 15 peanut crops in Samlout after the MWS 2010. The purpose of the survey was to gain a better understanding of the determinants of profitability for maize and the alternative crops soybean and peanut. Farmers' maize yields averaged 5.69 t/ha with a range from 3.2 to 12.5 t/ha. The average yield for soybean was 1.98 t/ha ranging from 1.04 to 3.0 t/ha and for peanut 3.0 t/ha ranging from 1.04 to 6.25 t/ha. The best fields equaled or exceeded the predicted yield potentials for the region. However, the minimum yields recorded were only 38% of the maximum for maize, 35% for soybean and 17% for peanut. The average variable cost for maize and soybean was $330/ha and $507/ha for peanut. Cost of seed and harvest costs were the main reasons for the higher variable cost for peanut. Maize variable costs ranged from $156/ha to $448.ha, soybean from $240/ha to $440/ha and peanut $391 to $675/ha. The costs of inputs varied widely according to the time of purchase and whether or not credit was required. The average gross margins were: maize $570/ha ranging from $216/ha to $1,583/ha; soybean $644/ha ranging from $151 to $1,185; and peanut $1,566 ranging from $376 to $3,709/ha. Despite the very high gross margins, farmers are reluctant to grow peanuts because of the high cost of inputs and the high demand for labour.

Conclusions and recommendations 2010

1. With improved practices, crop yields are significantly higher than farmer practice. For example in 2010, improved practice maize yield was 7.6 t/ha compared to 4.7 t/ha for farmer practice. In the gross margin survey, average farm yields for maize (46%), soybean (66%) and peanut (48%) were also well below the highest yields that were achieved on- farm. It is recommended that yield gap analyses be carried out to identify the important yield determinants for maize, mungbean, soybean, and peanut. Soil fertility, weed management, plant population and variety are among the factors that can be managed to increase crop yields.
2. The increasing cost and declining availability of labour has resulted in a dramatic uptake of mechanization for cultivation and sowing and the adoption of selective in- crop herbicides to replace hand weeding. It is expected that mechanization of maize harvesting will be the next development to reduce the reliance on hand labour. Mechanization of the maize harvest will bring opportunities for no- tillage crop production and the harvesting of maize stover for stock feed. It is recommended that a program of research be established to identify the benefits of conserving maize stover for improved soil management and harvesting for inclusion in livestock rations.
3. Availability, cost and quality of crop inputs (including the cost of credit) pose significant constraints to the adoption of alternative crops to maize. Examples of technologies and practices constrained by lack of input supplies include:
   a. Rhizobial inoculation. Rhizobial inoculation can increase the yields of legume crops (mungbean, peanut, soybean) by 10- 15%. Because of the low cost of the inoculum, these yield increases translate to a significant increase in profit. Farmers would readily adopt rhizobial inoculation if the inoculants were available. Options for inoculant supply are: (a) establishment of a rhizobium culture laboratory in Cambodia; (b) encouraging the private sector (eg silo

input suppliers) to import and provide short- term storage and distribution of inoculants to farmer clients.

b. Integrated Pest Management (IPM). As a result of project activities, farmers understand and recognize the value of IPM. However, lack of key inputs such as biological pesticides (eg Dipel) are preventing adoption. The supply of these inputs could be arranged through the supply chain or through Farmer Cooperatives.
c. Certified seed. Almost all farmers now plant hybrid maize seed such as CP888. However, about half the farmers purchase seed of the legume crops such as soybean and peanut. It is very difficult to obtain quality seed for soybean in particular. Even certified seed from Thailand can fail. The large- scale Silos currently provide hybrid maize seed to farmer clients on credit. A similar arrangement could be made for the appropriate storage and supply of quality soybean seed.

4. The gross margin for peanut ($1,566/ha) is almost three times that of maize. Despite this, farmers are reluctant to grow peanuts because of the high cost on inputs and the extra labour required at harvest. Another uncertainty is the availability of markets for expanded production of soybean and peanut. The current project collected a significant body of information on the maize value chain but not for the alternative crops such as soybean and peanut. A value chain and marketing analysis is required for alternative crops to maize such as soybean and peanut. This should also include the feasibility of local processing (eg soy milk, peanut butter) and organic production.

Results in 2011

Evaluation of maize hybrids

The number of maize hybrids available in NW Cambodia has increased dramatically in recent years and the purpose of this experiment was to assess the yield and quality of new hybrids compared to the existing hybrids. Twenty eight maize hybrids were evaluated at Samlout in 2011. These included currently available Thai hybrids from Charoen Pokphand (CP-888, CP-AAA and CP-QQQ), five hybrids from the MAFF breeding program, three hybrids from Advanta-Pacific, 10 hybrids from Dupont-Pioneer and seven hybrids from Seed Asia. With the exception of MAFF, all hybrids were from Thai breeding or seed production programs.

Table 12. Comparison of maize varieties at Samlout 2011.

Variety	Plant height (cm)	Cob height (cm)	100 seed weight	Leaf blight (1-5)*	Rust (1-5)	Grain yield (kg/ha)
CP-888	160	80	29.5	2.9	1.0	5785
Pio-30B80	172	80	35.0	2.0	1.3	6667
Pac-999-S	163	69	42.1	2.7	2.9	7181
SA-501	170	76	46.1	1.7	0.8	7386
Pio-4296	191	87	41.6	1.8	2.3	7905
Probability	**	**	**	**	**	**
5%LSD	14	7	8.8	0.7	0.9	1632

*5 = more disease.

Plot size was restricted by the small number of seeds available for the MAFF hybrids and as a result the experiment had a high coefficient of variation. Results for selected varieties are given in Table 12. The results show that there is significant potential for new varieties to out-yield the long-serving CP-888. The experiment experienced high disease pressure from Polysora Rust and Southern Corn Leaf Blight and varieties varied significantly in their tolerance of the two diseases. Advanta-Pacific 999S was relatively less resistant to both diseases. However, farmers gave 999S the highest ranking because of the large cob, good grain colour and small shank. Pioneer 30B80 and 4296 were down-graded by the farmers because of poor colour. These varieties have an open husk which exposes the grain to the weather (sprouting) and insect damage to the grain.

Soybean varietal evaluation

Five locally available soybean varieties were evaluated at Samlout in the MWS 2011 (Table 13). The final plant stand of the local variety was significantly greater than all other varieties and final plant stand for B-3039 was significantly lower.

Table 13. Soybean varietal evaluation at Samlout in 2011.

Variety	Final plants/m2	100 seed weight (g)	Kernel yield (kg/ha)
B-3039	8.6	31	1657
Sbang	9.9	18	1747
DT 84	9.7	29	1863
Local Variety	10.7	22	2283
Phka Sor	9.7	31	2327
5%LSD	1.0	3	488

The 100 seed weight for DT-84, Pkha Sor and B-3039 was significantly greater than for local variety and Sbang. The main advantage for the local variety appeared to be plant survival possibility due to resistance to disease.

Although the coefficient of variation in the experiment was high, it should be noted that the variety Pkha Sor (white flower) had the highest yield, large seed size and it also matured in 80 days compared to 95 for the local variety. This could be a significant advantage with regard to drought and seasonal moisture shortage and Pkha Sor warrants further trialling.

Peanut varietal evaluation 2011

Four public domain peanut varieties were introduced from Australia through the Cambodia plant quarantine process. The lines were obtained to determine the suitability of the Cambodian environment for the production of large-seeded specialty lines of peanut. Details of the varieties:

- *Streeton*. Streeton is a drought tolerant Virginia line produced by the Australian breeding program in the mid 90s. This is a very solid adaptable line and should do reasonably well in the Cambodian environment. It has a full season maturity (around 140 days in Queensland environment, but maybe <130 days in Cambodia).
- *Conder*. Conder is a high in-out irrigated Virginia line with very large kernel/pod produced by the Australian breeding program in the mid 90s. It is a full season maturity variety (around 145 days in Queensland environment, but maybe <130 in Cambodia).
- *NC-7*. NC-7 is an older N. Carolina Virginia line that did very well in Australia for many years. This is a public domain variety. It is a full season maturity variety (around 150 days in Queensland environment, but maybe <135 in Cambodia.
- *VB-97*. VB-97 is a mid season maturity line, with very large seed. A negative for this line is low kernel % (quite thick shell). Maturity is around 130 days in Kingaroy, so this variety might get through in around 120 days in Cambodia.

The Australian varieties (113 days) took longer to mature thn the local variety (91 days). The kernel yield for all four Australian varieties was significantly greater than the local variety (

Table 14). This was mainly due to the significantly larger kernel size as differences in plants/ha and pods per plant were not significant.

Table 14. Kernel yield and 100 seed weight of Peanut varieties at Samlout in 2011.

Variety	100 seed weight (g)	Kernel yield (kg/ha)
Local Variety	63	377
Streeton	73	908
NC-7	79	1136
Conder	107	1249
VB-97	84	1401
5% LSD	20	482

On-farm bench-marking of maize fields in Samlout and Pailin

A benchmarking survey was carried out in 58 farmers fields in Samlout in 2011. Measurements were taken of row spacing, plant spacing in the rows, total plant population, weed ground cover, disease, insect pests and crop yield components. There was a wide variation between fields for selected measurements (Table 15). Plant populations varied widely with the average of 61,255 plants/ha being below the recommended optimum of 72,000. The relationship between plant population and grain yield (Figure 6) also indicated that farmers' plant populations of around 60,000 plants / ha were below the optimimum which appeared to be between 70,000 and 80,000 plants / ha. Plant populations over 80,000/ha were associated with lower yields.

Table 15. Selected measurements in farmers' maize fields.

Row spacing (cm)	Plant spacing (m)	Plants/ha	Polysora rust (%)*	Southern Corn Leaf Blight (%)*	Weed ground cover (%)	Grain yield (t/ha)
250	143	19157	0	0	0	136
592	311	61255	12	46	27	4,684
1073	750	136364	80	100	100	14,447

*% loss of photosynthetic area.

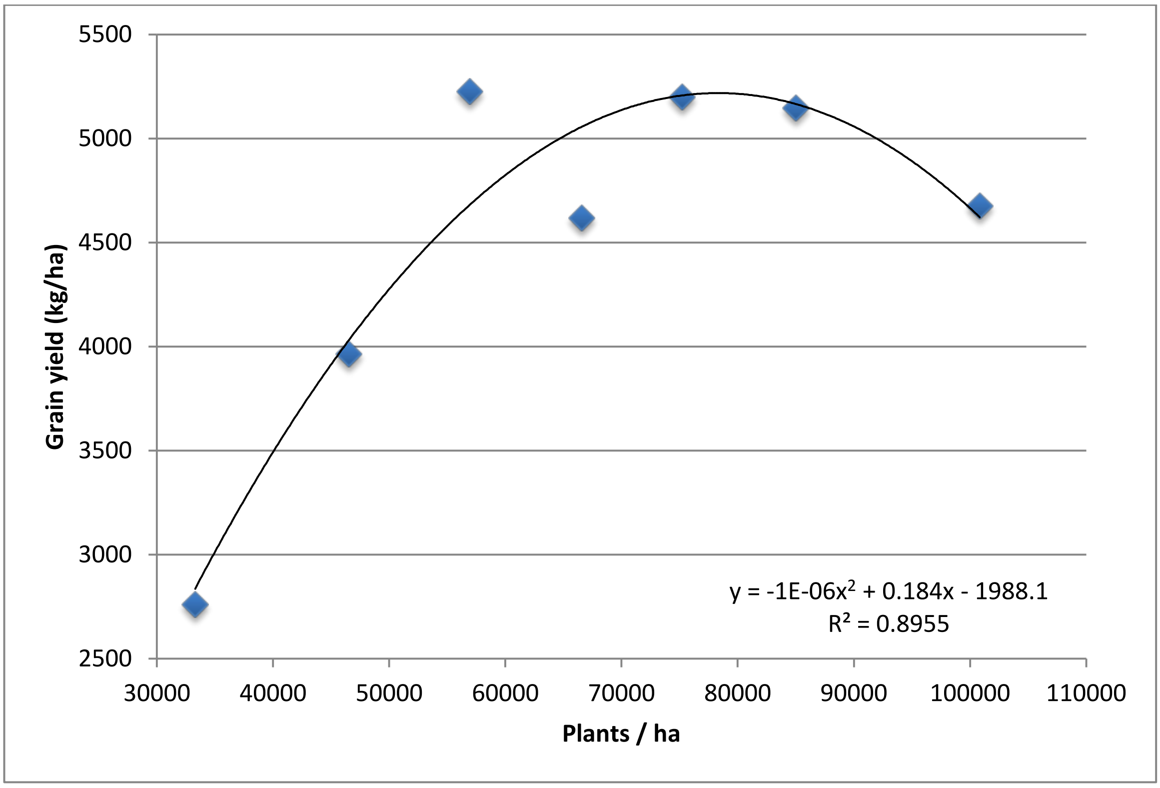

Figure 6. Relationship between plant population and grain yield in farmers fields.

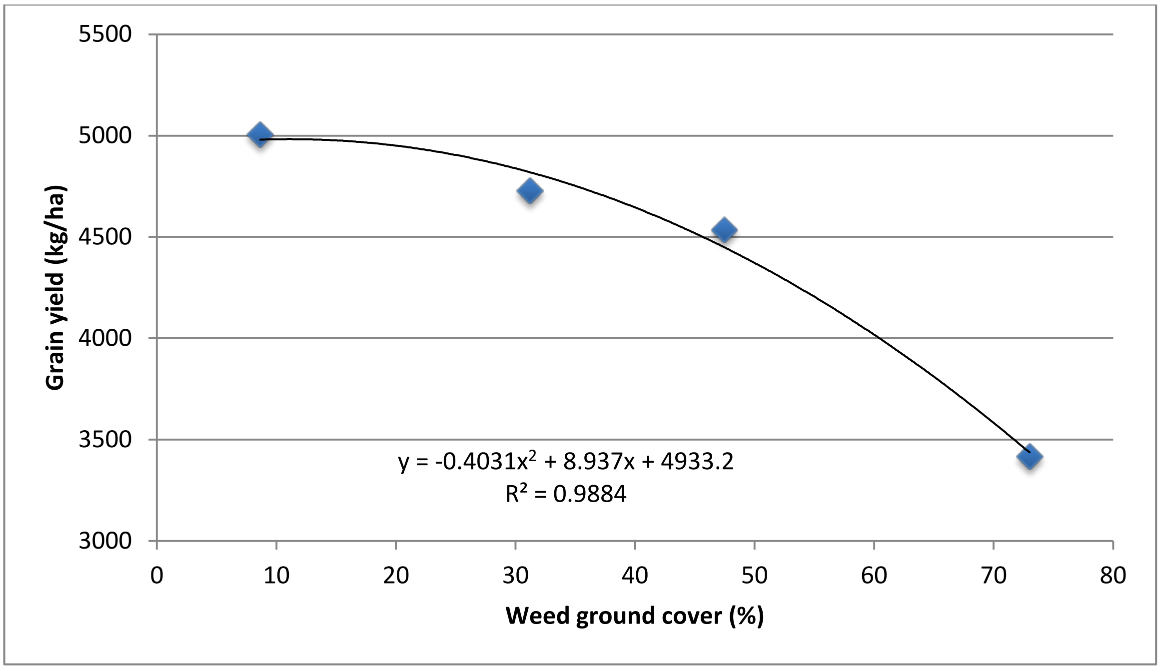

Figure 7. relationship between weed ground cover and maize yield in farmers' fields.

Poor weed management is considered to be one of the biggest threats to maize production in NW Cambodia. The field survey showed a strong negative relationship between weed ground cover and maize grain yield where weeds could reduce maize grain yields by more than 1,500 kg/ha (Figure 7). This problem is likely to get worse because the maize fields are being invaded by weeds not controlled by the herbicides in use – atrazine and 2,4-D. Shattercane (*Sorghum bicolor*) and Johnson grass (*S. halepense*) are not controlled by atrazine and are rapidly invading maize fields. Crop rotation and rotation of herbicides might provide a solution to the problem.

Farmer gross margin survey in collaboration with UBB

Gross margin surveys were calculated using farmers' data: maize (30 fields) and soybean (20 fields) in Samlout and on 23 cassava crops in Samlout and Pailin. Fourth year Farm Management students from the University of Battambang were trained to conduct the interviews.

Table 16. Gross margin sensitivity tables for cassava, maize, peanut and soybean.

Cassava fresh tuber*

Yield (kg/ha)	Price (US$/t)		
	32	64	95
20,000	$77	$711	$1,345
30,000	$115	**$1,066**	$2,017
40,000	$154	$1,422	$2,690

Maize on cob

Yield (kg/ha)	Price (US$/t)		
	127	159	191
3,000	$76	$171	$265
4,500	$280	**$437**	$595
7,000	$483	$704	$925

Peanut in shell

Yield (kg/ha)	Price (US$/t)		
	604	762	921
1,000	$123	$273	$423
2,000	$710	**$1,010**	$1,310
3,000	$1,297	$1,747	$2,197

Soybean kernel

Yield (kg/ha)	Price (US$/t)		
	400	450	500
1,000	$128	$178	$228
2,000	$468	**$568**	$668
3,000	$807	$957	$1,107

*Note when comparing gross margins, cassava is a one-year crop whereas the other crops can be grown two times per year.

Drawing from all of the gross margin data from the project has enabled the construction of gross margin sensitivity tables for cassava, maize, peanut and soybean (Table 16). These can also be made available in interactive spreadsheet format.

The cassava gross margin is highly sensitive to price compared to the other crops and the price is highly sensitive to fluctuations in supply and demand. So although from a production point of view cassava is seen by farmers as an easy crop to grow with respect to low inputs and low labour requirements, it is a high risk crop to grow with respect to price fluctuations.

Economics of weed management in Pailin

In 2011, project officer Mr Touch Van completed a survey of 88 households in Pailin to document weed management practices and to identify the social, economic and environmental constraints to the adoption of better weed management practices. This survey formed the thesis component of Mr Touch's Master's studies at the Royal University of Agriculture.

Data were collected from maize growers in six villages in Boryakha Commune in Pailin. A total of 88 households were selected randomly for the study. After a preliminary analysis, data were analyzed according to the following classifications:

- Replacement of the second cultivation with glyphosate with treatments being:
- No second cultivation and no glyphosate;
- Second cultivation and no glyphosate;
- Second cultivation plus glyphosate;
- Glyphosate only.

Replacement of hand-weeding with in-crop herbicides with treatments being:

- Hand-weeding only;
- Hand-weeding plus in-crop herbicide;
- In-crop herbicide only.

Table 17. Economic analysis of maize production in Pailin.

	Ave	Max	Min
Yield (t/ha)	4.07	8.27	1.05
Income	$700	$1,422	$180
Variable costs	$275	$491	$143
Gross margin	$425	$931	$37

The average maize yield was 4.07 t/ha and the average price was $172/t giving an average total income of $700/ha. The range of income, variable costs and gross margins is given in Table 17.

Table 18. Average variable costs for maize production in Pailin

Input	Farms (%)	Variable cost
1st ploughing	98	$43.29
2nd ploughing	59	$20.86
Seed	100	$59.96
Hand planting	44	$15.39
Machine planting	52	$14.97
1st hand weeding	34	$6.58
2nd hand weeding	13	$1.62
Atrazine	80	$3.69
2,4-D	78	$2.46
Paraquat	68	$9.18
Glyphosate	33	$3.71
1st spraying	39	$2.37
2nd spraying	85	$7.23
3rd spraying	76	$6.58
Harvest	100	$58.49
Threshing	2	$0.59
Transport	80	$18.10
Total variable costs	100	$275.37

The breakdown of variable costs is given in Table 18. In Pailin, land is usually ploughed twice before planting maize. The survey showed that only 59 percent of fields are ploughed a second time. This reduction is consistent with the number of farmers using glyphosate which is 33 percent. There is also a minority of farmers using hand-weeding for weed control: 34 percent for one hand-weeding and only 16 percent hand-weeding a second time.

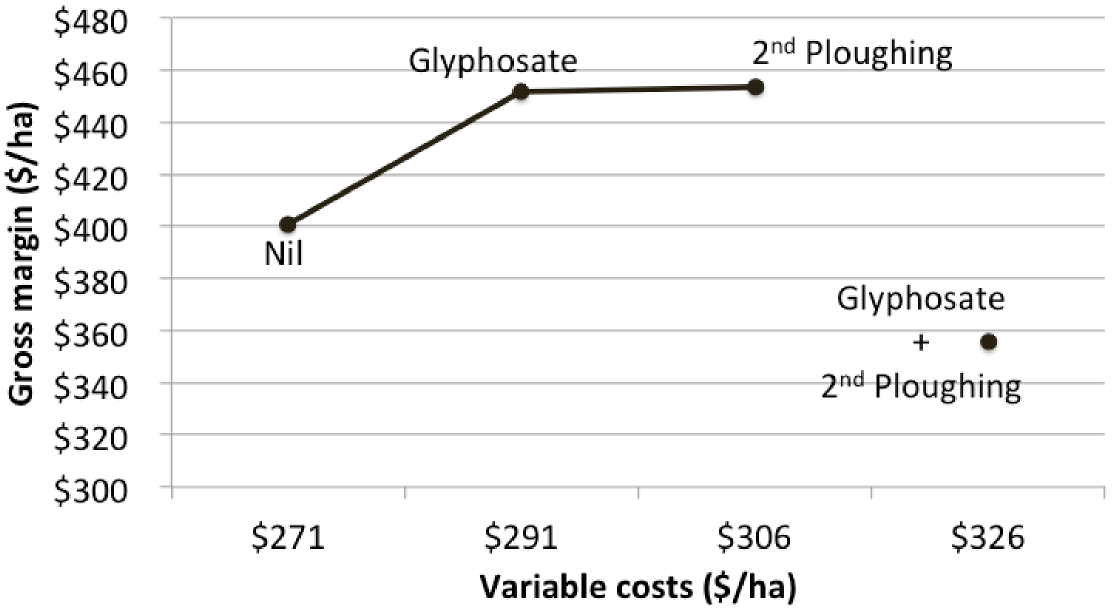

Figure 8. Net benefit curve: glyphosate vs 2nd ploughing.

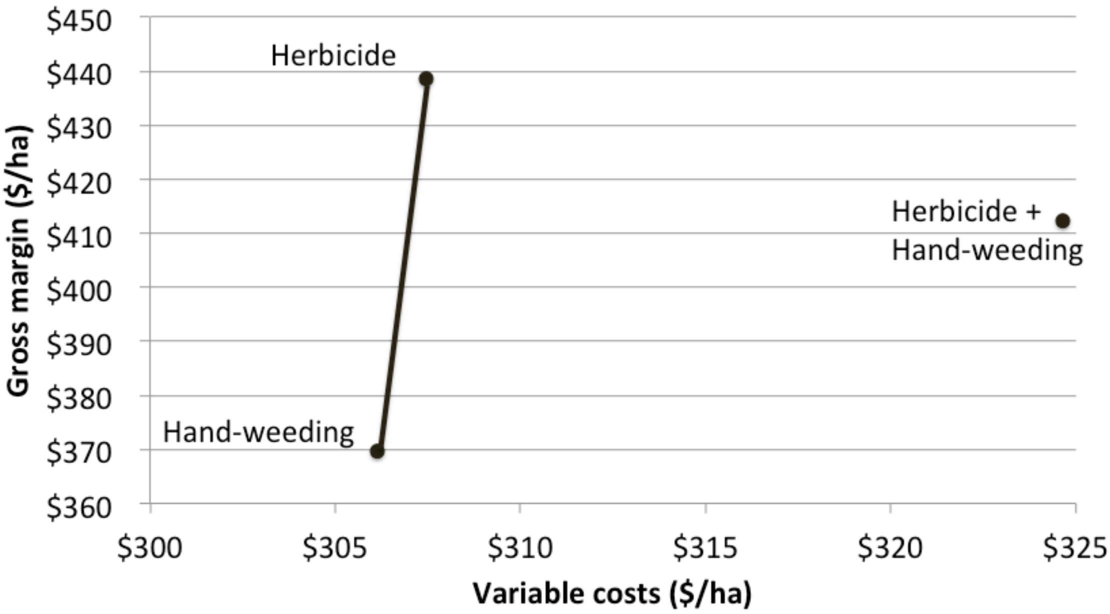

Figure 9. Net benefit curve: selective herbicide vs hand-weeding.

This study helped explain the trend for pre-sowing glyphosate being used to replace the second cultivation (Figure 8). The input cost for glyphosate ($19.95/ha) was significantly lower than for cultivation ($34.69/ha). The cost of a second cultivation plus glyphosate ($47.22/ha) was significantly greater than the 2^{nd} cultivation or glyphosate alone.

There were no significant effects on crop yield or gross margin for the substitution of the second cultivation with glyphosate. However, reduction in cultivation is likely to reduce soil fertility decline and soil erosion and therefore deliver economic benefits in the future. The project conducted demonstrations in 2009-2010 to show the benefit of replacing the pre-sowing cultivation with glyphosate which provided better weed control, conservation of soil moisture and more timely sowing. Therefore the farmers' move towards conservation tillage could be the result of the project activities.

A small minority of 10 % of farmers practiced hand weeding only and the average cost of weed control for hand weeding only was $35.19/ha. 25% of households used both hand weeding and herbicide at a cost of $53.71/ha. The majority of farmers (67%) used herbicide only for weed control at a cost of $36.53/ha.

Although there was a higher yield (NS) for hand-weeding plus herbicide, the cost was significantly greater than for hand-weeding or herbicide alone. Although not significant, the gross margin for herbicide alone was the highest (Figure 9).

The main drivers for change in weed management practices in maize appear to have been the cost and availability of hand labour. This has led to mechanization of land preparation and to the replacement of in-crop hand weeding with selective herbicides. Rotation of crops and herbicides will be necessary to prevent a build up of naturally resistant weeds and development of genetic herbicide resistance. Farmers also are at a disadvantage in not knowing how to apply herbicides at correct timing and rates due to the lack of application information in Khmer language.

7.2 Socio-economic issues for improved technology assessment and adoption

Introduction

A collaborative approach, involving Production, Marketing and Value-Chain activities interacting with Socio-Economic (SE) contributions, has been a feature of ACIAR project ASEM/2006/130. In Cambodia the SE Community of Practice (CoP) has (i) investigated the existing social and economic context of farming families, villages and communities in the target districts, (ii) asked farmers about their primary motivations for farm-level decisions, (iii) conducted economic evaluations of the production technologies being trialled and demonstrated in CCPMP as an input to project prioritization, (iv) been adaptive in investigating important issues as they have arisen in the course of the project, (v) contributed to human capital development, and (vi) evaluated the likely benefits from adoption of the technologies by farmers in the target villages and districts.

In Australia, a survey of growers was conducted in late 2010. The aim was to determine factors that influence farm practice change with a focus on adoption of conservation farming practices. It was a follow-up survey to that conducted by the National Soil Carbon Research Program regarding questions about the land use history and management of a selected paddock. Soil samples were also collected from the paddock for carbon analysis. Additional questions were asked about the sources of information growers relied on to decide the type of tillage system in current use and changes undertaken in the last 20 years. The purpose was to determine the social networks that influence farm practice change with a focus on adoption of conservation farming practices. The idea was to identify networking opportunities to accelerate adoption of sustainable farming practices in Australia.

In Cambodia the SE team has included the vital input of socio economists at CARDI led by Ms Chan Phaloeun and Ms El Sotheary. The process of engagement with Cambodian farmers has been by conducting village workshops in conjunction with farm walks and inspections of project trial/demonstration sites conducted by the Production CoP. Detailed reports of the workshops are found in Cambodian trip reports of Bob Farquharson, see the CCPMP wiki front page (http://ccpmp.pbworks.com/) and socio-economic resources (https://ccpmp.pbworks.com/browse/#view=ViewFolder&param=Socio-economics%2520resources).

This project follows on from a previous ACIAR project (ASEM/200/109, 'Farming Systems Research for Crop Diversification in Cambodia and Australia'). Some analysis and activities from that project have continued or been expanded in the current project.

Although the objective of projects such as this is to reduce poverty and improve food security through improved upland crop management and technologies, the project must operate in the context of the social, economic and farming systems realities that relate to the target farmer groups and villages.

Farmer and farming system characteristics

The farm district, farming systems and farm family characteristics for the project districts (the context for our project) have been surveyed and reported by Farquharson *et al*. (2006a) and Farquharson *et al*. (2010a, b). Average farm sizes of the surveyed farms were small (2-8 ha), capital (mechanical) equipment included draft animals, ox carts and mouldboard ploughs as well as tractors and disc ploughs in some areas. Levels of farmer education were relatively low and farm-family incomes were small. The cost of borrowing money for crop inputs in rural Cambodia can be 3-5% per month or more, depending on the source of funds. The observed price of hired farm labour has doubled in recent years (Figure 10). Problem areas for crops included low yields, lack of knowledge (especially about insects), concerns about profitability, land/soil constraints, labour/equipment issues and agronomic and climate risk (especially drought). There are significant numbers of female farmers.

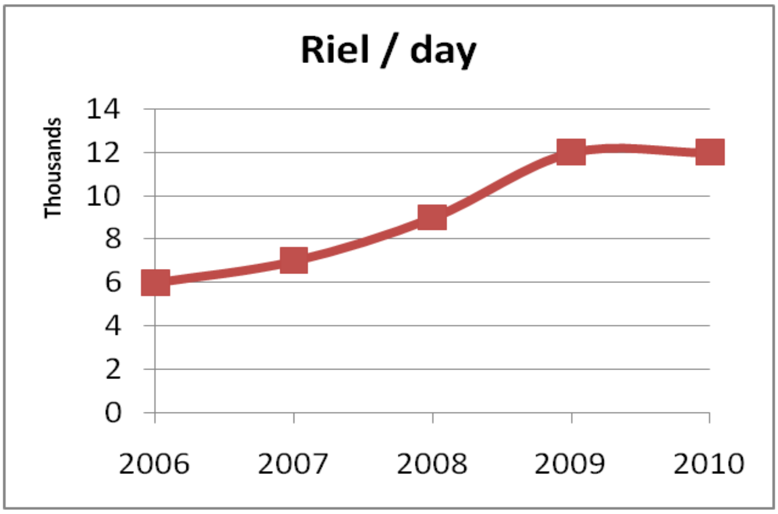

Figure 10. Price of farm labour in Cambodian upland districts 2006 – 2010

For the SE team an important early question related to the farmers' basic farm management orientation (primary motivations). In contrast to rice production in Cambodia, which has traditionally been of a subsistence nature, the upland production of maize and soybean is primarily for sale to domestic and export markets for human and animal consumption. Hence the orientation is mainly commercial and farm profits and farm management economics were assumed to be important issues for decisions and processes within the project.

Encouraging adoption and change by assessing technologies

While the project objectives are to reduce poverty and improve food security, the decision to adopt and change (especially in an economic context) remains one for the farmer, who must decide based on his or her own objectives and situation. This assumes that farmers have goals and can make choices according to their own free will (termed teleology by Dillon (1976)). To generate adoption and change the project must, in essence, search for 'new technologies' that are appealing enough for typical famers to want to change. The drive by CCPMP to generate improvements in farm income via improved management or technologies relies on finding technologies that are 'adoptable' to achieve such improvements.

There may not be feasible technologies or potential changes that are economically appealing enough for the farmers. This may be particularly so if other constraints (such as availability of inputs, cost of credit, infrastructure or market prices) are binding. So it might be that, despite substantial project efforts on adoption, eventual impact may not be observed.

The project commenced its agricultural production and socio-economic activities by focusing on six new technologies for the farming systems in these upland districts (introducing improved crop varieties, Rhizobium inoculation of legume seeds, applying nitrogen fertilizer (urea) to maize, changes in crop rotations or crop sequences, the use of reduced or conservation tillage, and Integrated Pest Management (IPM) for insect control), and another issue (improved weed control in crops) arose for consideration during the project. One technology (Rhizobium inoculation of legume seeds) was found through field trials and economic evaluations to be potentially very appealing to these farmers for a number of reasons.

Our approach has been adaptive, we have tailored our workshops to consider issues that have arisen during the project as new information and questions have arisen. Examples include the rise in farm labour costs and the impact on crop weeding (there has been a substitution of sprays for hand weeding), and further questioning and discussion of the cost of credit and micro-finance opportunities, estimates of farm family income and expenditure, the source of crop seeds used at planting, and questions about what farmers believe to be important characteristics of the technologies that we have been trialling and promoting.

Economic evaluations of technologies

Economic evaluations of crop production technologies were conducted and reported in Farquharson *et al.* (2006b, 2008) and Scott and Freeman (2007). These evaluations were for prospective technologies that were not yet available to farmers. The analysis of Scott and Freeman (2007) in the Samlout district involved comparing improved with farmer practice based on crop yields from field demonstrations and expressing the economic result as a ROI figure (as explained above). Their main result was indicative return of 743% for rhizobium inoculation of peanut seed. Farquharson *et al.* (2006b) used data from on-farm trials to assess the likely advantages for upland farmers of changing crop technology and management. Their main result (expressed in terms of ROI) was that rhizobium inoculation could return up to 600% for soybean. These are very high numbers based on a substantial yield improvement from rhizobium trials and an expected low cost for the technology. This technology was not available to upland farmers at the time of these analyses.

Use of Rhizobium to improve upland crop production

Despite the mixed results of on-farm Rhizobium trials reported above, the project brought in Rhizobium strains from Thailand and distributed the product to farmers for evaluation on their own farms. Farmers were also trained in applying the Rhizobium to their own legume crops. The last SE activity involved farmer surveys to assess Rhizobium in terms of its adoptability by farmers.

Authors such as Rogers (2003) and Douthwaite *et al*. (2001) have considered the characteristics of technologies in terms of their ‘adoptability’. These characteristics are:

1. **Relative Advantage**. This idea is that the use of Rhizobium is a better way for farmers to achieve farmer objectives than if they cannot use Rhizobium. Using Rhizobium may lead to increased crop yield, or increased crop income. But there might be extra costs involved in using Rhizobium, so we assumed a price of about US$5 per ha, that might affect profitability. We asked the farmers to consider Relative Advantage if Rhizobium costs $5 per ha? The answer could be ‘yes, it is superior’, or ‘no it is not superior’, or ‘I am uncertain if it is superior’;
2. **Compatibility**. This means that using Rhizobium is consistent with the farmer’s thinking about farming, or about producing crops on the farm. Is it consistent with how they think of themselves as farmers, or how they are used to producing crops now and in the future? The answer could be ‘yes, it is consistent’, or ‘no it is not consistent’, or ‘I am uncertain if it is consistent’.
3. **Complexity**. This means that the idea of using Rhizobium is difficult to understand and use. Do the farmers think that the Rhizobium management for crops is too complicated to be useful? The answer could be ‘yes, it is complex’, or ‘no it is not complex’, or ‘I am uncertain if it is complex’.
4. **Trialability**. This is the idea that something like Rhizobium can be trialed or experienced on a limited basis. It can be tried on a small scale. The answer could be ‘yes, it is trialable’, or ‘no it is not trialable’, or ‘I am uncertain if it is trialable’.
5. **Observability**. This means that the idea of Rhizobium is visible to many people. Is this an important thing for farmers in their consideration of a new idea such as Rhizobium? The answer could be ‘yes, it is observable’, or ‘no it is not observable’, or ‘I am uncertain if it is observable’.

A survey questionnaire was developed for individual farmers asking whether they would adopt, their responses to these five characteristics, and asking socio-economic characteristics of each farmer. The questionnaire was developed to investigate a statistical model to analyse the determinants of adoptability of a technology such as Rhizobium.

In each village we conducted a workshop with farmers aimed at investigating the 'adoptability' of Rhizobium inoculation of legume seeds. The CARDI team conducted these sessions, where a common session was held to state the aims and explain the five characteristics using flip charts. Then the farmers were individually interviewed using the questionnaire. The total number of farmers interviewed was 59, of which 57 were deemed suitable for analysis (Table 19).

Table 19. Farmer interview numbers by villages, June 2011 Samlout.

Village	Kantout	Sre reach	Boeung Run	Kampong Touk	Total
Interviews	14	16	11	16	57

A logistic model, such as developed by Askar *et al*. (2006), was developed for this farmer survey of agricultural technology adoption and innovation characteristics. Logistic stepwise regression analysis will be used to analyse adoption intentions and the importance of technology characteristics. The model developed was that adoption of Rhizobium may be determined by the five technology characteristics above plus socio-economic characteristics of each farmer.

The adoption response numbers by gender are shown in Table 20. Sixty percent of the interviewed farmers were female and 40% were male. Of the 57 farmers interviewed 81% (46) indicated that they would adopt Rhizobium and 19% (11) said they would not adopt. Of those who would adopt 65% were female and 35% were male. Of those who would not adopt 64% were male. However, the sample numbers are relatively low.

In Table 21 the percentage responses for the 5 adoptability characteristics by adopters show predominant agreement with the desirable adoption characteristics (i.e. relative advantage, compatibility, trialability and observability) and that Rhizobium ranked relatively low for complexity. These results might be expected. On the contrary in Table 22 (and also as expected) the non-adopters rated the desirable adoption characteristics lower, however, complexity was not rated higher. The non-adopters appeared to be less convinced there was a relative advantage due to lack of observability.

Table 20. Rhizobium adoption intentions by gender

	Will Adopt	Will Not Adopt	Total
	(No.)	(No.)	(No.)
Male	16	07	23
Female	30	04	34
Total	46	11	57

These results are only indicative and will be analyzed (with the other survey data) statistically in the proposed model above. However, they do present a picture that is consistent with positive adoption intentions being related to the adoption characteristics that were discussed in the literature. The full statistical analysis will be published when it is completed.

Table 21. Responses to adoptability characteristics by adopters

	Yes	No	Undecided
	(%)	(%)	(%)
Intend to adopt Rhizobium			
Relative Advantage	78	2	20
Compatibility	70	9	22
Complexity	9	85	7

Trialability	93	4	2
Observability	70	0	30

Table 22. Responses to adoptability characteristics by non-adopters

	Yes	No	Undecided
	(%)	(%)	(%)
Don't intend to adopt Rhizobium			
Relative Advantage	36	0	64
Compatibility	45	9	45
Complexity	0	91	9
Trialability	91	0	9
Observability	45	18	36

7.2.1 Improving post-harvest management and communications along the supply chain

This objective involved mapping the marketing system (post-harvest processes, socio-economics, communications and institutions) to determine the main constraints and opportunities for value chain improvements. The objective was to facilitate a process of change management for implementation of best-bet opportunities. Planned activities included:

- PAR to improve product quality and reduce costs through post-harvest storage, handling, transport, processing;
- Benefit-cost analysis of alternative post-harvest technologies, transport infrastructure, buyer surveys, buyer-seller relationships;
- Development of improved communications between different levels of the supply chain using SMS technology.

Ministry of Commerce (MoC)

The project team liaised with the Pailin MoC to:

1. Introduce the project and plans for value chain analysis;
2. Learning more about MoC strategy, rules, market situation;
3. How MoC may link to the project; and to
4. Gain some ideas for a middleperson workshop on 22 May 2009.

The government (MoC) strategies are to manage and improve businesses in Pailin province. Improvement of the supply chain is a high priority and promoted by the government strategy. In the Main Wet Season 2008, the Pailin market for cash crop experienced issues relating to price variation and decreases. It was also sometimes hard to sell. Around 90% of Pailin people are growing cash crops and rely on Thai, Phnom Penh and Vietnam markets.

To increase crop yield price and increase income, Pailin MoC Director, Mr Sokhun, highlighted the need for more grain drying, storage and packing facilities. MoC was also interested in greater processing or value-adding in Pailin which would provide employment opportunities for local people. Developing a Cambodian brand in packing was considered highly desirable by MoC.

Increased investment and road construction is required as transport infrastructure is currently weak. There are several existing projects but these are not enough.

In terms of partnership with the project, Sokhun showed his warm welcome, and proposed to have regular meetings about every three or five months and capacity building for MoC members. MoC will participate in middleman workshop and send a delegate (Deputy Director).

Overall, MoC was found to be very responsive to the value chain component of the project and they were very excited about the activity taking place in Pailin, and were keen to contribute where possible.

The Provincial Department of Agriculture (PDA)

The project team worked closely with Mr Phan Pech, Pailin PDA Director who showed strong interest in the project. Mr Pech advised that the maize production areas in Pailin were about 21,000 hectares and cassava around 8,000 hectares. Pailin's farmers had begun to adopt new crop production technologies introduced by the project and rolled out by CARE, PDA and other organizations.

Due to the fuel price decrease, one company near Phnom Penh which produces Ethanol using cassava has stopped purchasing cassava. This has caused problems to farmers growing cassava. The prices were very low and hard to sell out if compared to previous years. One of the major concerns of farmers is crop markets. Mr Pech made some suggestions to improve post harvest activities and marketing through developing grain drying, more storage, packaging and processing facilities in Pailin. The activities could be started through farmer associations. The need for storage was motivated by price fluctuations. For example, mungbean prices can be increased from $625 to $700/t by storing and waiting for a better price. Mr Pech also suggested that mungbean value-adding could occur with establishment of a cannery. Huge benefit could accrue from value-adding products.

In terms of international markets, Mr Pech suggested the need to classify the quality and have large scale quantities of crops such as maize available for export. He thought there was a need for Cambodian labels and packing in Pailin. There has been a recent government change aimed to increase investment in local areas, and the government are looking for a rural development project.

7.2.2 Post-harvest storage, handling, transport, processing

The analysis of post harvest technologies in Pailin commenced in the second half of 2009. In the first year of the project, an increased emphasis and timeframe was allocated to mapping out the supply chains for the CARE clusters. Information was gathered across seasons to get a temporal understanding of the supply chain mapping and to increase the robustness of analysis.

The socio economic and value chain teams worked together to design a suitable economic analysis for the value chain (post harvest) activities in Pailin. Data collected included the measurement of marketing margins at each stage and issues of pricing efficiency (i.e. if a price change at the top of the chain is transmitted down to the lower levels). Discussions also considered the suitable supply chain goals for Pailin, which may go beyond the traditional “lean” thinking to address potentially more attractive goals in agility and resilience.

7.2.3 Middleman workshop May 2009, Pailin

Fifteen of the twenty invited middlemen participated in the workshop, representing about 40,000 tonnes maize handled in a season. Each participant was asked list the key value chain issues and constraints from their perspective. Each participant listed their issues and constraints. After categorising, the three top issues/constraints were: Roads and transport, Markets, and Capital.

Major issues raised by the middlemen

Marketing

Issue	Solution	Constraint
Price variation	Improve grain quality to reach export standards. Processing in Pailin (Maize Powder or Animal Feeds)	Lack of techniques, cash and support from Government or NGO sectors.
International market & investment	Lack of investment Group farmers and make contract between farmers and company	Lack of communication, advertisement and skills
Lack of sponsorship from the government	Request for sponsorship from government, NGOs and other relevant institutions.	Poor communication and knowledge

NB: There is a strong expectation that the government, donors or NGOs will fix these problems. This is unrealistic and not commercially viable in the long term.

Roads and transport

Issue	Solution	Constraint
Roads	New roads need to be constructed from farms to main roads Need big roads	Lack of capital and participation between involved sectors.

NB: A recent issue that MJP has encountered with road improvement is that this immediately attracts large trucks which rapidly destroy the roads. If the community is not prepared to accept the cost of maintaining roads once they have been provided then the new roads will quickly become impassable again.

Capital

Issue	Solution	Constraint
To construct storage	Build drying & storage	Lack of capital and skills
Small capital to invest	Provide with very low interest rates	Lack of sponsorship and communication
Most profit gained by Thai	Construct processing facility in Pailin to grain profit in Pailin	Lack of cash, techniques No processing facility
Human capital	Request for capacity building on Business Management and Investment	Poor investment Have little idea on how to invest or joint venture.

NB: The value chain is rapidly evolving. Thailand is no longer the sole market, the number of large scale receival points has expanded and the level of competition to attract middlemen has increased. There are emerging opportunities for entrepreneurial medium sized traders but market forces should be left to determine which ones succeed and it would seem that intervention would be inappropriate.

Need for a storage model for middlemen

The need for a storage logistics and a financial model for storage facilities at middlemen scale was recognised earlier in the project. Observations which strengthened the case for such a model were:

- A storage facility for middleman makes the most sense, compared to a farmer or village scale. The survey data shows a middleman is a large enough scale player in the chain (1,000 to 8,000 tonnes per season). Farm scale is too small in nearly all cases and there are far too many of them. Storage at village or farmer association scale means a change to the existing supply chain structures, which

would greatly restrict large scale adoption. It was concluded that storage options outside the existing supply chain structures should be avoided.
- Middlemen are keen on the idea (as per workshop feedback), and most middlemen already own drying and transport infrastructure. Some probably own storage as well. In such a case, options should be explored for increasing storage size. A large proportion of Pailin middlemen are linked into the project via the middlemen workshops.
- The data are showing that Cambodian middlemen who sell to non-middlemen Thai (e.g. direct to Thai storage or processing) obtain a much greater profit margin than by selling to Thai middlemen.
- The larger scale Cambodian middlemen seem to buy the grain at a higher price from farmers compared to the smaller middlemen, though the data were insufficient to get strong correlations.
- There are large potential benefits of storing grain up to two months. The variation of price paid and price sold across the middleman surveys, shows there are significant opportunities from exploring storage options at the middleman scale.

Another possible exciting opportunity is to maximise the price paid/sold by co-ordinating storage at the middleman scale (e.g. a 3,000 tonne facility) and at the NAMA scale (e.g. 50,000 tonnes) and the logistics between them to maximise prices paid by international markets, and the flow of prices down to the farmers.

More recent discussions with KOGID also point to the potential viability of smaller scale storage facilities at the 3,000-5,000 tonne scale. The large receival points appear to have an interest in investing in such local storages so interventions should be of a facilitatory nature only in the first instance.

Survey of middlemen

A survey of 18 middlemen in Pailin in the EWS and MWS 2009 was carried out. On average a middleman collected from 158 farmers with a range from 35 to 700. Farmer issues recorded in the value-chain survey were:

- High costs of transport and short distances from farm to middleman (<5km);
- Availability of labour and time taken for harvest;
- Problems with management of insect pests – pesticides;
- Drought, crop establishment failures.

The cost of labour during the life of the project increased at around 20% per year. Farmers have responded by mechanising the land preparation and seeding operation and by replacing hand-weeding with in-crop selective herbicides. The main option remaining is to mechanise the harvest operation and it is expected that this will occur over the next couple of years.

7.2.4 Consultations and workshops in March 2010

The workshop was held to provide an update to the previous workshop held in May 2009 and to provide some solutions to the issues discussed. Two key concepts were to be proposed to the assembled group to provide feedback to the project team about direction for further work in the value chain. The two key concepts included the development of a grain trader level storage facility and the establishment of a grain trader (or middleman) association. These two proposed solutions arose to address the constraints identified by grain traders at the previous workshop.

Grain trader workshop

This workshop was arranged to follow up on a previous workshop in May 2009. Workshop participants were reintroduced to the 'value chain' concept. This provided some important background to why we were all gathered at the workshop and allowed the participants to understand their place as valued actors in the grain value chain in Pailin province. The progress achieved in the value chain component of the project was outlined to participants. These included the creation of a farmer's association; the finalisation of the value chain mapping and the early wet season (EWS) and main wet season (MWS) surveys.

Once it was explained what constituted the value chain in Pailin, the recently modified value chain map was examined and a discussion was opened on the accuracy of the map. Figure 11 shows the modified version of the value chain map for grain products in Pailin province. It was highlighted to the workshop audience that this is quite a simple value chain. There is limited or no transformation of the raw product before it leaves the province. This fact provided a stark illustration to the workshop participants that there is much scope to improve the value adding to grain products within the region.

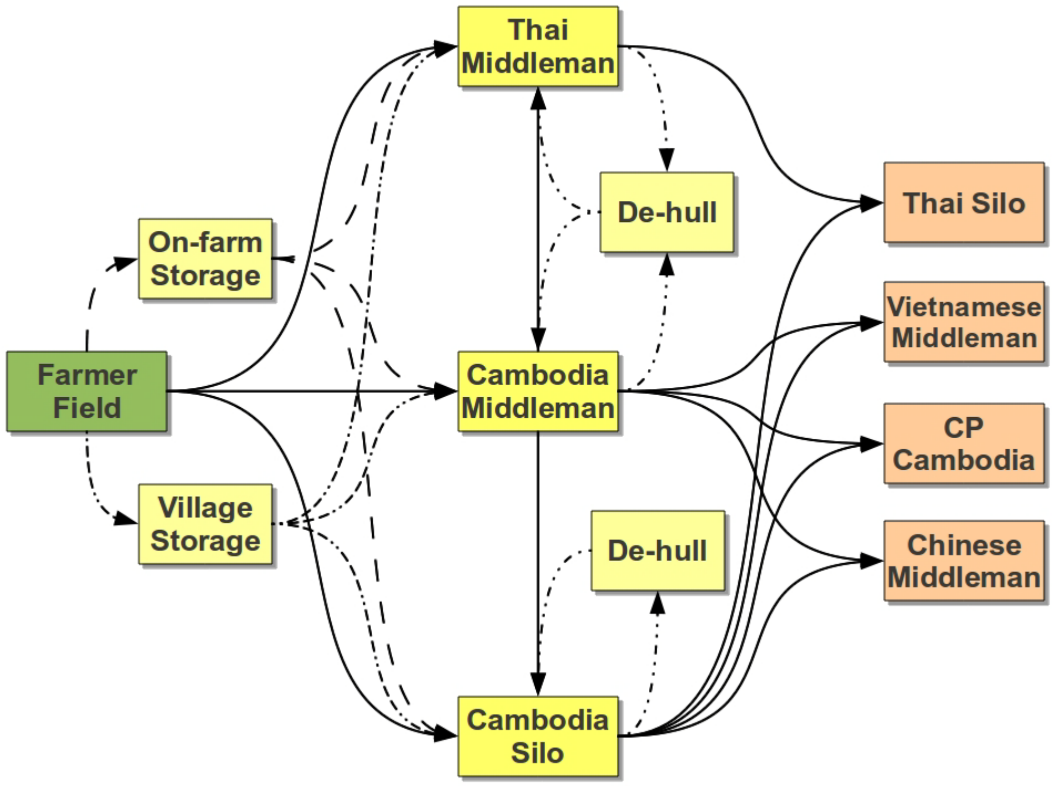

Figure 11: Modified value chain map for Pailin

The participants were reasonably satisfied with the value chain map and only minor modifications need to be made to finalise the map. Modifications will include a simplified layout to assist with interpretation and confirmation that some farmers sell directly to Thailand.

The workshop participants were also reintroduced to the EWS and MWS survey work performed primarily by Ly Bunthoeun in the Stung Kach commune, Pailin Province. Bunthoeun displayed a Pailin maize yield chart which prompted discussion about the data and comments about the increased area planted to maize over the periods 2008-2009.

The participants suggested the increase in yield came as a direct result of increased area planted to maize rather than any significant improvements in agronomic practices.

The workshop participants were introduced to the concept of ‘value adding’ in the grain value chain. With such a simple value chain the current prospects of product transformation is limited due to financial constraints.

The workshop participants were introduced to the business problems suggested by grain traders at the previous workshop in May 2009. The project team came up with possible solutions to the problems and discussed these with the workshop participants (Table 23).

Table 23: Problems and possible solutions for improved grain trading businesses in Pailin

Problems	Possible solutions
Price instability Seasonal price variation Grain quality issues	Storage facilities?
Credit/Human capital access to credit at lower interest rates · capacity building for improved financial skills	Trader association?
International markets and investment Lack of advertising, promotion of Pailin Investment in commodity marketing	Business development by Governor and DoC? Trader association?
Infrastructure Poor road quality Transportation – the weak link	Trader association?

The two solutions addressed by the workshop were the ‘storage facility’ and the ‘trader association’. The simplicity of the value chain requires the implementation of activities that will have an immediate impact on efficiencies and reduction of input costs. Large scale investment in infrastructure is a long term action that is beyond the scope of the project and is beyond the limited financial resources within the region at this stage.

Feasibility of on-farm grain storage – CARE, Pailin

Most farmers in Pailin believed that storage of their maize would result in better prices and it was suggested we develop farmer storage model. In 2009, CARE constructed two pilot on-farm storages for maize at a cost of $1,332 per storage. The store can hold around 16 tonnes of maize on the cob and more as grain. If the storage size were to be increased to 20 tonnes of maize on cob, the estimated cost would be around $2,000.

The idea is to work with farmers who already had the storages but did not store their maize. Some farmers feel storage is important and plan to construct storages themselves.

The average amount of maize produced per family is around 22 tonnes. Farmers will need to sell some of their maize to cover the costs of harvesting, transporting, threshing and around 60% of the total amount can be stored. The question asked is: what economic benefit might the farmers get if they store their maize for two months? Other farmers who could not store their maize can also benefit from the storage through less competition immediately after harvest. Case studies on storage improvement with key farmers could provide useful information.

Middleman grain storage model

The model assumed a storage capacity of 1,000 tonnes and showed the participants the concept of holding grain purchases to sell at the average price or above. This highlighted the idea that price can be volatile even on a daily basis. By keeping some of the grain and selling at a certain price, this volatility may be stabilised because larger quantities of grain may allow for better prices and efficiencies in logistics.

Table 24: Capital costs and depreciation of a 1,000 t maize storage facility

Transaction	Cost ($US)
Price paid for storage facility	$60,000
Loan amount	$55,000
Interest rates (%/yr)	12%
Term of loan (yrs)	30
Annual payment on loan	$6,828
Maintenance costs per year	$4,000
Wages costs per year	$3,000
Total annual costs	$13,828

Assumptions were made regarding the establishment and maintenance costs for the storage facility. and efficiencies in logistics.

Table 24 shows the establishment and maintenance assumptions for the model. Table 25 shows the potential profit from the model based on some simple assumptions.

Discussions were encouraged with the workshop participants to examine whether this model is a realistic scenario. Most were encouraged by the prospect of positive returns from a simple storage facility.

Table 25: Benefits of construction of a 1,000 t grain storage facility

Transaction	THB	$ US
Normal middleman gross profit margin	0.2 THB/kg	
Total price paid to farmers	35,162,580	$879,065
Total income from sales with storage	39,767,200	$994,180
Total income from sales without storage	36,578,500	$914,463
Cost of storage facility per year		$13,828
Income from storage	3,188,700	$79,718
Total profit gain from storage		$65,890

The concepts promoted to the group consisted of the following:

1. A storage facility may be owned and operated by a trader association or be owned and operated by a group of traders or investors acting together;
2. A storage facility may enable better prices or negotiation power by dealing with larger volumes.

Grain trader association

The workshop participants were separated into two groups to investigate the positive and negative issues surrounding the establishment of a grain trader association. Both groups actively embraced the activity and some interesting suggestions were provided in each list. Table 26 shows the response from the positive and negative groups.

Table 26: Positive and negative responses from the two workshop groups.

Positive	Negative

Good cooperation, communication, and sharing information and experience among the members Able to manage grain quantity and price in Pailin Grains can be gathered in anticipation of international exporting opportunities Look for international markets for selling grains Access to low interest rates from alternative sources Local potential for economic development and international investment Could seek technical support from government departments or NGOs Look to opportunities for improvements in the value chain such as: drying, storage, threshing, packaging etc.	Poor in communication, sharing information, etc. Lack of truth amongst members Lack of support from government departments or NGOs regarding technical support, loans with low interests, etc. Human resources are limited People think more on individual benefit Maybe risky to work in group/association

This activity served to involve the workshop participants in the thinking surrounding the development of a grain trader association. The majority of participants agreed that an association would be a positive development. The representatives from the DoC that were present at the meeting agreed to work closely with CARE Pailin to develop a plan to establish a grain trader association. Subsequently over the weeks after the workshop the CARE Pailin team progressed this activity to the point of developing a plan and a budget for establishing a grain trader association.

Follow-up activities included:

- Creation of grain trader (middleman) association documentation and budget proposal;
- Additional GIS training workshop;
- Targeted survey of key grain traders using SNA work developed from the 2008,2009 surveys; and
- Investigation of storage facility in Samlout.

Large scale grain storage

During the life of the project there was a rapid expansion in the number of large scale grain storages in Pailin and adjacent to Samlout. Grain storage and drying capacity grew from 7,000 tonnes in 2008 to at least 140,000 tonnes in 2011. This capacity is continuing to grow and at least one of the companies is considering the option to make livestock feed and to set up a feedlot piggery.

One of the more recent maize-cassava drying and storage facilities has been established by the Korea Overseas Grain Investment & Development (KOGID) at Ratanak Mondul. The facility has a capacity of 40,000 tonnes with scope to increase to 60,000 tonnes. KOGID takes grain from a 2 hour radius of the facility thus taking in Samlout and Pailin. In the EWS 2011 KOGID were paying $250-260/t for maize depending on quality.

KOGID are planning to move towards contract farming where an agreement on price is reached with the farmers at the start of the season. Other silos such as Chhamroeun Chhey in Pailin provide seed credit to farmers. Other silos such as Mittapheap don't provide seed credit but offer higher receival prices. There is potential for increasing competition between silos which could translate to better deals and higher prices for farmers.

Opportunities for collaboration discussed with KOGID included:

- Quality control systems: A partnership for improving the quality of grain delivered. This could involve workshops using MJP's existing farmer field schools for farmers and collectors on the quality standards KOGID is looking for and the price premiums for delivery of higher quality grain.
- Local micro-storage facility: KOGID has offered to invest in setting up a micro-storage facility at the farm/village/commune level (Samlout). This could go a long

way towards improving the quality of grain delivered to KOGID's processing facility and would be of mutual benefit to the farmers, collectors and the buyer.

- Crop diversification: There was also some discussion about the production of alternative crops to maize such as soybean, mungbean and peanut grown in rotation with the maize/cassava. KOGID is planning to build a soybean processing facility.
- Mechanisation of harvesting: The fourth point discussed was the mechanisation of the harvesting operation for small-scale farms. This would improve the quality of the product and at the same time reduce the damage to the cropping fields. Options for mechanisation should be explored with the large scale storage facilities.

More research might be required with regard to the determinants for prices down the value chain as well as to better understand conflicting statistics regarding prices and exports. Despite the potential for increased competition with the entry of new silos, the price for maize appears to be relatively insensitive to peaks in the world price (Figure 12). Although the IMF price for maize is currently $302 (July 2011), the receival price at the Pailin Mittapheap silo is currently $195. However, at the same time KOGID claimed to be buying at $260/tonne.

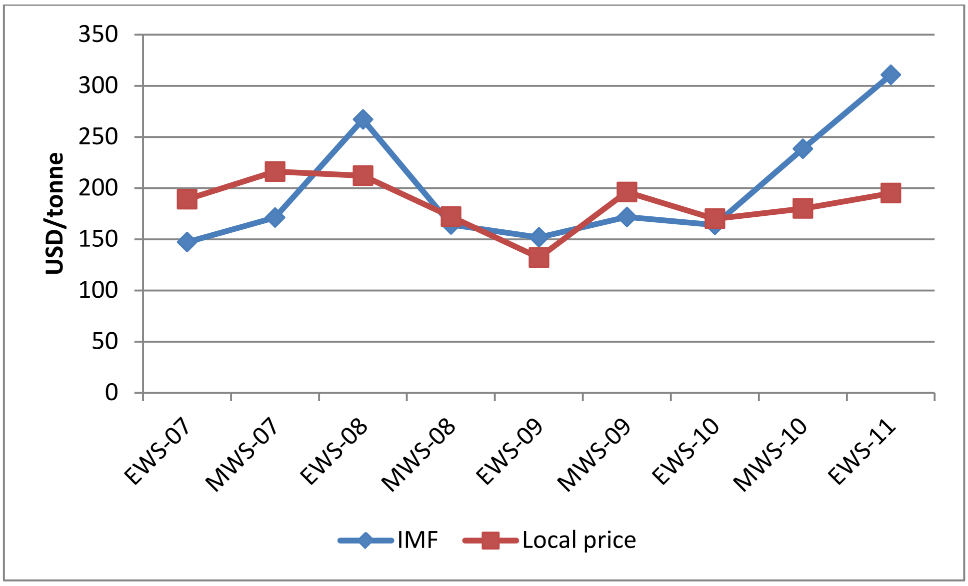

Figure 12. Pailin maize prices compared to the IMF price.

Export opportunities

Most of the KOGID grain is sold to CP Feeds at Phnom Penh. KOGID said they would like to export grain to Korea which imports 7.5 million tonnes annually mainly from the USA. Although KOGID did not mention it, the Phnom Penh Post reported that KOGID exported 50,000 tonnes of maize to Korea in 2010.

The main problems cited by KOGID for export were the cost of freight to the deep sea port at Sihanoukville and the cost of handling at Sihanoukville. However, it appears that shipments are being made from the port of Phnom Penh by KOGID and other companies such as CGARD another Korean contract farming company.

Development of the Northwest Agricultural Marketing Association (NAMA)

The idea for forming NAMA was first proposed by Professor John Spriggs under the previous ACIAR project (ASEM/2003/012). Under the current ACIAR project (ASEM/2006/130) we further discussed idea in 2008 with potential members and found strong local interest. The idea for NAMA grew from recognition of three levels of activity within ASEM/2006/130:

- MICRO level – partnered with MJP – deep, holistic development within a small, cohesive region. In agriculture, with a strong focus on food security - production issues were seen by locals (at least initially) to be more important than marketing;
- MESO level – partnered with CARE – a medium-sized region with a focus on raising farm incomes as well as food security. Production and marketing/value chain issues were both seen as important;
- MACRO level – work with NAMA – at the regional scale. Here the focus would be on raising incomes of all participants in the supply chain. At this level, marketing/value chain issues were seen by locals to be more important than production.

Objectives **of NAMA**

1. To improve export marketing of upland crops from northwest Cambodia.
2. Initially the only significant foreign buyer was CP Foods. Members of NAMA aimed to expand the number of foreign buyers and, in particular look to markets other than just Thailand.

Inputs into NAMA

Priorities for NAMA included:

- Access to low-interest credit;
- Assist export development;
- Assist development of NAMA as an organization; and
- Assist development of communications with members.

Project activities included:

- Assistance for development of NAMA as an organization;
- Assistance for NAMA to gain experience in export marketing outside of CP Foods; and
- Assistance to NAMA to develop as a communications hub (through Rob Fitzgerald's work on mobile-phone based technology).

NAMA's Development

- Background study by S. Gniel, with follow-up study by Nou Keosothea and Un Buntha. Buntha assisted registration of NAMA with the Ministry of Commerce in late 2008. Currently three core members (the silos at Pailin, Malai, Kamrieng) and a total of about 50 members in all accounting for 15 – 20% of all maize, soybeans, cassava grown in western Cambodia.

Further development of NAMA

The NAMA concept has been overtaken by the rapid expansion of grain receival facilities in North-Western Cambodia with the number of large silos servicing Palin/Samlout expanding from one to at least five during the life of the project. The new silos have different corporate objectives and competitive strategies and it is unlikely that they would work together as part of a silo association.

7.3 Development of improved communications between different levels of the supply chain using SMS technology

Workshops held in Cambodia (August 2008 and January 2009) raised awareness of the role that ICT and mobile technologies in particular (e.g. SMS) can play in the value chain for the sharing & exchange of information and the development of production/marketing communities of practice. Both MJP and CARE have a TOT/FFS model whereby project technologies are rolled out to the full MJP/CARE target groups.

A SMS workshop was held at Pailin in January 2011. There were 17 participants (a mix between farmers and traders, silo managers) with an additional four CARE Pailin staff. The SMS Information System workshop was an introduction for farmers and grain traders to the concept of information and pricing delivered via SMS technology. The majority of the participants were farmers from local villages surrounding Pailin. Many have only recently begun using mobile phone technology with the now rapidly expanding phone coverage across Cambodia. It was identified in previous surveys that SMS is rarely used. According to the workshop survey, the level of familiarization with SMS technology is loosely associated with age. Most participants aged under 30 were comfortable with SMS.

Two SMS Information platforms, Frontline SMS and 010xpress were introduced and delivered through a presentation of each system with a testing session. The Frontline SMS system is one that is currently being used worldwide as a system that allows SMS messages to be sent to a large number of people. It is often used in disaster management situations but also has wide applications in agriculture and development projects. The 010xpress system is one developed in Cambodia under a business model that can pull information from multiple sources and provide a system whereby customers can connect with business and organisations through SMS.

A positive response was received about the technology from the participants due to the fact they could see pricing information and seek other information over their phone if required. The most notable challenges to the systems noted during the workshop was the limited understanding of alpha characters on phones. This will continue to be a critical issue for the usability of the systems unless steps are taken to simplify messages and syntax.

Issues for SMS:

- Despite the apparent interest in SMS shown by farmers, the technology is far from becoming a reality. Although 80% of farmers in Samlout have mobile phones, only 3% use SMS. However 55% of farmers use the mobile phone to obtain farm business information.
- A large percentage of farmers purchase seed from the silo or middleman and therefore are not free to shop around for a higher price.
- With five major silos now operating in the Pailin/Samlout area, the competition has increased. Prices are posted by the silos daily during receival periods and any SMS system would need to have real-time price information. This does not seem to be achievable.

The exchange of information about production and marketing of produce at the local level is dynamic and fluid. It is likely that improved communication in the supply chain will come from variety of options and further Social Network Analysis could reveal the best opportunities to improve farmer access to market information.

7.4 Evolution from value chain to value network analysis

7.4.1 Tangibles and intangibles

Limitations were identified in the present approach to analysing the value chain. Previous surveys of the early wet season (EWS) and main wet season (MWS) focused on production data and sales data, which can be considered the "tangibles" in the chain. Data collection to date has been important and a valuable way to get a broad understanding of the value chain. Key intangibles include:

- Relationships between actors in the network: social and business (satisfaction with these relationships);
- Information flows between actors: e.g. who provides the key information to farmers;
- Arrangements surrounding the supply of inputs to farmers;
- Arrangements surrounding credit: cash/seed. Often the middleman that provides seed credit to the farmer is also the collector. This means the farmer is a price-taker.

Traditional value chains are typically linear relating to operations such as how to produce and exchange and relationships such as how to develop relationships to maximize potential of the chain. Value networks pay attention to "intangibles" which are network-like. The intangibles relate to identification of the social network of relationships between actors. Both "tangibles" and "intangibles" are important for a clear understanding of grain production and marketing in NW Cambodia.

7.4.2 Understanding the supply chain for crop inputs

Survey of herbicide use in soybeans – MWS 2009

A survey of herbicide use in soybean in the MWS was carried out in Samlout to follow up on questions asked by the socio-economics team in October 2009. Farmers involved in the October workshops were followed up individually. Sixty five farmers in the four village clusters were interviewed. Fifty three of these farmers grew soybeans in MWS 2009 (82%). Of the 53 farmers who grew soybeans, 40 (75%) used Quizalofop and Fomesafen selective herbicides in soybean.

Seventy percent of farmers said they heard about the herbicide from their neighbour, 11% from the seller, 13% from himself and 2% from advertisement. Forty percent of farmers received herbicide advice from the seller, 34% from neighbour and 19% from their own knowledge. Some of the farmers can read Thai and therefore the herbicide label. Some farmers have been using herbicide for up to 10 years but most have started using herbicides in the last 3-4 years.

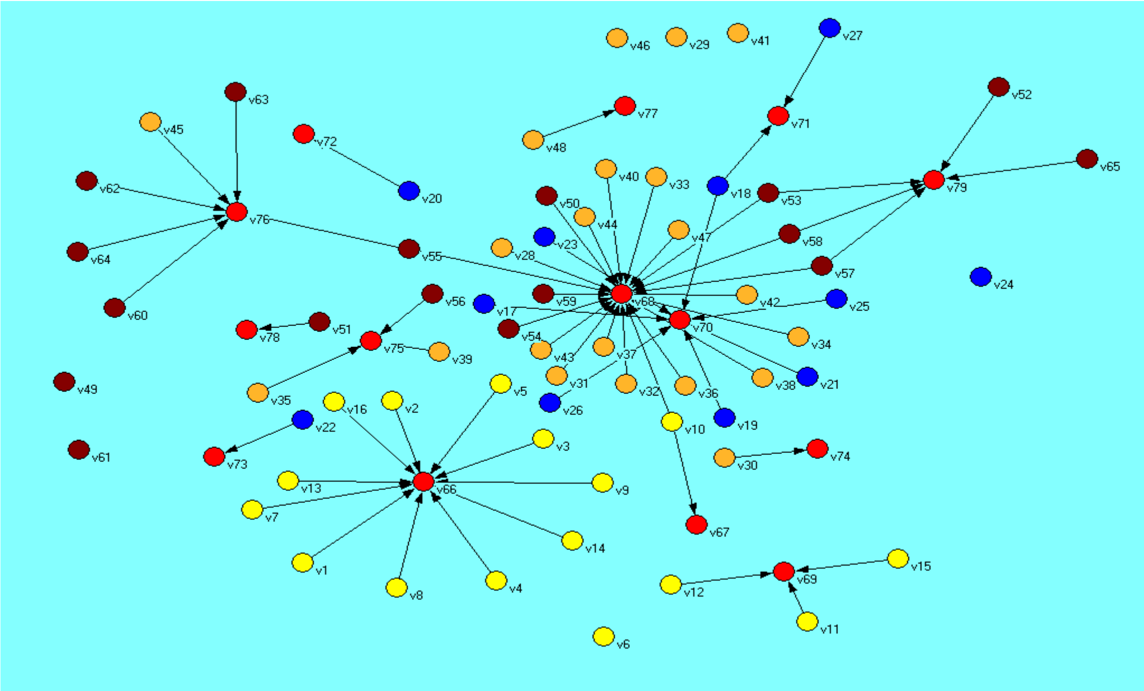

Figure 13: Social network diagram for suppliers of herbicides to farmers in Samlout.

Contact details were obtained for the sellers and these were followed up to track the herbicide up the supply chain (Figure 13). Some farmers obtain information on pesticides directly. For example one farmer in Boeung Run village travelled to Pailin seeking information on how to control stem rot in sesame. She provided the business card of Mr Toep Sovann of CSB who supplied the chemical (Metalaxyl) and the advice. We also found promotional material for the OPLE/PANTERRA herbicide combination for soybean in the village.

Suppliers of seed, fertiliser and agricultural chemicals are also the most important source of information about their use. Further research is required to see if input suppliers are willing to provide extension material to the farmers on other aspects of crop production. Suppliers might also be an option to import rhizobium inoculants and biological pesticides from Thailand.

7.5 Value chain and marketing outcomes with NGO partners

MJP (Samlout)

A survey of 99 farmers in the 2010 EWS at Samlout showed that 54% of households received cash credit for a total of US$101,960. There was a wide range of loan amounts taken out with three farmers with loans of over $7,000. However the most common loan amount was approximately $119. The median was $238 and the mean value $843. Seventy three farmers took bank loans with a value of $90,258 out of the total $101,960 in the survey. Bank loans made up 89% of the total loans represented in the survey.

In the end-of project survey in the MWS 2010, most Samlout farmers (77%) stated that the main problem they faced when selling their agricultural products was the low price offered by the middlemen: 38% believed the reason for this low price was the bad roads, which is especially a problem in the EWS. Interestingly, 24% of households claimed that the main reason agricultural products received a low price was the poor quality of their products. Most households (82%) sold their crops from their house immediately after the harvesting period; 45% of widow and vulnerable families (WVF) did so as they claimed it was too difficult to store their produce due to bad weather conditions and the lack of available storage facilities. Another 40% sold their crops after harvest as they needed the income to pay back existing loans. Only 7% of households stored their crops in order to wait for higher market prices before selling.

Another problem related to the income received from cash cropping activities is the poor access farmers have to market information. Information is often provided by the middlemen or sellers (agricultural products); 57% and 33% of WVF received their information from local middlemen and neighbours respectively. These middlemen are seen to have an interest in increasing their profits at the expense of the poor farmers. A survey conducted of 36 middlemen in Pailin in 2009 revealed that, on average, middlemen were taking 8 to 10% of the revenue generated by the crops for their services (Post-harvest and Value Chain Analysis in Pailin, 2009). In other words, if farmers were to cut out the middlemen and sell directly to the silos they would receive 8 to 10% more income for their crops. While this may appear to be a small proportion of farmers' total income, it can still represent a significant amount of money for vulnerable farmers in Samlout where 70% of WVF are still living on less than or equal to one dollar a day (Food Security Nutrition Evaluation 2008-2010 Samlout).

Devising interventions that contribute to increased household incomes is an important way in which MJP's agriculture team have improved food security in the Samlout Target Area. The main source of income in this area comes from farm activities such as cash crop production and livestock raising. Off-farm income such as selling labour and goods contribute 16% of the average annual income for WVF. Average annual household income for WVF has increased from year to year from $1,099 in 2008 to $1,549 in 2010. Training provided by MJP, yield increases, market factors such as the price of crops and inputs, improved road conditions (partly funded by MJP), and the availability of tools and materials are all factors which have contributed to the increase in incomes. At the same time, the proportion of WVFs who earn less than or equal to $1 per day per person has decreased from 80% in 2007 to 70% in 2010, which is an important achievement for poverty alleviation in the target area. The proportion of households that earn from $1 to $2/day per person and more than $2/day per person has steadily increased in the area.

Although income has increased since MJP commenced its agriculture program, the survey revealed that annual expenditure is greater than annual income and that the two do not equate. In 2010, for example, annual household expenditure was $1,812, whereas income was only $1,549. Average annual expenditure on health was $115 a year and on education was $171, which made up a significant proportion of total household expenditure. It is important to note that the high cost of schooling is due to the fees associated with sending children to local secondary school and schools or universities in the city, as primary school is provided for free.

As a result of the mismatch between expenditure and income, farmers need to borrow money every year to address their expenditure requirements; 79% of WVF borrowed money. On average, households borrowed $428, with an average monthly interest rate of 3.12%. Of all the loans that were taken, 49% were spent on daily household requirements, 38% on crop production activities, and 9.8% were used to repay existing debts. It must be noted that 32% and 25% of WVF bought seed and crop production materials on credit supplied by local middlemen and paid monthly interest rates of 11.3% for seed and 10.4% for materials. Some households even paid interest rates as high as 50% per business/harvest cycle. Debt and middlemen credit (to buy seed and/or materials) are key challenges facing MJP's agriculture team and threaten the achievability of a wide array of different interventions.

Poor household financial management and planning skills within the community also contribute to this problem of debt, and act as a constraint to reducing poverty. The lack of basic business skills amongst WVF in Samlout prevents farmers from launching effective and efficient Small and Medium Enterprises (SME). Improving farmers knowledge and management of expenditure and income is a crucial step in allowing them to start treating the farm as a business and fostering the emergence of profitable smallholder agro-businesses.

CARE (Pailin)

As a result of project and CARE activities, the biggest improvements in post-harvest management were the adoption of proper harvesting techniques (from 25 to 74%) and proper drying (from 18 to 45%). There was not much change in improved storage with only 27% of households having proper storage facilities. Only around 3.5% of households in the project harvested their crop using machines.

The proportion of the households who were aware of market information for agricultural inputs and outputs increased greatly over the project implementation period. Over 90% of the total households who were engaged in cultivating crops now have access to information on the prices of inputs and products compared less than 20% at commencement of the project.

At commencement of the project, the main source of information about agricultural inputs and outputs was from the supplier/collector (70%). By the end of the project there was a significant shift to community-based information networks for provision of market information.

Information source	Baseline	Endline
Farmer Cooperative	0	17
Announcement board	0	30
Radio/TV	15	76
Neighbor	22	75
Market/Seller	70	76

These results indicate that most of the target community members gained better access to market information through support mechanisms available in their target areas including information board, radio announcement, and farmer cooperatives.

Questions regarding the place of buying a particular agricultural input were asked of each household during the survey. The market is the main place to purchase the agricultural inputs by the majority of households. By the end of the project, farmer cooperatives had become the main supplier for crop seeds with 46% of the target households purchasing seed in this way.

Regarding the sale of product, middlemen remained the main purchaser of product. Better mechanisms are still required to support households for the sale of products. The middleman margin is around 10%. The main reason for households not being able to bypass middlemen was the lack of transport.

Farmer cooperatives formed by the project generated significant capital gains and successfully managed seed, cash credits and savings for the target community. The cooperatives were running the business smoothly and networking with other agencies was strengthened. The community members acknowledged the benefits of farmer cooperatives compared to working individually. The cooperatives helped community to build solidarity and reduced reliance on the private sector for access to agricultural inputs at reasonable price and acceptable quality. Farmer cooperatives proved to be a viable provider of credit, a reliable source of market information and forum for sharing improved agricultural techniques.

There is room for improvement in the following areas:

- Poor communication or networking between farmer cooperatives and other relevant agencies;
- Low participation rates among cooperative members;
- Capital of raised by the cooperatives was not yet sufficient to provide credit to all households;

- Capacity of the committee members for documentation needed to be strengthened.

There were significant increases in proportions of the households engaged in community credit systems including savings, financial credit and seed credit in the target areas by the end of project. Around 70% of households reported money savings at the end of the project compared to 5 percent at baseline. Out of the households who saved their money, around 48 percent saved money in Farmer Cooperatives, 36 percent participated in village saving groups, and 11 percent kept the money at home.

During the period of the project, community members become less reliant on the private sector to borrow money and more reliant on community credit systems where loan conditions were less onerous. However, they complained that the loan size from community credit schemes were too to run the business and that there were no proper mechanisms to check on the appropriate use of loans.

By the end of the project there had been a major shift in the source of seed credit from CARE, private organisations, and neighbours to almost complete reliance on community credit schemes.

7.5.1 Simulation modelling of alternative strategies for adaptation of sorghum to climate change in north-western NSW

In the short term climate change scenario to 2030, it has been suggested that farmers could exploit existing strategies developed to cope with the variable climate in the summer rainfall cropping zone of north-eastern Australia. These strategies include: varying crop residues at sowing; varying plant population; varying row configuration; changing the sowing window; and varying the crop duration. This paper reports the results of APSIM simulations of sorghum yields and economic analysis based on stochastic weather generation downscaled CSIRO Mk 3.5 projections for 2030, 2060 and 2090.

Two sites were chosen for the analysis: Quirindi representing cooler higher rainfall conditions and Moree representing warmer lower rainfall conditions. By 2030 maximum and minimum temperatures are projected to rise by 1.6-1.7oC and rainfall to decrease by 10-11% at Quirindi and Moree. Some of the climate change adaptation options favoured by farmers did not deliver the expected results. These included reducing planting density, skip row configurations, early planting and quicker maturing varieties at both Quirindi and Moree. For Quirindi the best strategy to maximise sorghum yields and returns in 2030 is to plant a medium maturity variety in November-December at 5-7 plants/m2 in a solid row configuration with maximum crop residue retention. The result for Moree was similar except that October and December plantings were better than November.

Gross margin budgets were used to estimate individual crop profitability under the different scenarios. When additional modelling is undertaken to include rotation crops such as wheat, barley and chickpeas, whole-farm economic case studies will be used to identify optimum business strategies under different climate change scenarios. We plan to engage farmers in Participatory Action Research to identify strategies for optimum choices of crop species and sequences to cope with climate variability and climate change.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The on-farm demonstration protocols developed in the project have been integrated into the demonstration programs of MJP and CARE and now operate independently of the project.

The mungbean variety, AFT3944, introduced to the CARDI breeding program in ASEM/2000/109 and further tested in ASEM/2006/130 has now been released commercially in Cambodia as CMB3 (Ouk 2009). 11 mungbean varieties were obtained from CSIRO in 2003. The best (ATF 3944) was included in on-farm demonstrations at Samlout/Pailin in 2007. ATF 3944 yielded 21% more than local varieties in CARDI trials. ATF 3944 was released for commercial production in Cambodia as CMB3.

The project contributed papers to the first International Conference on Environment and Rural Development which was held in Phnom Penh in March 2010. Bob Martin was asked to review manuscripts and is now Vice President of ISERD representing Australia.

As a result of presentation of the paper ('The 'Jorani Project': Incorporating principles of Sustainable Rural Development into the Education System of Cambodia') at ICERD 2010, Bob Martin was approached by Nami Akimoto of Action with Lao Children (ALC) to have the book published in Lao language. This has now been done.

The Jorani education concept linking agricultural research with the primary school system described by Martin etal (2010) has now been adopted by MJP and is being extended to a new program linking vegetable production with human nutrition.

The project has successfully researched and demonstrated the importance of rhizobial inoculation of legumes. This technology is now being used by other programs in Cambodia such as IDE and CIRAD. A paper on “ Adoption of rhizobium inoculation in Cambodia” was presented at the 2nd Asian Conference on Plant-Microbe Symbiosis and Nitrogen Fixation, Phuket Thailand in October 2012.

The project will also contribute to the 4th International Conference on Environment and Rural Development which will be held at Siem Reap in January 2013. A paper authored by Touch Van, Bob Martin and Fiona Scott has been accepted on: Economics of weed management in maize in Pailin Province Cambodia.

8.2 Capacity impacts – now and in 5 years

Summary

- Change in the knowledge and skills of individuals
  - Training: statistical analysis, economic analysis and report writing (project staff)
  - Workshops on economic analysis, IPM, soil management, rhizobial inoculation (project staff, PDA, key farmers)
  - Technical manuals (IPM, Soil Management, Rhizobial Inoculation)
  - ACIAR monographs (Maize manual, Soybean manual, Weed guide, Insect guide, Jorani books, 16 Farmer FactSheets)
  - Scientific and Conference publications
  - John Allwright Fellowships (5)
  - AYAD volunteers (2)

    - Undergraduate teaching in Plant Protection and Farm Management at the University of Battambang
- Equipment (hardware and software)
    - 4-WD utility, motor bikes, computers

Training approach for farmer cooperatives

In collaboration with MJP and CARE, the project has worked with Farmer Cooperatives (FC) with the activities, supporting inputs and technical training. The role of project staff has been to carry out TOT (training of trainer) activities so that project technologies can be rolled out to farmer groups beyond the scope of the project. After completion of training, TOT members continued delivering training to Farmer Field School (FFS) beyond the project with the support from project team from 2008 onwards.

In EWS 2010, CARE provided 8,720 kg of high quality maize seed to 289 farmers, 7,532 kg of mungbean seed to 276 families, 680 kg of peanut seed to 13 families. Rhizobium liquid, inoculum was also provided: 196 bottles for mungbean to 141 families and peanut rhizobium: 32 bottles for 32 families.

Integrated pest management (IPM)

Several workshops were conducted to introduce the concept of IPM to MJP/CARE staff, PDA and key farmers. This was extended to school teachers in conjunction with the 'Jorani Project'.

An illustrated children's book "Jorani and the Green Vegetable Bugs" was published as an ACIAR Monograph in English, Khmer and Lao language to teach children and teachers in rural areas about integrated pest management (IPM) in upland crops and the positive impacts on the environment and human health in Cambodia. The project involved introducing the Jorani Project to school directors and teachers; development of a teacher guide; implementation in schools; and celebration and public launch. Further books in the series are planned to teach the benefits of other sustainable land management practices.

The project targeted five primary schools in Samlout where MJP, in collaboration with the Ministry of Education, Youth and Sport (MoEYS) is working to strengthen primary education for all school-aged boys and girls.

The potential to achieve the stated agricultural extension and primary education objectives will be evaluated after completion of the pilot project. Social network analysis will be used to test the effectiveness of the proposed learning environment model. Depending on the findings, a Life Skills framework for rural primary schools will presented to the MoEYS for endorsement and roll-out to primary schools in other Districts and Provinces in Cambodia.

Data management and basic statistical analysis of experimental data

Workshops were held in January each year to enable MJP and CARE project team members to share results and summarise each team's results for the year. The workshop format covered data management, experimental layout, data and file management, analysis of variance, and regression and correlation. Economic analysis of significant data sets was also carried out. The workshop included planning for activities for the following year: Field Log Books (trial design; data recording); Annual Work Plan Budgets; personal/professional development and project integration. The workshops also covered report writing and presentation of results. At the end of the workshop series, MJP and CARE project staff were able to set up Excel data files in the format required by IRRISTAT and independently perform analysis of variance, regression and economic analysis on data sets from their own field trials.

Rhizobium application - training of trainer

A major activity for the production team was the rollout of the rhizobium inoculant samples for farmers to test in their own fields. The rhizobium inoculant was obtained from the Suranaree University of Technology, Nakhon Ratchasima, North-East Thailand. We provided 500 100mL bottles for each of soybean, peanut and mungbean in 2010 and 400 each for soybean and peanut in 2011. This was enough to inoculate seed for around 290 hectares of crop. Train-the-trainer workshops were held for project staff, village officials and key farmers in the four village clusters in both Samlout and Pailin. The workshops went well with many questions and a lot of interest from the farmers present. Mr Toep Sovann Pailin distributor for CSB is a possible contact to discuss supply of rhizobium inoculants.

Geographic Information Systems (GIS) training

A four hour training session was held in Pailin in March 2010 to provide introductory GIS training in spatial data presentation and aerial image manipulation. This elementary training focussed on bringing data from the early wet season (EWS) and main wet season (MWS) into a GIS so that a visual understanding of the distribution of the farmers and middlemen could be assessed. The main benefit will be the maps that can be produced to insert into reports.

Marketing

This project represents a cross-disciplinary approach to development research involving the production, (farm-level) socio-economics, value chain and marketing. As with any cross-disciplinary project this is a significant challenge because the researchers come from very different research cultures, but the project team has taken on this challenge and is actively exploring innovative ways to make this work and to learn from this challenge. Capacity building for the MJP/CARE production team included training in data management, statistical analysis, economic analysis, report writing and presentation.

Assistance was provided to NAMA to establish itself as a marketing association for upland crops in northwest Cambodia. Even with the ultimately unsuccessful pilot initiative to export certified seed to Taiwan, the NAMA executive said they learned a lot about the need for quality control and how to do business with exporters. We have also helped the NAMA executive to develop a broad vision for the future development of the region and its place in that region.

Human capital development within the SE team

Human capital development within the SE team has involved training in simple economic techniques (Scott 2008) and assistance in running writing workshops for Cambodian professional staff. Fiona Scott and Bob Farquharson assisted Dr Bob Brown in a writing workshop held at CARDI in June 2006 and Fiona ran another 1-day seminar on paper writing and analysis in June 2010. She has conducted workshops in gross margin budget analysis and has also conducted a 2 day workshop in June 2010 delivering training in loan interest calculation, cash-flow budgeting and whole farm budgeting.

The 2009 edition of the Cambodian Journal of Agriculture (see http://www.cardi.org.kh/images/stories/CJA/Vol_9_No_1-2_Jan_Dec_09.pdf) has 4 of the 6 articles from this project and attendees of the original writing workshop (e.g. Chea *et al*. 2009). John Allwright fellowships have been awarded to 2 members of the CARDI SE team – CHEA Sareth (University of Queensland) and SRET Sinath (studying English language prior to attending the University of Melbourne). In addition Bob Martin and Bob Farquharson are supervisors of Chan Phaloeun studying for a PhD at the Royal University of Cambodia in Phnom Penh (see Chan *et al*. 2009). Bob Martin and Bob Farquharson are members of the Editorial Board of the International Journal of Environment and Rural Development (see http://int-erd.org/index.php?option=com_content&view=article&id=73&Itemid=74). Bob Farquharson presented guest lectures to undergraduate students at the University of Battambang on 12 October 2009 and 24 June 2011.

The SE team has also contributed to planning (Spriggs *et al*. 2010) and developing information for project evaluation.

Undergraduate courses at UBB

In 2011, Bob Martin delivered the Plant Protection course at UBB. This is a 60 hour series of lectures delivered to 3rd year undergraduates – approximately 60 students in 2011 and 140 students in 2012. A component of the Farm Management course is also delivered – on-farm economic analysis. The course notes focus on upland cropping systems and draw heavily on data collected in ASEM/2006/130.

8.3 Community impacts – now and in 5 years

Eight focus village clusters were established in Samlout (4) and Pailin (4). Farmers have attended field days and have been involved in discussion about the adoption of new technologies presented. Farmers are interested in adopting new technologies such as improved varieties and rhizobium inoculation. Further experimentation, economic analysis and discussion is required to see if farmers will adopt fertiliser application.

8.3.1 Economic impacts

Gross margin analysis indicates that improved varieties and rhizobium inoculation have the potential for significant economic impacts. Experimental yields for the focus crops are more than double the average being achieved in farmers' fields. With improved agronomy and weed control, farmers should be able to achieve these yields and obtain a significant increase in cash income.

The most significant economic factor facing farmers in NW Cambodia at present is the increasing cost of farm labour. This has resulted in rapid adoption of selective herbicides to replace hand weeding in maize and soybean. It is anticipated that the cost and shortage of labour for harvesting will lead to the adoption of machine harvesting of maize in the region. This will open the door for demonstration of reduced and no-tillage crop production.

8.3.2 Social impacts

During 2009, we commenced evaluation of Social Network Analysis (SNA). SNA views social relationships in terms of network theory consisting of nodes and ties. Nodes are the individual actors within the networks, and ties are the relationships between the actors. The resulting graph-based structures are often very complex. SNA was used to determine the information and knowledge transfer regarding herbicide use in soybean. This will enable us to identify suppliers who can import rhizobium inoculants, other inputs and calendar-based extension alerts. SNA was also used to identify the key actors in the farmer/grain trader network.

8.3.3 Environmental impacts

The potential positive environmental impacts of the project are significant. The project focussed on (a) reducing the need for application of artificial fertilisers through biological nitrogen fixation by rhizobium inoculation (b) reduced soil erosion through reduced tillage and (c) reduced pesticide residues by encouraging IPM.

8.4 Communication and dissemination: rollout of project outputs

MJP

MJP has been conducting agricultural interventions in Samlout (10 villages) since 2007 through farmer field training schools. The ASEM/2006/130 project staff were integrated into the MJP Agriculture Program in 2008. In 2007, 11 demonstration field days were held with over 50 participants, in 2008, 59 field training schools were established with 303 farmer participants, in 2009 there were 59 schools with 343 farmers and in 2010 41 schools were formed with 301 participants. These schools have been established to build the capacity of local farmers to produce cash crops, raise livestock, maintain home gardens, establish fish ponds and grow fruit trees. ASEM/2006/130 provided technical support to the cash crop program.

A survey conducted on 302 out of a total of 857 Widow and Vulnerable Households (WVF) in the target area showed that the economic and food security situation of these households has improved considerably compared to the situation that existed before 2007. WVF are those families that were classified as the poor and poorest households in the 2007 baseline survey. The survey focused on reviewing MJP's agricultural interventions, which have been delivered and implemented in all target villages. It aimed to: (i) assess the food security situation of WVF (ii) identify the strengths and weaknesses of agricultural interventions (ii) re-identify constraints and opportunities (iv) and review activities that have been implemented to help with the planning and renewal of agricultural intervention strategies.

One of the criteria that the survey reviewed was the size of households; this factor influences household income, which is an important determinant of food security. The average number of family members in each household did not change significantly between 2007 (before the project commenced) and 2010 (after implementing the project in the area), and remained at approximately 5 people per household. Family labour supports the daily needs of the household, and was on average 3 people per household.

The size of land that households have access to was one of the criteria used by MJP to classify the poverty status of households in a 2007 baseline survey. Landholding size was chosen as a socio-economic indicator as it can have important implications for food security. As 84% of the income received by vulnerable households in the Samlout Target Area (STA) is generated by on-farm activities, access to land can strongly influence a family's ability to produce crops and generate income. The survey revealed that 16% of all WVF in the area increased the size of their land from under 3 ha to between 3 and 5 ha per household. This can be seen as a positive improvement as it has raised the total potential crops or livestock that these families can produce; increasing household income and reducing the risk of food insecurity. However, although many farmers increased the size of their farms, 28% and 46% of all households in Samlout are still in the poor (between 1 and 3 ha) and poorest (equal to or less than 1 ha) category respectively, based on landholding size only. Amongst the households interviewed, 30% of households recorded that they rent, on average, 1.4 ha of land and make an average rental payment of $183/ha a year.

A key component of MJP's agricultural support are technical support packages (TIP) for cash crop, home garden, fish ponds, pig and chicken raising, aimed at improving livelihoods and food security. These have played an important role in alleviating food shortages in the target areas.

Despite the important progress that the TIPs have achieved in improving farming techniques and household income, constraints to the uptake of these innovations have restricted the extent to which they have been able to alleviate poverty and eliminate food shortages. The survey revealed that farmers that attended training events, on average, retained around 50% of the agricultural technical knowledge provided to them in the TIP. Of those families that did not adopt the TIP, 45% said that economic problems within the household were the main constraints to adoption. Another 22% did not understand the technology or know how to apply it, and 24% found it too difficult to apply. Furthermore, the survey found that over 10% of respondents did not adopt the new improved technologies because the materials and tools required were difficult to find or unavailable in the area in which they lived.

Subject Matter Specialists (SMS), MJPs community extension workers responsible for disseminating the TIPs, need to take this information into account and review their training methodology and materials/tools to ensure that technologies are more easily understood and the TIP adoption rate is improved. The SMS should also aim to ensure that the inputs required for the TIP are easily acquirable locally and should work to address any market constraints.

Another factor that has compounded the problem of low technology adoption is the poor level of education within the community. The survey found that the average education level attained by the head of the household was very low. The head of households are the key decision makers for income expenditure and farm production. On average, these community members finished their schooling after completing Grade 3. While this shows the challenges the SMS team face in disseminating new technologies, it also reinforces the need for them to conduct training activities that are suitable to the learning abilities of the community. Improving the pedagogical and facilitation skills of staff in delivering/innovating new technologies to farmers is instrumental to increasing the efficacy and uptake of MJP interventions.

An important reason why farmers have been able to reduce or eliminate food shortages is the increase in cash crop yields from year to year. For example, maize yields increased from 4 t/ha in 2006 to >5 t/ ha in 2010. MJP's farmer training schools have played an important role in this increase; farmers applied 65% of the technical knowledge provided to them on cash crop cultivation. Unlike the other crops grown in the area, the yields of mungbean and sesame have slowly declined from 2008 to 2010. The reason for this decline is related to weather conditions, such as excessive rainfall during mungbean harvesting and disease that affected production of both crop species. Along with increases in the yields of cash crops, crop prices have also improved significantly from 2008 to 2010. Nonetheless, the cost of production has also increased over this period, especially the cost of labour.

Another problem that the survey identified was related to the agricultural kits that MJP provided to farmers engaged in crop production. The survey found that while the kits were effective, an insufficient number were being provided to WVF. For example, most farmers had 2 hectare farming plots and required two agronomy kits to produce crops on their available farming land, however, MJP provided only one kit which would only be of use for 1 hectare of land. As a result, some farmers did not have enough inputs to reach the maximum production potential of their land and often had to buy or borrow extra inputs on credit from middlemen or financial institutions that charged high interest rates. Ensuring that sufficient agricultural kits are provided to WVF is an important step in enabling increased production and thus enhancing food security.

Despite these problems, there are many opportunities to improve the impact of agricultural activities in the region. Cooperation with local authorities can and should be improved, especially with the Provincial Department of Agriculture (PDA), which currently has minimal involvement with MJP's agricultural interventions. Experience has clearly shown that greater collaboration with local and provincial authorities has helped projects meet their goals and objectives in a more sustainable fashion. Local geography and resources in the area are also very favourable to agricultural production and provide substantial income-earning opportunities if properly managed.

In order to effectively assess the needs of WVF they were asked what they thought was the best way they can improve their livelihoods; 30% of farmers viewed the expansion and diversification of cash crops as the best activity whereas 22% thought that improved livestock raising was of most importance. With regard to the MJP interventions that WVF thought were most beneficial, 28% of farmers thought that MJP should provide more crop production materials and seed, and 23% viewed the reparation of rural roads as the most important form of support. According to the respondents, these actions will most effectively improve the economic status of households in STA.

CARE

ASEM/2006/130 was aligned to the AusAID Australia Cambodia Integrated Mine action Project (ACIMA) via CARE in Pailin as a means of rolling out project outputs to a wider audience of farmers. Relevant activities of the two projects were closely integrated. ACIMA targeted 3,485 households (18,122 people) from 2006 to 2011. Target households received support to improve their cash crop growing (60%) and post-harvest activities (50%) by the end of project.

At the end of the project, of maize production per hectare was increased by 55% for EWS crops and by 29% for MWS crops compared to the baseline survey. Mungbean production was also increased but the yields were only around ¼ that expected from best-practice. Although soybean yields were greater at the end of the project, the area sown had reduced. Crop diversity had decreased during the course of the project with a shift towards intensification of maize production.

Improved technologies most readily adopted by ACIMA households were improved varieties and improved crop establishment practices for maize. There were no reductions in the amount of ploughing or increases in straw mulching, fertiliser application or rhizobium inoculation. However, as a result of project activities, farmer awareness of the negative impacts of the improper use of pesticides had increased.

The biggest problems in crop production reported by farmers were drought and insect pest damage. The number of farmers reporting drought problems was less at the end of the project but the number reporting insect pest problems remained the same.

8.4.1 Making use of all available communication options

To help spread the new ideas and technologies beyond the areas where the MJP Foundation and CARE International are currently working is the next challenge. There are four avenues for reaching farmers—through provincial government extension offices, NGOs, the private sector and the education sector (Figure 14). They all have different strengths and to be successful, we need to look at all of the options.

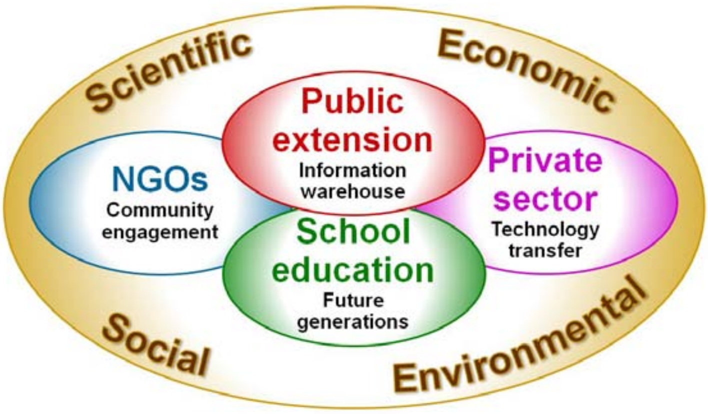

Figure 14. Potential sources of information for farm households.

This project has produced a number of hands-on manuals for growing upland crops. These are valuable resources for the public sector extension services, and other extension providers, such as NGOs. Since agricultural input suppliers reach all the farmers, talks are under way to engage them to transfer technology. The ones we've spoken to are keen to hand out leaflets or booklets with the seed and agricultural products they sell. There is a lot of value in getting information out about the safe use of pesticides and having instructions in Khmer on the safe and effective use of the chemicals. Farmers need access to techniques that improve sustainability. These include crop rotations, reducing the amount of tillage and adopting conservation agriculture-type principles.

9 Conclusions and recommendations

9.1 Conclusions

On-farm trials and demonstration of improved production practices

Maize, peanut, soybean and mungbean were shown to be capable of exceeding the predicted yield potentials of 10, 6, 3 and 2 t/ha. However sustainable crop production is threatened by excessive cultivation and burning in NW Cambodia. Demonstration of no-tillage and conservation practices was limited by lack of equipment in ASEM/2006/130.

Rhizobial inoculation can increase the yields of legume crops (mungbean, peanut, soybean) by 10-15%. Because of the low cost of the inoculum, these yield increases translate to a significant increase in profit. Farmers would readily adopt rhizobial inoculation if the inoculants were available.

As a result of project activities, farmers understand and recognize the value of IPM. However, lack of key inputs such as biological pesticides (eg Dipel) are preventing adoption.

The gross margin for peanut ($1,566/ha) is almost three times that of maize. Despite this, farmers are reluctant to grow peanuts because of the high cost on inputs and the extra labour required at harvest. Another uncertainty is the availability of markets for expanded production of soybean and peanut.

Socio-economic issues for improved technology assessment and adoption

The project focussed on six new technologies: introducing improved crop varieties; rhizobium inoculation; applying nitrogen fertilizer (urea) to maize; changes in crop rotations or crop sequences; the use of reduced or conservation tillage; and Integrated Pest Management (IPM) for insect control. Improved in-crop weed control in arose for consideration during the project.

Rhizobium inoculation can produce up to 600% Return on Investment (ROI) for legume crops. Farmer workshops at Samlout in 2011 revealed that 81% of farmers would adopt inoculation and 19% said they would not adopt. The non-adopters appeared to be less convinced there was a relative advantage due to lack of observability.

Improving post-harvest management and communications along the supply chain

The value chain is rapidly evolving in NW Cambodia. Thailand is no longer the sole market, the number of large scale receival points has expanded and the level of competition to attract middlemen has increased.

Discussions with large-scale silo managers point to the potential viability of smaller scale storage facilities at the 3,000-5,000 tonne scale.

During the life of the project there was a rapid expansion in the number of large scale grain storages in Pailin and adjacent to Samlout. Grain storage and drying capacity grew from 7,000 tonnes in 2008 to at least 140,000 tonnes in 2011. Opportunities for collaboration with these operators should be explored.

Despite the potential for increased competition with the entry of new silos, the price for maize appears to be relatively insensitive to peaks in the world price.

The grains belt in NW Cambodia is not well placed geographically for export because of the cost of freight and the cost of handling at ports. Although significant exports of maize are being reported, this does not appear to correspond with Government statistics.

Regional value-adding through construction of feed mills and feedlots is an alternative option.

The concept of the Northwest Agricultural Marketing Association (NAMA) has been overtaken by the rapid expansion of grain receival facilities in North-Western Cambodia with the number of large silos servicing Palin/Samlout expanding from one to at least five during the life of the project. The new silos have different corporate objectives and competitive strategies and it is unlikely that they would work together as part of a silo association.

Development of improved communications between different levels of the supply chain using SMS technology

Despite the apparent interest in SMS shown by farmers, the technology is far from becoming a reality. Although 80% of farmers in Samlout have mobile phones, only 3% use SMS. However 55% of farmers use the mobile phone to obtain farm business information.

A large percentage of farmers purchase seed from the silo or middleman and therefore are not free to shop around for a higher price.

With at least five major silos now operating in the Pailin/Samlout area, the competition has increased. Prices are posted by the silos daily during receival periods and any SMS system would need to have real-time price information. This does not seem to be achievable.

The exchange of information about production and marketing of produce at the local level is dynamic and fluid. It is likely that improved communication in the supply chain will come from variety of options.

Suppliers of seed, fertiliser and agricultural chemicals are also the most important source of information about their use.

Value chain and marketing outcomes with NGO partners

Poor household financial management and planning skills within the community contributes to the problem of debt, and act as a constraint to reducing poverty. The lack of basic business skills prevents farmers from implementing improvements in efficiency. Improving farmers knowledge and management of expenditure and income is a crucial step in allowing them to start treating the farm as a business and fostering the emergence of profitable smallholder agro-businesses.

Farmer cooperatives formed by the project generated significant capital gains and successfully managed seed, cash credits and savings for the target community. The cooperatives helped community to build solidarity and reduced reliance on the private sector for access to agricultural inputs at reasonable price and acceptable quality. Farmer cooperatives proved to be a viable provider of credit, a reliable source of market information and forum for sharing improved agricultural techniques.

Simulation modelling of for climate change adaptation strategies in Australia

In the short term climate change scenario to 2030, it has been suggested that farmers could exploit existing strategies developed to cope with existing climate variability. These strategies included: varying crop residues at sowing; varying plant population; varying row configuration; changing the sowing window; and varying the crop duration. Some of the climate change adaptation options favoured by farmers did not deliver the expected results. These included reducing planting density, skip row configurations, early planting and quicker maturing varieties. Gross margin budgets were used to estimate individual crop profitability under the different scenarios.

Communication and dissemination

The project partnerships with MJP and CARE proved to be very effective for rollout of project outputs to a wider audience of farmers. The PAR approach is consistent to the approach employed by the NGOs. CARE, in particular, was able to roll out project outputs through support from the AusAID ACIMA project. Unfortunately CARE was unable to obtain on-going support from AusAID and have had to withdraw from Pailin.

9.2 Recommendations

Recommendation 1. *Research and demonstration of no-tillage and conservation farming practices should be the focus of future projects in NW Cambodia to prevent or delay the rate of soil degradation which has already commenced.*

Recommendation 2. *Options for rhizobial inoculant supply in Cambodia should be explored by: (a) establishment of a rhizobium culture laboratory in Cambodia; or (b) encouraging the private sector (eg silo input suppliers) to import and provide short-term storage and distribution of inoculants to farmer clients*.

Recommendation 3. *Local input suppliers should be engaged to improve the knowledge and choice of inputs such as seed, fertiliser and chemicals as well as for the provision of advice on more environmentally-friendly practices.*

Recommendation 4. *Some of the large-scale silos currently provide hybrid maize seed to farmer clients on credit. A similar arrangement should be explored for the promotion of diversification crops such as soybean, peanut and mungbean.*

Recommendation 5. *Further socio-economic research is required to better understand and overcome constraints to adoption of improved technologies and sustainable farming practices.*

Recommendation 6. *There are emerging opportunities for entrepreneurial medium sized traders but market forces should be left to determine which ones succeed and it would seem that intervention would be inappropriate.*

Recommendation 7. *The large receival points appear to have an interest in investing in such local storages so interventions should be of a facilitatory nature only in the first instance.*

Recommendation 8. *Partnership opportunities with grain receival points should be explored for improving the quality of grain delivered. This could involve workshops using MJP's existing farmer field schools for farmers and collectors on the quality standards KOGID is looking for and the price premiums for delivery of higher quality grain.*

Recommendation 9. *Large-scale grain receival points should be encouraged to invest in setting up a micro-storage facility at the farm/village/commune level (Samlout). This could go a long way towards improving the quality of grain delivered to processing facilities and would be of mutual benefit to the farmers, collectors and the buyer.*

Recommendation 10. *Mechanisation of the harvesting operation for small-scale farms could improve the quality of the product and at the same time reduce the damage to the cropping fields. Options for mechanisation should be explored with the large scale storage facilities.*

Recommendation 11. *More research might be required with regard to the determinants for prices down the value chain as well as to better understand conflicting statistics regarding prices and exports.*

Recommendation 12. *Opportunities should be explored for value-adding and a shift away from export of undifferentiated low value (and often poor quality) raw commodities.*

Recommendation 13. *Further Social Network Analysis could reveal the best opportunities to improve farmer access to market information.*

Recommendation 14. *Further research is required to see if input suppliers are willing to provide extension material to the farmers on other aspects of crop production. Suppliers might also be an option to import rhizobium inoculants and biological pesticides from Thailand.*

Recommendation 15. *Follow-up research on farmer cooperatives and community savings groups formed in the project is required to assess their evolution and sustainability.*

Recommendation 16. *Additional modelling of Australian cropping systems is required to include rotation crops such as wheat, barley and chickpeas, whole-farm economic case studies are also required to identify optimum business strategies under different climate change scenarios.*

Recommendation 17. *There is a strong case for AusAID to be involved with or briefed on ACIAR new project developments. Development support from AusAID would be useful to facilitate the adoption of improved technologies and sustainable practices.*

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