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project

Farming systems research for crop diversification in Cambodia and Australia

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prepared by Professor Bob Martin, University of New England

co-authors/ contributors/ collaborators

Dr Bob Farquharson, NSW Department of Primary Industries

Ms Fiona Scott, NSW Department of Primary Industries

Ms Stephanie Belfield, NSW Department of Primary Industries

Ms Chan Phaloeun, Cambodian Agricultural Research and Development Institute

approved by Dr Caroline Lemerle

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ACIAR
GPO Box 1571
Canberra ACT 2601
Australia

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1 Acknowledgments

ASEM/2000/109 was an ambitious project which made significant advances in laying the foundations for productive, profitable and sustainable upland cropping systems in Cambodia. The achievements were the result of the project participants' teamwork, friendship and commitment that went well beyond expectations and contractual time commitments. The original participants from NSW Agriculture (now NSW DPI) were: Ms Stephanie Belfield, Ms Natalie Elias, Dr Peter Hayman, Dr Bob Farquharson, Mr John Holland and Ms Fiona Scott. Later additions to the NSW DPI team were Mr Bruce Haigh, Ms Loretta Serafin and Mr Ron Southwell. The original participants from CARDI were: Ms Chan Phaloeun (Cambodian leader), Mr Pol Chanthy, Mr Ung Sopheap, Mr Kep Poch, Mr Sieng Lay Heng, Uy Sokco, Mr Pao Sinath, Mr Hin Sarith, Mr Pin Dara, Mr Nin Charya and Mr Chapho Samrong Chittra. Later additions to the CARDI team were Ms Sakhon Sophany and Ms Srey Sinath.

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2 Executive summary

This project (ASEM/2000/109 - Farming systems research for crop diversification in Cambodia and Australia) has been a collaborative effort of researchers at the Cambodian Agricultural Research and Development Institute (CARDI) and New South Wales Department of Primary Industries (NSW DPI).

The Cambodian priority was to increase focus on non-rice upland crops for the purpose of poverty reduction. Crop intensification and diversification were priorities for CARDI research. The Australian priority was to examine cultural and crop-choice dimensions for crops other than wheat in northern NSW. The parallels in these priorities allowed a common theme of activities in each country which could be serviced by the project team.

Specific objectives of the project were to:

1. Identify and overcome constraints to the adoption of non-rice upland crops in Cambodia and non-cereal crops in north-eastern Australia by analysis of on-farm data and experimentation
2. Develop simple diagnostic and analysis tools that farmers and advisers can use to monitor the performance of their crops and how they fit into the farming system
3. Produce appropriately packaged technical and financial information.

In Cambodia, a total of 153 on-farm experiments and demonstrations were conducted between 2004 and 2006: variety evaluation (43); insect pest and disease (19); reduced tillage (22); agronomy & farming systems (69). This work has impacted significantly on the CARDI approach to research in the uplands.

A significant response to inoculation of rhizobium on legumes was identified during the Project research, and rhizobium inoculation techniques have been demonstrated to advisers in Cambodia. A rapid soil nitrate test has also been demonstrated to advisers and tested on 100 on-farm sites in Cambodia.

Field guides were produced for insect pest and weed identification in upland crops as well as Field Crop Manuals for soybean and maize in Cambodia. A 60 page book was also produced on gross margin analyses and general marketing information for the 6 focus crops in Cambodia is under preparation. This information could potentially impact on the economic improvement of on-farm profitability leading to poverty reduction.

An evaluation of the barriers to the adoption of no-tillage and conservation farming practices in Australia conducted by the NSW DPI showed that in 2000-2001, 24 percent of landholders surveyed reported no cultivation except at sowing (no tillage), 47 percent cultivated once or twice before sowing (minimum tillage) and 29 percent fell into the ‘other’ category, implying three or more cultivations (conventional tillage). Although there has been a shift towards no-till, the question was asked: “Why are almost 30% on average still using ‘conventional’ tillage?

A series of 18 focus group meetings (involving 100 farmers and 20 agribusiness representatives) was conducted in NW NSW in 2005 to identify the barriers to the adoption of no-tillage and conservation farming practices. This culminated in a national conference attended by 130 people and publication of a book of 12 case studies on no-till conversions (in press).

Improved practices identified in ASEM/2000/109 will be further developed in a follow-up project, ASEM/2006/130, 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 at all stages of the value chain from farmer to end-user.

3 Background

3.1 Key issues addressed by the project

Researchers at the Cambodian Agricultural Research & Development Institute (CARDI) and the New South Wales Department of Primary Industries (NSW DPI) had common interests in participatory on-farm research regarding the adoption of alternative crops and management practices; integrating economic, social and biophysical research to overcome the constraints to improved productivity and natural resource management. The CARDI priority (driven by the national government) to increase focus on non-rice upland crops meshed with the NSW DPI priority to examine cultural and crop choice decisions for crops other than wheat.

In Cambodia, the project focused on provinces with potential for expansion of upland non-rice crops and where the AusAID-funded extension project, CAAEP, has a strong presence, in order to ensure appropriate research/extension linkages. The provinces identified were Battambang and Kampong Cham. However, the results were seen to be broadly applicable to other Cambodian upland agricultural systems. In Battambang, the area of upland crop is expanding rapidly on newly cleared areas of fertile soils of volcanic or limestone parent material. In Kampong Cham, a large proportion of upland crops are grown on retired rubber plantations or in association with replanted rubber on volcanic soil. Cowpea, maize, mungbean, peanut, sesame and soybean were chosen as the focus crops. Farmers in upland areas attempt to grow 2 crops during the rainy season with a typical sequence being sesame, mungbean or peanut in the early wet season followed by soybean or maize. At the start of the project in 2004 there was virtually no scientific knowledge of the agronomy or on-farm management of these crops in Cambodia, hence the project started with a clean slate for the growing of these crops.

In Australia the adoption of sustainable practices and crop diversification in large-scale cropping enterprises in the sub-tropical slopes and plains agro-ecological region of north-eastern Australia has been slow. This region has also been shown to have the lowest farm product diversity. Previous work by NSW DPI had shown that changing tillage practices and diversifying crops together provided the highest returns. However the adoption of these systems had been slow. Pulse crops still make up less than 5% of the crop area sown. It is commonly accepted that a desirable level of pulses in the rotation would be 20%. Data were collected from farms which had/had not adopted the technology to identify the essential critical control points that maximise the chance of success.

3.2 Project justification

In 2002, CARDI was diversifying its research programs to include a wider range of crops and livestock production and to focus on technology that could substantially increase farmers' incomes. This was in line with the Poverty Reduction Strategy Paper of the Cambodian Government, August 2002. Crop intensification and diversification were therefore priorities for CARDI research. Most of CARDI's past research had been component research focussed on rice.

A workshop was held at CARDI in 2002 to identify the strengths, weaknesses, opportunities and threats (SWOT) for the research proposal. The key elements of the SWOT analysis were taken account of and incorporated into the design of the project (see below).

- Strengths: focus on non-rice upland cash crops and greater involvement in market access and development; a farming systems approach - farmer participation, demonstrations in farmers' fields and crop monitoring, critical control point methodology.
- Weaknesses: this was the first non-rice project in Cambodia - it was anticipated that it would be difficult to get farmers to embrace non-rice upland crops (perceived risks, variable results, access to markets); there was a lack of technical information, research and extension experience; the project needed a substantial on-ground presence in Cambodia by the Australian team.
- Opportunities: the project was well timed to address national strategic needs and was aligned with government policy for diversification; it was seen to contribute to increased production, improved human nutrition and living standards, new market opportunities, less risk of crop failure, more income for the farmer; improved research capacity, better collaboration between research and extension, participation by farmers and private enterprise - capacity building.
- Threats: poor infrastructure in Cambodia - poor roads, lack of intellectual property law, lack of rapid response availability, unsafe land areas (uncleared land mines); socio-economic challenges in both Cambodia and Australia - cultural barriers to change, the technology may not be appropriate or match the farmers' needs.

In 2002, the area cropped in Cambodia was 2.38 million ha and of this 2.19 million ha was sown to rice (92 %). The area planted to maize was 60,063 ha (2.5 %), vegetables 35,311 ha (1.5 %), soybean, 31,997 ha (1.3 %), mungbean, 29,431 ha (1.2 %), sesame 20,158 ha (0.8%), and peanut, 11,913 ha (0.5%). There were no statistics for cowpea, however it appeared to be widely grown and sold in Cambodian markets. However, with better varieties and better agronomy, it is expected that yields can be significantly increased. For example yields of up to 1.5 t/ha for soybean and 1.0 t/ha for mungbean are obtainable in the Cambodian environment.

The dryland and irrigated area cropped in north-eastern Australia was approximately 3.6 million hectares. The average percentage of this area sown to major crops during the period 1980-1997 was wheat (54%), barley (11%), oats (3%), sorghum (17%), sunflower (4%), cotton (8%), chickpea (1%) and mungbean (1%). The average annual value of production of these crops was over $2 billion. NSW DPI research had shown that, over a 10 year period, wheat yields following chickpea crops could be increased by an average of 0.9 t/ha. It was anticipated that moving to a higher component of legume in the rotation would result in additional farm productivity.

In both Cambodia and Australia the project attempted to integrate and analyse contextual (farmer) and outside (researcher) knowledge and establish an independent capability of advisers and farmers to “do their own research” after the project is completed. However, there was little information available on the soils and no technical material relevant to the major activities of farmers living in these areas. Yields of soybean, mungbean and maize were highly variable but generally well below potential. The project set out to provide extension workers and NGOs with technical information that could be included in Technical Implementation Procedures (TIPs) and technical manuals.

4 Objectives

The overall goal of this project in Cambodia was to contribute to food security at household and national levels through the development of technologies and opportunities for the production of non-rice upland crops. In Australia the overall goal of the project was to overcome the constraints to crop diversification and adoption of sustainable practices in large-scale cropping enterprises in the sub-tropical slopes and plains agro-ecological region of north-eastern Australia. Specific objectives were to:

1. Identify and overcome constraints to the adoption of non-rice upland crops in Cambodia and non-cereal crops in north-eastern Australia by analysis of on-farm data and experimentation
2. Develop simple diagnostic and analysis tools that farmers and advisers can use to monitor the performance of their crops and how they fit into the farming system
3. Produce appropriately packaged technical and financial information.

5 Methodology

The research process in Cambodia involved discussion with farmers, validation of local knowledge, documentation of case studies and conducting agronomic field experiments. Problems and research questions were identified in partnership with farmer and community groups with support from the Department of Agricultural Extension through links with the AusAID funded Cambodia Australia Agricultural Extension Project.

Farmer attitudes to the focus crops (soybean, mungbean, peanut, cowpea, maize and sesame) were surveyed and benchmarked at commencement of the project.

Fields of the focus crops were surveyed and monitored each year. Experiments in Cambodia included variety evaluation with respect to matching phenology to sowing opportunities; varietal resistance to pests and diseases; nutrition and legume nitrogen fixation; reduced tillage and mulching to minimise soil water loss during seedbed preparation; and crop rotations.

Annual workshops were conducted to provide extension collaborators with training in improved crop production technologies; implementation of on-farm trials; and to obtain feedback on adoption issues. In the final year of the project a major workshop was convened in Phnom Penh on non-rice upland farming systems for Cambodia.

In Australia, impediments to diversification and constraints to farm decision making were identified through farm surveys, farmer focus group meetings and case studies. Whole farm models were utilised and farm case studies were prepared for situations where crop diversification has been successful in each region. The focus crops in Australia were chickpea, faba bean and canola. Tools were developed for climate risk analysis of alternative crop sequences.

In Cambodia, the project focussed on provinces where an AusAID funded project had carried out agro-ecological appraisals and had strengthened the capacity of provincial extension staff to implement improved technologies. This was aimed at facilitating uptake of project results, as well as providing technical information and extension tools to the AusAID collaborators (and advisers). In both countries, there was an annual comparative analysis report/workshop in conjunction with extension collaborators.

The Project Team ran training workshops (supported by the Crawford Fund) and compiled manuals and crop monitoring procedures for extension workers. Interactive paper-based extension packages for Cambodian crops were developed based on the Cropcheck concept developed by NSW DPI.

6 Achievements against activities and outputs/milestones

Objective 1: To identify and overcome constraints to the adoption of non-rice upland crops in Cambodia and non-cereal crops in north-eastern Australia by analysis of on-farm data and experimentation.

no.	activity	outputs/ milestones	completion date	comments
1.1	In collaboration with farmers and advisers, identify research needs and do experiments and demonstrations on 200 sites for target crops (PC)	(a) Cropcheck card prototypes produced from target crop case studies	(a) Yr 1 m 3	(a) Crop check protocols developed and tested for focus crops (110 fields done).
		(b) Grower meetings to design experiments, demonstrations	(b) Yr 1,2,3 m 10	(b) 10 farmer workshops (250 farmers) to identify farming systems research priorities.
		(c) Experiments carried out and results analysed	(c) Yr 1 m 11-12 Yr 2 m 1-4 & m 11-12 Yr 3 m 1-4 & m 11-12, Yr 4 m 1-4	(c) 153 on-farm experiments on variety evaluation (43); insect pest and disease (19); reduced tillage (22); agronomy & farming systems (69).
1.2	In collaboration with farmers and District Agronomists, establish a regional network of 200 on-farm crop monitoring sites for target crops (A)	(a) Pre-season grower meetings to update crop monitoring protocols	(a) Yr 1,2,3 m 10	(a) 120 chickpea paddocks benchmarked.6 presentations. 11 experiments on climate risk for summer crops.
		(b) In-crop data collected and entered into database	(b) Yr 1 m 11-12	(b) Data collected, entered onto database and used to identify factors limiting crop yields. Results reported at workshops and conferences.
		(c) Comparative analysis of results with farmer groups	(c) Yr 2 m 1-4 & m 11-12, Yr 3 m 1-4 & m 11-12, Yr 4 m 1-4, Yr 2,3,4 m 6	
1.3	Socio-economic case studies of constraints and opportunities for adoption of new crops (PC)	In outputs table (3.2) but not flow chart (3.3a)	Not specified	In collaboration with LWRI/2001/051, survey of contemporary practices, constraints and opportunities for non-rice crops in Cambodia on 382 farm families in Battambang, Kampong Cham and Takeo.

PC = partner country, A = Australia

Objective 2: To develop simple diagnostic and analysis tools that farmers and advisers can use to monitor the performance of their crops and how they fit into the farming system.

no.	activity	outputs/ milestones	completion date	comments
2.1	Crop monitoring database updated with new crop species, information on crop phenology, varieties, fertilisers, crop protection, managing climate variability, economics and marketing (PC and A)	(a) Cropcheck database updated, analysis and training on data access and management	(a) Yr 1, m 7	(a) Cropcheck database created, analysed and incorporated into project publications.
		(b) Climate and economic risk analysis - reports and training	(b) Yr 1,2,3 m 10	(b) Climate and economic risk analysis training, reports and publications completed (some in collaboration with LWR/2001/051).
		(c) Growing guides for target crops produced and/or revised. Cropcheck cards adapted for wider use	(c) Yr 1,2,3 m 9	(c) Improved Technology Packages manual published, Maize Field Crop Manual published, Soybean FCM in preparation, Weed field guide published, Insect field guide in preparation, Gross margin guide ready for electronic publication, IPM school book in preparation. (d) Crop simulation models used to predict nitrogen fertility available to maize, use of rhizobium in soybean, and effect of delay in planting early-wet-season crops for Cambodia. (e) 6 CARDI Technical Notes in Khmer language were produced for upland crop production.
2.2	Diagnostic tools developed and tested with extension workers and farmers (PC and A)	(a) Review of existing information and tools	(a) Yr 1 m 3	(a) Virtually no extension material available for upland crops in Cambodia at outset of project.
		(b) Test procedures with farmers in field	(b) Yr 1 m 11-12 Yr 2 m 1-4 & m 11-12, Yr 3 m 1-4 & m 11-12, Yr 4 m 1-4	(b) See above, 153 trials and demonstrations carried out with farmer and extension worker participation.
		(c) Diagnostic tool kits produced for wider use	(c) Yr 4, m 6	(c) Workshop manuals and tool-kits produced for gross margin analysis, rhizobium inoculation, soil nitrate testing, soil management, crop agronomy & management, reduced tillage, insect IPM, TBIA virus testing.

PC = partner country, A = Australia

Objective 3. To produce appropriately packaged technical and financial information

no.	activity	outputs/ milestones	completion date	comments
3.1	Analysis of production, economic and social constraints to adoption of new crops.	(a) Report on applicability of results to other agro-ecological zones	(a) Yr 4, m 12	(a) See 1.3, survey data analysed and presented at National Conference on Upland Crops in Cambodia - papers in press. In Australia, report prepared on focus group study to identify barriers to adoption of no-tillage and conservation farming practices; Conference in Australia to facilitate change in conservation farming practices.
		(b) Update technical information packages.	(b) Yr 2,3,4 m 10	(b) In Cambodia, see 2.2 (c), new resource material produced - no existing technical information packages were in existence. In Australia, book of case studies of successful adopters of no-tillage and conservation farming prepared for publication. Findings of crop benchmarking reported to grower updates and incorporated into NSW DPI extension material.
3.2	Document market specifications, on-farm processing and storage requirements for target crops (PC)	(a) Document value chain for target crops	(a) Yr 1, m 6	This aspect of the project was taken over in ASEM 2003/012 which identified poor communication between different levels of the supply chain as a key constraint to improving the marketing system in Cambodia. Issues identified were: lack of marketing information on price, quality requirements and alternative buyers; and poor relationship between buyers and sellers. Electronic communications (SMS) was seen as a way to improve marketing and market information.
		(b) Incorporate economic and marketing checks into Cropcheck cards	(b) Yr 1 m 7	
		(c) Disseminate information on market specifications for target crops	(c) Yr 4 m 6	
3.3	Extension packages replicated for broader use by farmers and advisers not involved in the original activity (PC and A)	(a) Training in use of diagnostic tools and decision support packages	(a) Yr 5, m1 to m6	(a) Support was obtained from the Crawford Fund to provide 3 courses during the project. These covered training in diagnostic tools for soils (pH, rapid nitrate tests, structure texture), reduced tillage, rhizobium inoculation, economic analysis, scientific writing.
		(b) Extension packages and manuals for key crops produced for wider distribution.	(b) Yr 4 m 12	(b) 7 major extension publications were produced - see 2.1c above. These are for wider distribution and are in high demand from PDA extension staff and NGOs.

PC = partner country, A = Australia

7 Key results and discussion

7.1 Objective 1. Identify and overcome constraints to the adoption of non-rice upland crops in Cambodia and non-cereal crops in north-eastern Australia by analysis of on-farm data and experimentation.

7.1.1 Documentation of farmers' contextual knowledge – socio-economic and biophysical insights.

In Cambodia, farmer workshops were convened between July 2004 and February 2006 to obtain information about the traditional practices and problems associated with growing and marketing upland crops such as cowpea, maize, mungbean, peanut, sesame and soybean in Cambodia. The workshops were held in Ratanak Mondul District Battambang Province and Chamkar Leu, O'Rieng Ov and Tbaung Khmom Districts in Kampong Cham Province. Farm families were selected with assistance from extension cooperators and by negotiation with Commune Chiefs.

In upland areas, it was identified that farmers generally attempt to grow two upland crops during the rainy season. The first is planted in March-April and the second in July-August. The most commonly given reason for growing each crop was good market demand. High prices for the product and ease of production were of equal importance. Low cost of seed or inputs and medium or high yield potential were also important. Short duration was an important consideration for early wet season crops. The most commonly given reason for not growing a crop was damage from insect pests followed by risk of crop failure, drought or natural disaster and high cost of seed and other inputs.

The farmer workshops provided researchers with a better understanding of traditional practices and problems associated with the growing and marketing upland crops in Cambodia. This information formed the basis for farming systems research priorities for upland crops.

Strategies include: ways to manage crop input costs:

- plant breeding objectives from a farming systems perspective
- the need to develop Integrated Pest Management for upland crops
- reduced tillage and crop residue retention to reduce the impact of drought
- alternatives to application of chemical fertilisers for maintaining soil fertility.

In Australia, chickpea paddocks were benchmarked in 2002, 2003 and 2004 in NW NSW. These data were combined with data from the Pulse Australia Chickpea Competition to provide records from a total of 120 paddocks: 25 in 2002, 40 in 2003 and 55 in 2004. The growers provided information on rainfall, previous rotations, tillage practices, fallow management, soil test data, fertiliser use, sowing and, weed, disease and insect management.

The take-home messages were:

- Some growers achieved water-use efficiencies of 20 kg/mm and some as little as 5 kg/mm for their chickpeas (the average was 11 kg/mm). The wide range in WUE indicates considerable potential for the identification and elimination of yield-limiting factors.

- As much as 80% of the variation in chickpea yield is being caused by factors other than calculated plant-available water. This could include soil constraints as well as fallowing efficiency and other management issues.
- The number of herbicide and fungicide applications varied widely without having significant effects on chickpea yield. Therefore the implications for gross margins could be serious.
- The intention is to build on this data set to enable the study of economic implications and risks associated with high levels of crop inputs.

An evaluation of the barriers to the adoption of no-tillage and conservation farming practices in Australia conducted by the NSW DPI showed that in 2000-2001, 24 percent of landholders surveyed by the ABS reported no cultivation except at sowing (no tillage), 47 percent cultivated once or twice before sowing (minimum tillage) and 29 percent fell into the 'other' category, implying three or more cultivations (conventional tillage).

Although there has been a shift towards no-till, the question was asked: "Why are almost 30% on average still using 'conventional' tillage? Given the apparent advantages of these technologies and the efforts to promote them by many organisations, it seems surprising that the adoption figures are not higher."

A series of 18 focus group meetings (involving 100 farmers and 20 agribusiness representatives) was conducted in NW NSW in 2005 to identify the barriers to the adoption of no-tillage and conservation farming practices. This culminated in a national conference attended by 130 people co-sponsored by the Grains Research Development Corporation (GRDC), the University of New England (UNE) and the Namoi Catchment Management Authority (CMA). The outcomes of the conference were:

- The formation of a national working group to act on the barriers identified
- Publication of a book of 12 case studies on no-till conversions (in press)
- Commitment from CMAs to support the development of a farmer workshop series to assist farmers to adopt no-tillage and conservation farming practices.

7.1.2 Research ideas (outside knowledge) validated on-farm.

In Cambodia, 153 on-farm experiments and demonstrations were conducted between 2004-06 included: variety evaluation (43); insect pest and disease (19); reduced tillage (22); agronomy & farming systems (69).

Most of these experiments were carried out on farmers fields in collaboration with the Office of Agricultural Extension (OAE) and Provincial Department of Agriculture (PDA). Farmer field days were held at some sites and farmers expressed considerable interest with the tested improved technologies such as the new varieties, rhizobium inoculation, straw mulching and integrated crop management.

In 2005-06, 11 experiments were undertaken in Australia to study the risk of growing summer crops (cowpea, maize, mungbean, peanut, sesame, sorghum, soybean, sunflower). These crops are similar to those grown in Cambodia and provide better opportunities for collaborative research between the two countries.

At the end of year 3, suitable varieties of mungbean and soybean were identified for release to upland farmers in Cambodia. Other crops require further work, some of which will form part of the regular CARDI research activities.

Evaluation of upland crops for resistance to major pests and diseases revealed the susceptibility of currently recommended varieties and varieties with greater resistance were identified. These varieties will be a significant component of integrated pest management practices for the uplands.

Further evaluation of soybean and mungbean varieties is underway with funding from the Cambodia Agricultural Research Fund (CARF). This work is under CARF Project ID: CARDI 56 “Soybean and mungbean improvement for Cambodian farmers” and CARF Project ID PLNSA 97 “Improvement of groundnut (Arachis hypogea L.) management and production through farmer participatory research”. Additional CARF projects inspired by the Project on upland farming systems includes CARF Project ID: WV 64. “Identification of second alternative crops following rice using zero tillage” and CARF Project ID CARDI 57. “Crop management for sustainable upland crop farming”.

Zero till research in Cambodia revealed significant advantages for this technology particularly when the farmers realized they could produce similar grain yields from no tillage as produced after ploughing.

The increasing cost of fuel has encouraged farmers to examine this technology closely – one farmer admitting that he now ploughs shallower than in the past to conserve fuel. The modification of farm equipment by the agricultural engineers resulted in a chisel plough which killed weeds more effectively and reduced fuel consumption. Other prototype equipment developed by the Project may also prove useful for the uplands of Cambodia.

This work has impacted significantly on the CARDI approach to research in the uplands. As a result research on long term tillage has been relocated from Kampong Cham to Preah Vihear where the effect of tillage methods will be measured over a 5-10 year period or longer.

Weed control proved to be the greatest problem for zero tillage practices. In-crop herbicides were used but other non-chemical methods evaluated on different trials included the effect of rice mulching on the establishment and growth of upland crops in Cambodia. Rice straw at 3t/ha provided good ground cover and significantly increased the yield of upland crops. Future research may concentrate on the use of existing trash to reduce the cost of transport and increase profitability.

Rhizobium inoculation significantly increased yield of soybean (8%) mungbean (8%) and peanut (8%) under Cambodian upland conditions. Some results indicated an increase of up to 20% using this technology revealing the potential to increase productivity reasonably effectively if inoculum is available. A proposal needs to be developed on how this is to be achieved in a developing country possessing low levels of refrigeration.

7.1.3 Socio-economic case studies of constraints and opportunities for adoption of new crops.

In collaboration with LWRI/2001/051, a survey of contemporary practices, constraints and opportunities for non-rice crops in Cambodia was conducted across 272 farms in two districts of Battambang, two districts of Kampong Cham and in one district of Takeo. The main reasons given for not growing crops were:

- poor yield performance
- lack of knowledge (especially about insects)
- concerns about profitability, land/soil constraints
- labour/equipment issues
- agronomic and climate risk (including drought).

These results support the results of the farmer workshops described in Section 1.1. They also point to the need for focused research on new technologies and management as they affect crop yields and profits, and for increased extension to Cambodian farmers of this information.

7.2 Objective 2. Develop simple diagnostic and analysis tools that farmers and advisers can use to monitor the performance of their crops and how they fit into the farming system.

7.2.1 Diagnostic tool kits for soil management and plant protection.

Draft field guides have been produced for insect pest and weed identification in upland crops in Cambodia. These insect pests and weed problems were initially identified by the farmers at field days, during socio-economic surveys, from Provincial Agricultural Officers from the extension section and directly from farmers at the on-farm trial sites. When completed, the guides will consist of a photograph of the weed or insect and a description in Khmer language. Both the field guides of major weeds and for insects will be ready for publication in May, 2007.

A significant response to inoculation of rhizobium on legumes was identified during the Project research and rhizobium inoculation techniques have been demonstrated to advisers in Cambodia. A rapid soil nitrate test has also been demonstrated to advisers and tested on 100 on-farm sites in Cambodia.

There is a need for a field guide for the management of upland soils in Cambodia. Soil samples have been analysed for the basic elements (NPK) and described physically by this Project and others. However, a series of fertilizer trials need to be conducted for the development of fertilizer recommendations. Much of this information could be provided by the Soil and Water Section of CARDI, possibly through the ACIAR funded LWRI/2001/051 project.

7.2.2 Seasonal calendars of crop phenological development relative to seasonal events

Seasonal calendars developed for the focus crops. Training was provided to extension cooperators on field benchmarking for crop yield potential and fertiliser needs. One hundred fields were benchmarked for soil fertility and suitability for upland crop production.

Risk of sowing in the early wet season appears to be a major issue that requires further climate and economic analysis. The risk could be reduced by reducing the amount of ploughing and increasing the amount of ground cover but this is not likely to be enough to prevent crop failure during very dry years. Including upland rice in the rotation could be an alternative to spreading rice straw as a way of increasing ground cover. Waiting for enough rain to store soil water in the soil could be an option to reduce the risk of crop failure.

In Australia, work commenced on the "CropChoice" seasonal calendar in Australia. Its value was recognized by GRDC who took over this responsibility to develop the useful "CropMate". Cropmate includes wide ranging information including potential rainfall to assist with crop management systems.

7.2.3 Cropcheck type system developed for Cambodia – adapted to target crops and socio-economic needs.

Cropcheck protocols were evaluated on 110 Cambodian farmer fields in 2004. Useful information was obtained about cropping practices and production problems. This was reported in project publications and incorporated into the improved technologies manual and field crop manuals. Training was also provided for Cambodian extension collaborators on field benchmarking techniques. However, crop checking is an intensive extension activity that requires facilitators to have a high level of knowledge of factors affecting crop production. This level of expertise in upland cropping systems is beyond the capability of most Cambodian extension workers at present. Crop checking also

requires the extensionist to facilitate farmer group activities at 5 - 6 times during the crop cycle. Provincial department of agriculture staff do not currently have the on-going resources for this level of activity.

7.3 Objective 3. Produce appropriately packaged technical and financial information.

7.3.1 Analysis of production, economic and social constraints to adoption of new crops.

A socio-economic survey was undertaken in 2005 which assisted in developing research priorities based on farmer needs. Research in the project identified promising improved practices and technologies to address these needs and these were presented to farmers in pilot on-farm trials of improved technologies based on the results. The strategies to address production and economic constraints were:

- Improved varieties
- Application of basal fertiliser
- Rhizobium inoculation for legumes
- Nitrogen topdressing
- Reduced tillage and addition/retention of crop residues.

Farmers at field days at trial sites displayed considerable interest in the new technologies and individual farmers have tried parts of the technology practices on their own farms. Farmer feed-back at these field days was recorded to allow the refinement of the improved technologies and practices in the future. The value of the on-farm trials is enhanced when they are implemented in combination with farmer field days and field schools. Farmers have the chance to observe and discuss the results and to have input into the design of future trials. Potential economic and social constraints to adoption of these strategies were identified and are being addressed in a new project ASEM/2006/130.

In north-western NSW there is an extensive body of knowledge underpinning the problem of soil erosion and soil fertility decline associated with traditional cultivation practices. However, after almost 30 years of research, only 50% of farmers have adopted no-tillage and conservation farming practices. Focus group workshops identified a list of technical constraints. However, case studies of successful adopters showed that these constraints were not insurmountable. The new project, ASEM/2006/130 is investigating the adequacy of existing extension strategies as well as socio-economic constraints to adoption.

7.3.2 Technical information packages that disseminate findings outside the study areas

Farmer workshops and meetings identified the constraints to upland crop production. This information was used to design research trials to overcome the constraints. Such trials contributed data for the development of field crop manuals. At the end of year 3, draft Field Crop Manuals for soybean, maize, mungbean, peanut, cowpea and sesame were prepared in collaboration with extension staff in Cambodia. Included is information on suitable varieties, costs, markets, time of sowing, nutrition, rotations, insects, pests and diseases, harvesting and grain storage. It is expected that the manuals will contain information for general use both in the study provinces and other areas. The first edition is expected to be published by May, 2007.

7.3.3 Guidelines to assist Cambodian farmers meet market specifications for cash crop products.

A set of financial results on the new cropping technologies were prepared during the initial three year project period. These analysis tools will give confidence to extension workers promoting new management. To assist with this process a 60 page book of gross margin analyses and general marketing information for the 6 focus crops in Cambodia is under preparation. This information could potentially impact on the economic improvement of on-farm profitability leading to poverty reduction.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The scientific publication output of the Project has been significant with the completion of:

- 13 papers for the Cambodian Journal of agriculture (2 published, 11 in preparation)
- 7 Extension publications in Khmer language (in preparation)
- 6 CARDI Technical Notes on upland crops (Cambodia)
- 6 advisor updates (Australia)
- 5 International conference papers
- 2 Research reports (Australia)
- 4 Honours theses in Cambodia
- 2 Honours theses in Australia

Project personnel have contributed 11 papers for a special edition of the Cambodian Journal of Agriculture. The work has also encouraged one student from Australia and one from Cambodia to study for their PhDs at Australian universities and for the Crawford Fund to support three courses in Cambodia.

Successful Project activities have encouraged others to apply for funding from the CARF (see details in 2.4 above) to conduct research in the uplands. The results of some of these research programs will feed directly into a new project ASEM/2006/130 *Enhancing production and marketing of maize and soybean in north-western Cambodia and production of summer crops in north-eastern Australia.*

Sesame research in Australia may directly benefit from ASEM/2000/109 through the discovery of a non shedding variety during a study tour to Vietnam. The variety is now in Australian quarantine and may revolutionize the way sesame is cultivated in both countries. Options for other cropping patterns identified in Cambodia will also be evaluated in Australia.

8.2 Capacity impacts – now and in 5 years

Personnel from both the Cambodian and Australian teams have benefited considerably from working on the Project in addition to the general public and farmers. Three Crawford Fund courses were conducted in association with the project:

- Farming Systems for Crop Diversification in Cambodia. The course comprised 2 components. The first was a 3 day workshop held at CARDI (15 -17 February 2005). The second component involved three weeks of practical training on principles of conservation farming practices (21 February – 11 March 2005).
- Scientific Writing Workshop for Cambodian Agricultural Scientists. The course was held over 5 days at CARDI (4-8 June 2007).
- Improved practices for upland crop production in Cambodia. Training courses in soil management, crop agronomy and economics of production for extension workers and key farmers. Samlaut: 7-10 February 2008 and Pailin: 11-13 February 2008.

Cambodian researchers have improved their knowledge by implementing the Farmer Participatory Research (FPR) based research program, attending meetings, conferences and training programs, field visits and study tours, plus preparing scientific papers.

Australian personnel joined many of these activities and learned from their Cambodian counterparts technical aspects of tropical regions. They will also benefit from the publications resulting from the Project. Research personnel will be able to put to use these experiences for the benefit of other programs in both Cambodia and Australia. Hopefully, extra funding will become available for CARDI to continue related research as designed in the Master Plan for National Agricultural Research, Cambodia (MAFF, 2006) and utilize this expertise in a constructive manner.

In addition, ACIAR funding (John Allwright Fellowship) will support one Cambodian PhD scholar from the Project to complete his studies in Australia. GRDC has also awarded one Australian Project officer to complete her PhD in Australia. Additionally, five Cambodian and two Australian honours students have to date completed their final year thesis studies with Project funding. Two volunteers were also sufficiently enthused by Project activities to visit Cambodia to help further the insect field guides over an 8 week period.

Farmer meetings (six to Feb. 2006, plus two field days in June, 2006) were initially designed to collect information from the farmers. Interactions with the farmers during these events and through their collaboration during the implementation of the trials has improved farmer understanding of issues such as “friendly” insects and rhizobium for nitrogen fixation. Some farmers are altering their practices because of their direct experiences. Adoption may be measurable at a later date. Provincial extension and agricultural personnel were similarly influenced by their interactions with the program.

Project staff have also benefited from short term training in Australia (2 Cambodians going in 2004) and by joining study tours to Thailand and Vietnam (Both Australian and Cambodian researchers). Their experiences made an impact on the science implemented in Australia and Cambodia.

8.3 Community impacts – now and in 5 years

In the words of the project's reviewer, the goal and objectives of ASEM/2000/109 were very ambitious. It would be extremely difficult for any agricultural research program to help “reduce poverty and contribute to food security at household and national levels” within a three or four year period. This is now being attempted in the project's successor ASEM/2006/130 and it is expected that these impacts will begin to be realised during the next 5 years.

8.3.1 Economic impacts

It is too early to measure significant economic impacts from this Project. Yield increases from improved varieties and technology and from an expansion of upland areas are not yet attributable to the Project in Cambodia within the three year project execution period.

In Australia, the working groups established as a result of the Project will almost certainly encourage the adoption of increased areas of zero till technology and include legumes in the rotation. Wheat grown after legumes is expected to increase grain production by up to 20% providing significant improvements in profitability. Adoption of zero till practices will also increase profitability.

Measurements may be possible after year 4 to evaluate the economic advantages of the project recommended technologies in both Cambodia and Australia, although these benefits may take much longer to accumulate.

8.3.2 Social impacts

The Project has influenced the way that farmers think about no till and associated technologies in Australia and Cambodia. Project sponsored workshops in Australia have encouraged the development of farmer based working groups to discuss the pro’s and

cons of adopting zero till technologies. This has led to the adoption of reduced tillage by an increased number (yet to be measured) of farmers in NW NSW. Farmers spend less time on the tractor and are able to devote more of their time to other activities.

In Cambodia, cooperating farmers have been provided with alternative technologies to deep ploughing. The rising cost of fuel should increase the level of interest in reduced tillage. Farmers have viewed zero till/mulching demonstrations with special interest. Adoption of these technologies may follow in the near future rather than later. Farmers have learned from project trials that shallow ploughing or use of chisel ploughs rather than discs is not only effective but reduces fuel consumption.

Project research was conducted with a farmer participatory approach and this resulted in positive community interest. This research style also helped the researchers and extension personnel to work closer together, reducing the time necessary to “package” the technology for extension to farmers. The Project may expand its impact in other upland areas by engaging some NGOs currently working in these areas. NGOs are often well funded and organized. They generally also have a close contact with farmers which is some times more challenging in the Government sector.

Development of the uplands is considered of high importance to Cambodia, constituting over 57% of the proposed research funding in the country’s Master Plan for National Agricultural Research (2006). Government funding is currently not available and ASEM/2000/109 is the only significantly sized activity conducting research specifically on upland cropping. Other projects support land suitability studies or agro-forestry but not on farming systems research in upland crops. The existence of the Project therefore sets a standard on which other upland crop research is evaluated.

8.3.3 Environmental impacts

The environmental advantages of zero till practices are well documented. Farmers report improved soil organic matter levels (resulting in decreased fertilizer loss into the environment), decreased compaction, improved soil structure, improved crop establishment, improved water use efficiency, greater efficiency (improved time allocation) and greatly reduced soil erosion. Farmers in both Australia and Cambodia will benefit from these factors as they adopt Project promoted technologies.

Once the inoculum supply chain has been developed for Cambodia, inoculating legumes with appropriate rhizobium strains will result in reduced applications of chemical nitrogen which, if used inefficiently, can end up in streams or aquifers.

The integrated crop management practices promoted by the Project will also influence upland farmers to evaluate their pesticide application regimes. Project personnel train farmers on identifying “friendly insects” in the field for biological control and are in the process of developing pest diagnosis tools which can be used by extension personnel to expand the farmers knowledgebase on integrated pest management. A reduction in the use of pesticides will have a significant impact on human as well as environmental health.

Pesticide application on Cambodian fields are currently at a low level. However, the chemicals in use are Class 1 pesticides of high toxicity. Applications of glyphosate are considered to have low impact on the environment. Although the Project does not recommend any pesticides its use is implicit in the zero till technology. It will therefore be necessary for some recommendations to be made in the future to ensure the use of low toxicity chemicals. In Australia, some farmers are applying a very large number of pesticides – up to 13 herbicide applications or 8 fungicides are mentioned in one study on chick peas in Australia. The Project should investigate ways of reducing this number.

8.4 Communication and dissemination activities

Communication and dissemination of was an integral part of the project's activities. Provincial Department of Agriculture extension staff from Kampong Cham and Battambang provinces were engaged in all project activities. They assisted with the collection of farm survey data, facilitation of farmer workshops, and implementation of on-farm experiments and demonstrations. Extension cooperators received training in improved technologies, production techniques and economics of upland crop production. Each February, the project team held workshops with extension collaborators to discuss the results of the previous seasons activities and to plan and provide training for the coming season's activities.

Technical information packages were produced to disseminate findings outside the study areas (section 7.3.2) and guidelines produced to assist Cambodian farmers meet market specifications for cash crop products (section 7.3.3). A set of seven extension publications will be translated to Khmer for wider distribution to government and non-government extension workers in Cambodia. These publications are a significant development because prior to the project there were no extension publications for upland crops in Cambodia.

In the follow-on project, ASEM/2006/130, the communication and dissemination strategies will be complemented by web-based methods that will be used to help promote adoption of project results in order to ultimately derive the economic and other impacts.

It is anticipated that these publications will make a significant contribution towards achieving impacts in the future.

9 Conclusions and recommendations

9.1 Conclusions

ASEM/2000/019 was designed to conduct crop diversification research in Cambodia and Australia with the goal of improving sustainable production in upland farming enterprises of both countries. A review of the Project concluded that ASEM/2000/109 enjoyed a very productive relationship between Cambodian and Australian team members. The teams possessed a close sense of collaboration while maintaining a professional approach to their activities. This was seen as an indication for useful outputs and potential for making an impact on both Australian and Cambodian farming systems. At the start of the project there was virtually no scientific knowledge of the agronomy of these non-rice crops in Cambodia.

On completion of ASEM/2000/109, it was decided that a follow-on project be designed to extend and integrate results of ASEM/2000/109 and ASEM/2003/012. ASEM/2000/109 was concerned with reducing poverty and improving food security by investigating the farm production systems for upland crops (to improve cash income) in Cambodia, while ASEM/2003/012 was concerned with improving the marketing systems for upland crops in Cambodia. A review of ASEM/2000/109 recommended that the follow up project be designed to take advantage of the results of that project. The emphasis of the new project would be less on replicated trial research and more on-farm adaptive trials to evaluate and improve the technologies and practices initially tested in 2007. In line with ACIAR's shift towards larger integrated projects, the new project, ASEM/2006/130 was expanded to integrate the development of sustainable production and marketing systems in a trans-disciplinary approach.

9.2 Recommendations

It was recommended that a follow up project on upland crops be designed to take advantage of the results of ASEM/2000/109. The emphasis of the new project to commence at the beginning of 2008 should be less on replicated trial research and more on-farm adaptive trials to evaluate and improve the technology packages initially tested in 2007. Reducing risk, especially in the early wet season can be a focus. This could possibly be done with different rotations, intercropping or relay cropping with proven technology packages.

In Cambodia, the work should concentrate in the current two provinces for at least the first two years of the new project to consolidate the initial results. An expansion into other provinces can be considered in later years. Changing into other provinces will assist evaluate the impact of the new technologies on crop production and the community. The new project should also expand its activities with the extension services in both the provinces and at the central level.

Because of the high number of women heads of households in Cambodia, attention should be given to collecting gender specific information to ensure recommended technologies do not disadvantage women.

In Australia, the benchmark studies conducted on chick peas should be expanded to other legume and non cereal crops Associated with the development of extension packages should be a full understanding of the economic and social implications of their adoption by farmers in both countries.

Specific recommendations which will be addressed in ASEM/2006/130 in Cambodia are 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.
- Review and assess project impacts, and plan for further innovation and improvement
- Address off-farm constraints including 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 lack of adoption of no-tillage and conservation farming practices needs to be addressed 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 will also provide options for adaptation to climate change. Future work should include:

- A bio-economic evaluation of the technologies and strategies to reduce the impact of climate variability and climate change on farm families.
- Adaptation and development of whole-farm models for extension programs.
- Understanding the social networks that influence farm practice change with a focus on adoption of conservation farming practices.

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