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Final report

Small research and development activity

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Contents

1 Acknowledgments

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- From the University of Melbourne: Dr. Lauren Rickards, Prof. Garry Griffith, Assoc. Prof. Bill Malcolm and Ms. Angeliki Balayannis;
- From CARDI: Dr. Chea Sareth;
- From PNCA: Dr. Nou Keosothea.

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2 Executive summary

There are mixed results on adoption of improved agricultural technology and changes in management of farming systems in Cambodia. There is substantial agricultural research being conducted within the country, and there are potential benefits if an improved understanding of farmer perceptions and behaviour can lead to more adoption of agricultural technology and improvements of farm-family wellbeing. The objectives of this project were to study smallholder perspectives and decisions concerning technology adoption in agro-ecological zones and farming systems of Cambodia. It sought to broaden our understanding of this issue by including a wider range of individuals, experts, and organisations than is typical to such studies.

Observations of contemporary Cambodian agricultural practice and discussions at the ACIAR Policy Dialogue on Rice Futures in Phnom Penh emphasised the importance of agricultural labour and off-farm employment opportunities in farmer decision making. The Cambodian economy is growing and diversifying rapidly, which presents researchers, non-government organisations (NGOs), and donors with a dynamic situation in which to contribute. Adoption of mechanisation to replace animal draft power and human inputs for rice production is an example of technology adoption driven by reduced supply of farm labour and increased wages. Opportunities for off-farm employment by family members are thought to influence the adoption of new technologies. Rice and upland crop production is being commercialised as the traditional subsistence systems become semi-subsistence, with some crops sold at market. Farm-family livelihoods and social factors are increasingly important in considering decisions relating to production, particularly investment in new technologies. This project investigated the social and economic contexts of farmer adoption and decision making within lowland and upland farming systems.

Mixed social and economic methods were used in the project. A literature review analysed contemporary research, development, and extension (RD&E), focussing particularly on how the demand for, and supply of, agricultural technology is transmitted as part of agricultural extension. To understand the perceptions of not only farmers and scientists, but also agricultural development project leaders, agricultural funding managers, Cambodian government officials, and NGOs, a semi-structured interview process was undertaken to explore what they considered to be their ‘measures of success’ in the RD&E process. Field work, consisting of focus group workshops and ethnographic village research in the four target villages, was conducted to expose current farming systems, problems, and challenges, analysing what farmers considered would help to make them more successful. A farm economic analysis was conducted to consider the economic incentives in changing to new rice production technologies when the full opportunity cost of agricultural labour was included. A serendipitous piece of social research was conducted to consider the issue of agricultural pesticide use in Cambodia.

Conclusions from the different research components were as follows. From the literature review an improved understanding of barriers to adoption involves a greater focus on context and recognition of a larger number and scale of factors being influences on adopters and the adoption process. From the focus group workshops the participants in all four villages consistently responded that the majority of villagers showed no intention of leaving their farm in order to seek non-farm opportunities, but they either considered or intended to have children live outside villages or earn income from non-farm businesses. There was also widespread desire for technologies to help reduce labour requirements and increase profits. The challenges for rainfed lowland farming were water shortages, insects and diseases, and lack of new technology, and for upland farming were unfavourable rainfall (irregular patterns and fluctuation of amount), insects, roads and transport, markets, and farm-gate prices. From ethnographic research, farmers indicated their main challenges to be lack of water, many rats and insects, low productivity and low

prices, drought and flood, and many farmers being poor and lacking credit to buy agricultural inputs. From the semi-structured interviews there is an array of contradictory agendas and unequal power for funding organisations to consider when contributing to farmer decision making and the development of agricultural technologies – or to make the most of existing knowledge. For example, in explaining the importance of national directives and policy, a representative from an international donor stated that rice production

> *"is the solution or that is the goal of the Ministry of Agriculture and that it has been decreed from the top. Whether it makes economic sense for the individual household is not a concern as far as I can tell".*

The economic analysis was conducted by including off-farm work opportunities for family labour (i.e. using a family livelihoods framework), and showed that, as off-farm work is undertaken by adolescent family members, the household income more than doubles and there is an impact on rice technology choice; inversely, if labour is in short supply the adoption of new rice technologies is expected to be reduced. The pesticide research methods involved following the pesticide, examining practices involved in manufacturing and using commodities across political borders, understanding scales and actors, asking how commodities are made and used, and reconnecting commodities to their networks. A high proportion of pesticides sold in Cambodia are illegal and there is great uncertainty (quantity, type, and safe usage), a major problem is importing through Customs (graft), and famers who want fast and visible results – they are aware of the health hazards and would use less harmful methods if they were similarly effective.

Major findings and recommendations are that:

1. There are gaps in our understanding of the environment for RD&E in Cambodia and of the factors influencing Cambodian farmer technology adoption and management change;
2. Research questions arising from this observation relate to how social and economic factors and context influence Cambodian farmers as they consider new agricultural technologies. This raises the possibility that evidence from past agricultural development projects (with different levels of technology adoption 'successes) may help explain how social and economic factors have interacted with technologies in the context of successful adoption;
3. An objective of future work is to understand the role and importance of social and economic factors as determinants of past adoption decisions and develop a framework for how these factors can be integrated into future project scoping, planning, and dissemination of technologies, knowledge, and results;
4. A strategy for further work is to conduct detailed social and economic analysis of technology adoption experiences at the village level to increase understanding of the context for adoption. This is not an assessment of the level of project success (in terms of adoption), but rather an examination of the factors associated with (or determining) the level of success. The strategy includes applied research with Cambodian academic and institutional collaborators;
5. The methods will include focus group workshops, ethnographic research, semi-structured interviews, and farm-level economic analysis of representative farms and case studies using a livelihoods framework;
6. A proposal will be developed from these findings to understand social and economic imperatives for successful agricultural development and technology change. Such a project will use the above social and economic methods to assess the perceptions, livelihoods, and needs of smallholder farmers associated with previous agricultural development projects, and then consider how potential productivity-enhancing technologies can be viewed in this context.

3 Introduction

This small research and development activity (SRA) grew in part from work by Dr. Bob Farquharson in a previous ACIAR project in Cambodia (ASEM/2006/130: Sustainable Integrated Development of Agricultural Systems in Cambodia and Australia). In that project the issue of adoption of new technologies by smallholders in upland areas was investigated for potential uptake of rhizobium inoculation of legume seed by Cambodian farmers. A paper was published from this work (Farquharson et al. 2013).

That paper considered whether the processes of farm-level change and adoption of new technologies in Cambodia could be related to the adoptability characteristics of a technology. Literature posits that technologies can be assessed in terms of relative advantage, compatibility, complexity, trial-ability and observability (Rogers (2003), Pannell et al. (2006)). Other socio-economic factors may also be important in the adoption process. The analysis tested these propositions among commercial upland farmers in north-west Cambodia for rhizobium inoculation of legume seeds to increase crop yields. In promoting this technology the objective was to increase farm income and help reduce poverty and improve food security. The authors surveyed farmers who had been involved in a project that tested and demonstrated rhizobium inoculation (along with other technologies) and statistically analysed the data.

The result was that, with respect to their rhizobium-adoption intentions, relative advantage (incentive) is the predominant characteristic, with observability also being important. Other socio-economic characteristics in their adoption intentions included whether they grew legumes, the source of first contact, the period since the technology was introduced, and farm size. That the innovation demonstrated high relative advantage was confirmed by separate economic analyses of the likely return on investment for rhizobium in these upland farming systems. The authors concluded that using an approach of assessing adoptability characteristics prior to release may provide a better basis for developing and screening technologies for successful adoption, rather than trying to adapt ill-suited (in terms of these characteristics) technologies after the event. Such an approach was considered likely to be more efficient for project sponsors to achieve desirable change

Subsequently Dr. Bob Farquharson and Dr. Brian Cook developed ideas about social and economic factors which could be investigated in adoption intentions, and the current SRA was developed and funded by ACIAR. Dr. Caroline Lemerle provided valuable guidance and support in developing this project.

4 Understanding smallholder decision making

This SRA aimed to better understand smallholder decision making with regard to adoption of new or developed technologies. This was accomplished by accessing, assessing, and comparing the perceptions of Cambodian farmers. But to make sense of these perceptions, the views of Cambodian agricultural extension officials, foreign experts working to modernize Cambodian agricultural production, and organizations that fund agricultural development were also integrated (i.e. micro-finance organizations, the Asian Development Bank (ADB), and the Food and Agricultural Organization of the United Nations (FAO)). By accounting for the range of differing 'worldviews' actively shaping the agricultural development of Cambodia, the project offered a broader picture of the competing interpretations and agendas that influence adoption. In this context, the decision to adopt a new technology (e.g. new rice variety, tractor, fertilizer, new household distribution of labour, or to rent land) was explored in the context of household concerns, rather than being isolated and decontextualized.

The SRA was developed to engage with Cambodian smallholder farmers and experienced researchers in Cambodia and Australia to take a new look at the social, economic, and cultural context for technology adoption and change in contrasting Cambodian agro-ecological zones and farming systems.

The core issue addressed in the SRA was an apparent lack of understanding of the reasons for low adoption of improved agricultural technology and changes in management of farming systems in Cambodia. Despite a significant research effort over more than a decade in lowland and upland regions of Cambodia, there has apparently been little adoption of more productive farming systems based on research conducted within the country. There is an apparent disconnection between known technological advancements and farmer choice, which was the focus of this SRA.

Adoption of practices and technologies could provide small-scale Cambodian farmers (smallholders) with improved profitability and livelihoods. Previous research in the rainfed lowland rice systems has included short-duration rice varieties, direct seeding and weed management, double cropping, crop diversification, reduced tillage, and land levelling. In upland areas the research has focused on improved crop varieties, mechanisation, soil fertility management, rhizobia to inoculate legume seeds, livestock, and improved weed management practices. However, large-scale adoption of these innovations and changes has not occurred, despite indications of improved productivity. This disconnection is presently explained only with anecdote, contributing to a system in which many gains are possible, but potential pathways to those gains remain unclear.

5 Project activities

5.1 Project activities

At the start of the project Dr. Bob Farquharson and Dr. Brian Cook attended one day of the ACIAR Policy Dialogue on Rice Futures in Phnom Penh (8 May 2014). This exposure to the issues and discussions influenced the SRA in a number of ways. Specifically:

- Rice is a low profitability crop and much research appears to have been about rice productivity improvements, which may only have small impacts on farm performance and profitability, given small farm sizes;
- Economic growth in Cambodia, the emergence of off-farm work opportunities, and trends in labour migration and wage remittances have changed the nature of agricultural industries in terms of farm family objectives, management, incentives, and decision making;
- Cambodian Government policy to encourage increased rice production and exports seem at odds with the desire to maintain low domestic rice consumption prices (higher farm prices will be required to encourage extra production); and
- Expressions of doubt about research objectives of improved production and farm income when such opportunities (technologies), if adopted, are unlikely to make much difference to farm poverty levels.

This experience reinforced the research issues for the SRA, of investigating Cambodian farmer perspectives and decisions concerning adoption of technology from research projects.

The SRA then proceeded to use social and economic research methods to assess farmer perceptions, but with enhanced understanding of the contemporary context for Cambodian agricultural decision makers. Brian visited PNCA and trained staff and students in ethnographic research methods to enable them to conduct the ethnographic research.

Five research sub-projects were conducted within the SRA – a literature review, three social research activities, and an economic analysis at the farm level. The SRA also encouraged student activities and a substantial piece of work was conducted investigating pesticide issues in Cambodia.

Two Cambodian collaborating institutions, CARDI and PNCA, conducted social research and Prof. Bob Martin (ASR Cambodia Ltd) provided coordination and liaison services.

A final project workshop was held on Phnom Penh on 13 April 2015.

5.2 ACIAR Policy Dialogue on Rice Futures

Robins (2014) reported on the Policy Dialogue on Rice Futures for rice-based farming systems research in the Mekong Region. At that meeting there was strong debate and some criticism of the focus and implied objectives of many research projects (reducing poverty by improving rice crop productivity). Issues of economic growth, off-farm work opportunities, farm labour migration, and wage remittances are now very important for many smallholders in the Mekong region as they consider how to use their family resources (especially labour) to improve their livelihoods. This has implications for incentives to adopt new technologies on semi-subsistence rice farms.

The Policy Dialogue found that ‘economic development in Cambodia is moving fast’ and that, while rice and agriculture are still important, the need is to adjust: ‘the challenge is more complex than technical issues’ Wade (2014). On issues of intensification and mechanisation, the Dialogue found that ‘there is a significant gap between the information

generated by scientists and what farmers need at their fingertips to produce the crop' (Newman (2014)). With respect to policy and knowledge, the Dialogue found that 'agricultural policies need to be analysed and evaluated in terms of their impact on the decisions made by farm households and their livelihood outcomes' (Cramb (2014)). 'The World Bank recently asked if rice was the answer to poverty reduction' (Wade (2014)), who also noted that the profitability of rice remains low for farmers, so that the future of rice growing alone seems pessimistic.

Dr. Iean Russell leads an FAO project at Siem Reap studying smallholder farmers and adoption of new technologies, and he commented in a personal communication that:

> "*In an agricultural setting, I believe many of them are not really interested in being better farmers, they just want to escape that life, but lack the fortune to do so*".

5.3 Field work

Social research field work in Cambodia consisted of focus group workshops, ethnographic research, semi-structured interviews, and pesticide research.

5.3.1 Focus group workshops

The socio-economic team of CARDI, led by Dr. Chea Sareth, conducted the focus group workshops in the four target villages of the project. A summary report is in Appendix 11.1.

5.3.2 Ethnographic research

Dr. Brian Cook provided training for PNCA staff and students in ethnographic research methods. Dr. Nou Keosothea and his research team conducted a pilot of ethnographic research in Anchane village of Kampong Chhnang Province. The full ethnographic research project was then conducted in the four target villages.

5.3.3 Semi-structured interviews

Dr. Brian Cook conducted semi-structured interviews in Cambodia and Australia.

5.3.4 Economic analysis

The economic analysis was conducted by Dr. Bob Farquharson as desk-based research that incorporated case-study data from the unpublished PhD thesis of Dr. Chea Sareth (Chea 2015). The paper is in Appendix 11.2.

5.3.5 Pesticides research

Ms. Angeliki Balayannis conducted interviews and collected secondary data from field work in Cambodia on the issue of pesticide production, transfer, and use.

5.4 Project final workshop

A project final workshop was held in Phnom Penh on 13 April 2015. The workshop agenda is shown in Table 1 and the workshop participants are listed in Table 2.

Table 1: Workshop agenda, 13 April 2015

9:15 – 9:35	Open and Introduction	Bob Farquharson
9:35 – 10:00	Triangulating methodology	Brian Cook
10:00 – 10:30	Barriers to adoption	Lauren Rickards
10:30 – 11:00	MORNING TEA	
11:00 – 11:30	Focus Group workshops	Chea Sareth
11:30 – 12:00	Ethnographic research	Nou Keosothea
12:00 – 1:00	LUNCH	
1:00 – 1:30	Framing technology transfer	Brian Cook
1:30 – 2:00	Economic analysis	Bob Farquharson
2:00 – 2:30	Pesticides	Angeliki Balayannis
2:30 – 3:00	Rapporteur comments	Rob Cramb

Table 2: Workshop attendees

Names	Affiliation
Bob Farquharson, Brian Cook, Garry Griffith, Lauren Rickards, Angeliki Balayannis	University of Melbourne
Rob Cramb	Queensland University
Chea Sareth	CARDI
Nou Keosothea, Chan Phally, Seng Srey, Eap Chemsileg, Phal Chendra	PNCA
Bob Martin	ASR Cambodia Ltd

6 Methods and locations

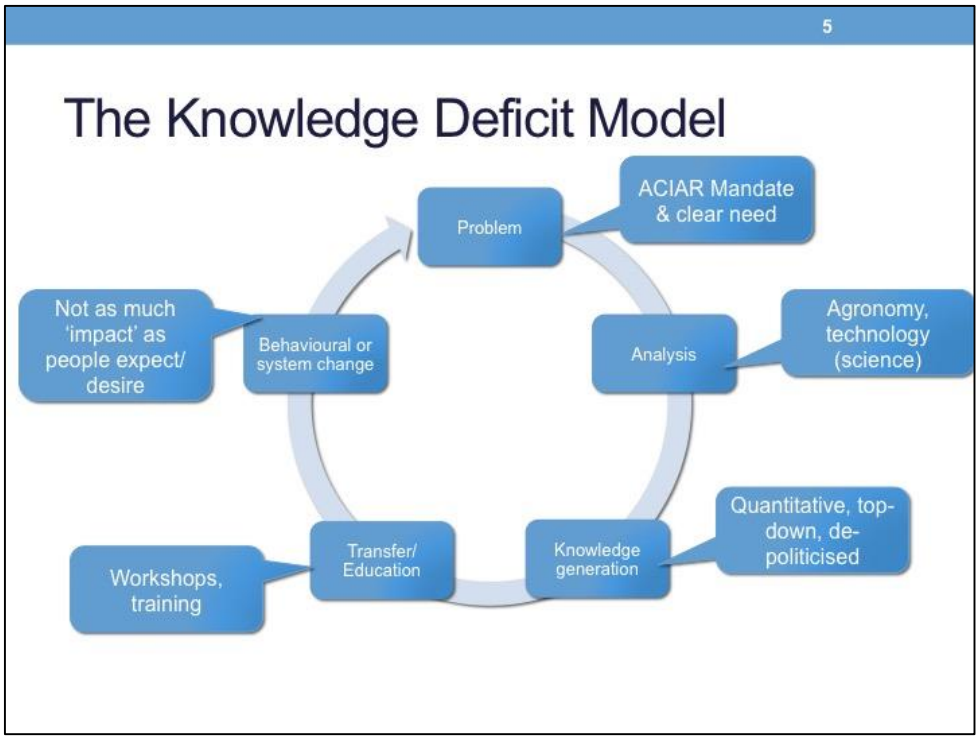
6.1 Project methods

6.1.1 Overview

At the final workshop Dr. Brian Cook noted that the project sought to develop a more holistic approach for analysing and understanding the adoption of technologies. The question of technology transfer and adoption is one burdened by the volume of information, rather than by paucity. The uncertainty surrounding questions of why individuals do not adopt technologies 'proven' to be more profitable, productive, or sustainable, then, is better conceived as connected to the array of competing interpretations that populate discourse and practices, rather than in terms of 'gaps in knowledge' (see Figure 1). The challenge, and where we envision our contribution to this substantial debate, rests in making sense of the 'mess' of competing claims, with emphasis on the socio-economic factors.

We used mixed methods to generate data, which were analysed from a socio-economic perspective to develop a better understanding of the receptiveness to system change by smallholder farmers. A mixed-methods approach was chosen, which incorporated ethnography, focus groups, semi-structured interviews, and economic modelling. In order to unite the data generated by these methods, a set of research themes and questions were developed, drawing from the Wisner et al. (2004) 'Pressure and Release' model and their integration of Blaikie's development of political ecology (Blaikie, P. 2006, 2008; Blaikie, Piers & Brookfield 1987), as well as discussions exploring and explaining the 'Livelihood Approach' (Chambers 1980; Chambers & Conway 1992). Together, these theoretical discussions informed and guided our analysis, though with some amendments to accommodate our specific interests in barriers to adoption of technologies. There is a range of actors who contribute to, influence, and are affected by the agricultural system in Cambodia; all of whom require analysis if we are to better understand what shapes farmer decision making.

Figure 1: The challenge and the Knowledge Deficit criticism



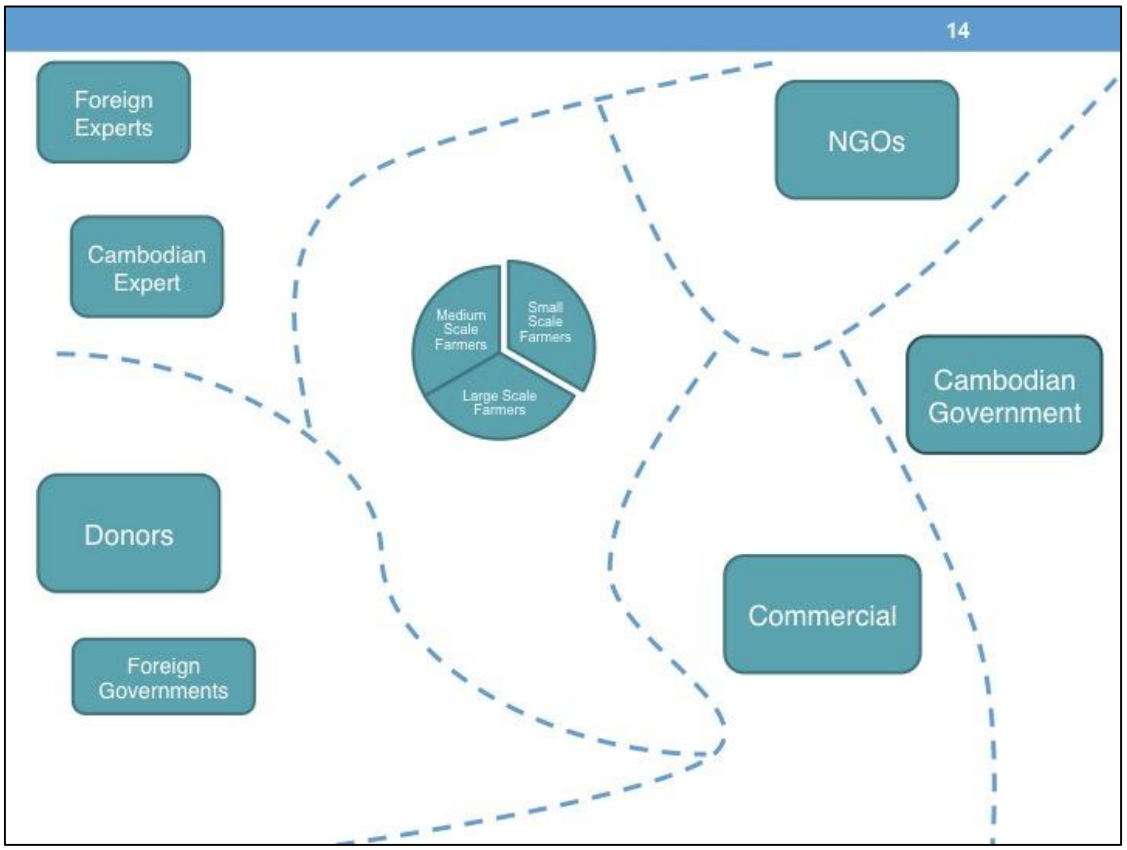
6.1.2 Framing the questions

For an issue as dynamic as agricultural development and farmer decision making – with added concern for technology adoption – it is critical that we understand the range of actors, perceptions, interests, and agendas that are at play. Brian introduced the concept of framing: "writers invoke the concept of 'framing' in reference to the perceptual lenses, worldviews, or underlying assumptions that guide communal interpretation and definition of particular issues" (Miller 2000, p.: 211), see Figure 2.

Three social methods were used in the project to uncover and analyse framings amongst a range of actors: focus group workshops, ethnographic research, and semi-structured interviews. Focus groups appear to be the dominant model for assessing farmer perceptions in Cambodia, which is central for our analysis of 'how actors know and justify what is being done'. For the ethnographic analysis we required local researchers who could conduct longer-term visits with farmers, experiencing farmers' lives and livelihoods, and who could document their concerns in a less formal setting.

However, it is also clear that there are a very small number of individuals and organisations who are extremely influential in the context of the agricultural sector in Cambodia. We required analysis and comparison of how those individuals think, and how they rationalise what is done. Knowing what powerful actors think 'should be done' is critical if we are to better understand the context in which farmers make decisions concerning technology.

Figure 2: Framing the actors who influence farmer decision making



In order to understand how the various framings interact, it was vital to use multiple methods, to explore multiple perspectives, covering multiple issues. The three methods are each attuned to socio-economic factors through their shared research questions. In

this way, the mixed methods addressed the same research questions using different techniques (see Table 3), enabling a triangulation of the findings.

Table 3: Interview template for the three social research methods

Semi-Structured Interview	Focus Group	Ethnography
1. What are the actor's objectives/goals?		
• **What is your job?** • **How long have you held this position?** • **What are you and your organization attempting to do?** • **Who determines the objectives?** • **What would you consider to be success/failure?** • **How do you measure success/failure?**	• How long have the individuals farmed? • Do they plan to always be farmers? • What would they like to do if they were not farmers? •	• Watch what farmers and farmer households do. • Is farming discussed and, if so, in what ways? • How is farming integrated into the household activities? • Is farming discussed in terms of the future? • Which family members are responsible for farming and farm planning?
2. How do actors involved in agricultural development in Cambodia interpret the 'agricultural system'?		
• **Describe your involvement in the agricultural system/sector in Cambodia?** • **In recent years, what changes to the system have you noticed?** • **How do you think the system will change in the coming years? 5 Years?** • **What individuals or forces influence the agricultural sector in Cambodia?**	• What crops do the farmers produce? Why? • How long have they produced that crop? • What other crops have they produced? • What crops would they like to produce? • Will their families continue to farm in the future? • Who purchases their products? • What influences the price of their products?	• Who does the farming and how are tasks allocated? • What other actors are involved in their farming activities? • Who does the farmer/family consult for advice? • Listen to their plans for the future. • Ask about any recent changes to their farming practices. • Ask about the 'place' of farming in the family? • How much time/resources are dedicated to farming?
3. What are the most significant challenges that inhibit the actor from realizing their aims or goals?		
• **What individuals and factors inhibit you and your organization from realizing objectives?**	• What are the biggest problems/challenges for farmers in Cambodia? • What are their experiences with those problems?	• Listen for common complaints facing the farmer or household? • Watch for differences of opinion with regards to on-farm activities? • Do the farmers refer to dishonest individuals or unjust practices? • Who do farmers blame for challenges associated with the agricultural system?
4. What changes to the system does the actor believe would help them realize their objectives/goals?		
• **How might those individuals and factors be 'fixed'?**	• What changes would help farmers be more successful? • How would those changes help them?	• When complaining, what solutions are discussed? • If past 'better times' are discussed, what issues are identified as being better?
Have they mentioned 'technology'? If not, ask directly.		
• **What technologies might help you realize your goals?** • **What factors influence the adoption of technology in Cambodia?**	• Are they aware of any technologies that would help them be more successful?	• Do they discuss technologies and change?

6.1.3 Semi-structured interviews

Semi-structured interviews were conducted with the aim of eliciting the opinions of key, influential individuals. These views were envisioned to help contextualise the wider forces and factors that affect smallholder farmer decision making. The individuals represented international donors, NGOs, experts, government agents, and small and medium scale farmers.

The interviews were each conducted by Dr. Brian Cook, in Cambodia. They were undertaken at the individual's place of work or a nearby café where the respondent felt at ease. The research questions (see Table 3) had sub-questions designed to help elicit responses that might expose the respondent's perceptions of farmer decision making. As a result, the questions are intentionally broad in order to allow the respondents to answer without undue bias from the interviewer. For each response, the interviewer would prod and ask follow-up questions in order to better understand the rationale underlying the response.

6.1.4 Focus groups

Focus group methods are said to be the dominant social science method conducted in Cambodia in the context of agricultural research. As such, we needed to include this method in order to compare and triangulate data from the less common ethnography and semi-structured interview methods. The focus group activities allowed this project to elicit responses from a large number of cases (4) and farmers (8-16 in each case). This provides this SRA with a broad data set, but also with key avenues for comparison: for example, farmer-expert, group farmer-individual farmer, farmer-government agent. Given the aim of uncovering the competing framings – and associated knowledge and interests – this approach and comparison is essential.

6.1.5 Ethnographic research

Ethnography was incorporated into the SRA research methodology in order to deepen our understanding of farmer decision making. Ethnography opens researchers to alternate types of data: namely, practices. In this way, in addition to farmer and expert perceptions, we analysed what farmers did when not being interviewed or taking part in a focus group. This data is essential because all people have difficulties expressing 'why' they act in particular manners, with most people not having the time or inclination to reflect on what they do. The ethnography allows this project to compare what farmers say with what they do, providing another window into the decision making processes underlying the adoption of technology.

6.1.6 Economic analysis

A preliminary economic analysis was conducted for a case study farm which included both a farm and farm-family perspective. The latter is the household or livelihood analysis. An economic analysis was conducted on the basis that semi-subsistence agriculture is implicitly concerned with costs and benefits – an economic objective for Cambodian farmers was assumed.

The issue of labour supply and demand as it affects choice of farm management and technology was thought to be crucial. Accounting for the financial and opportunity costs of labour was the main aspect of the analysis. To achieve this, a constrained optimising method (Linear Programming) was used. LP has been used extensively for farm-level analysis, but it has not previously been used for Cambodian research questions and has not (to the author's knowledge) been used to consider labour resource issues. The main data source was from a recently completed PhD thesis (Chea 2015).

The economic research addressed the question of 'how the incentives to change on-farm rice production and management methods in Cambodia might be affected by new labour and technology options?' The analysis was for semi-subsistence lowlands rice production.

For a farm economic objective the choice of farm activities, and of the best use of farm resources, must be made by fully accounting for the opportunity costs of such resource use (Dent et al. (1986)). The cost of undertaking a farm activity is the value of the best alternative action that has to be foregone. This concept applies to the use of resources, such as land and labour, as well as to the choice of farm activity.

LP (Pannell (1997)) was used to conduct the analysis in this paper since both the choice of farm activity (change or adoption of new methods to improve profits) and the best use of labour (on- or off-farm in a livelihoods framework) are specifically addressed by this method. The optimising LP method fully accounts for the opportunity costs of resources used.

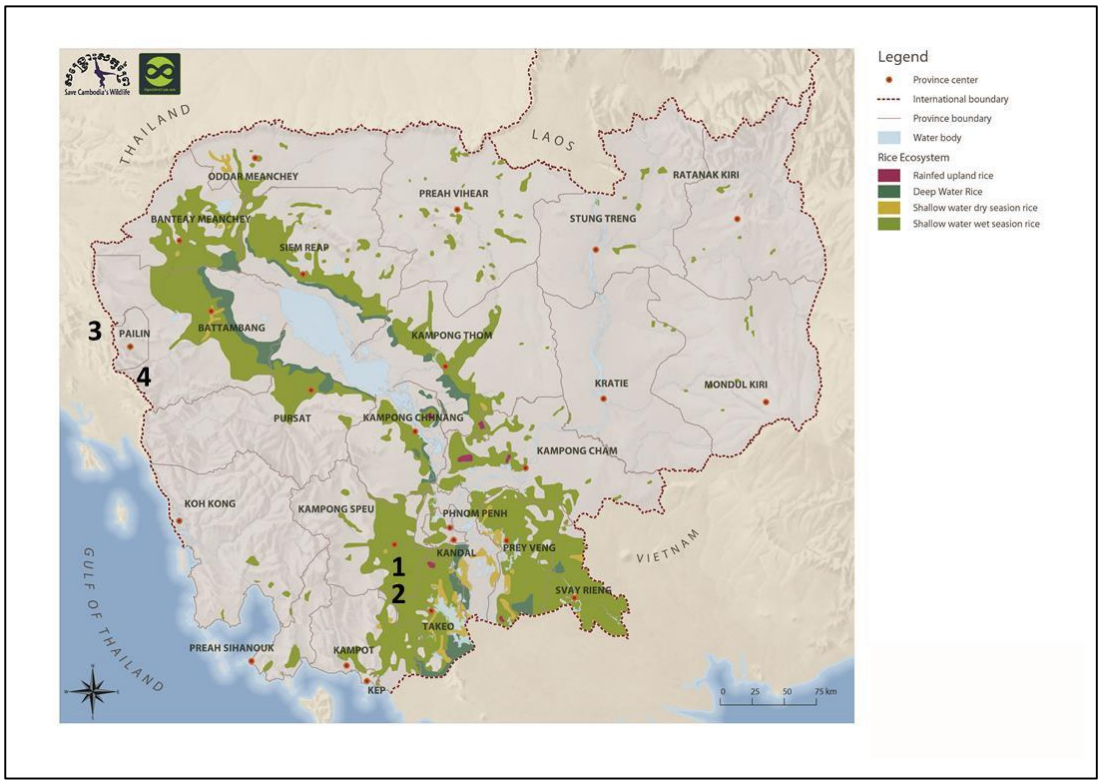
6.2 Project locations

This project addressed farmers that were associated with research projects across lowland and upland agro-ecosystems and farming systems. The villages included in field research and associated details are shown in Table 4 and Figure 3.

Table 4: Village details

Agro-ecosystem	ACIAR project	Village	District	Province
Lowland	CSE/2009/037	Steung	Tramkak	Takeo
Lowland	CSE/2009/037	Trapeang Chak	Tramkak	Takeo
Upland	ASEM/2010/049	O'Andoung		Pailin
Upland	ASEM/2010/049	Kantuat		Battambang

Figure 3: Case study locations



7 Results

Six research projects were conducted in this SRA. The main results from these projects are presented in this section. The material in this chapter is substantially the information presented at the project final workshop.

7.1 Review of literature

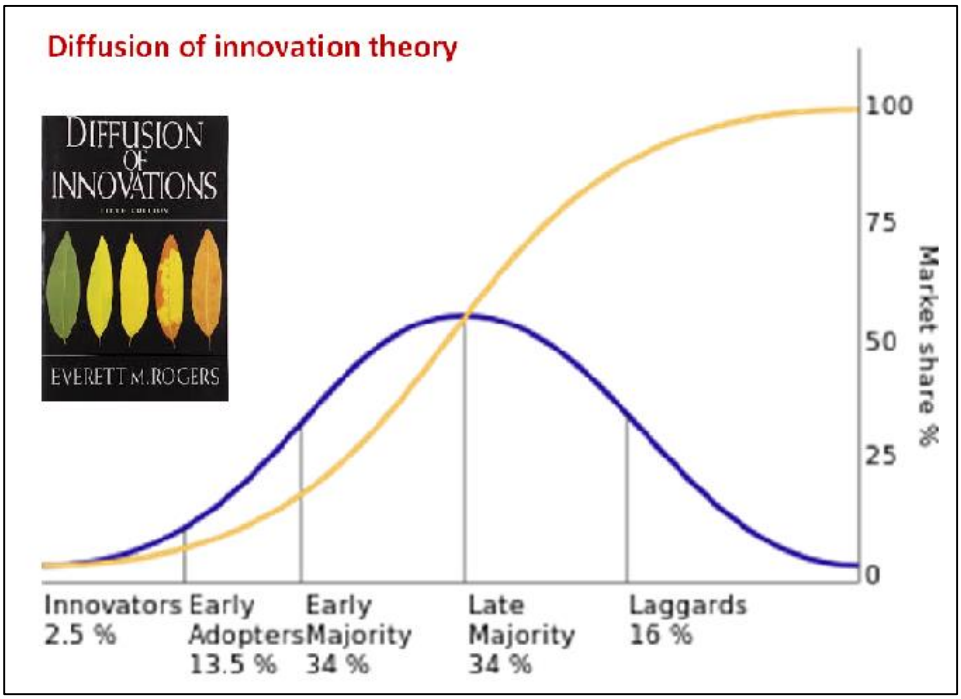
Dr. Lauren Rickards reviewed literature relating to pressures on agricultural research, development and extension (RD&E) actors to develop new approaches to farmer adoption. She discussed the evolving missions of agricultural RD&E, critiques of classical agricultural extension, and contemporary models of farmer engagement. Contemporary agriculture has long been subject to compassionate and critical intervention, and today its governance is increasingly complex and contested. There are multiple agendas, actors and approaches at work. Questions are now being asked of actors in the agricultural RD&E system, as of farmers. These questions relate to how they can be made more productive. What characterises the actors involved and how does this affect what they do? How can they be encouraged to adopt new knowledge and improved practices, but also who should determine what gets promoted for adoption?

Adoption can be defined as a normative desire for change. Although the overall "agricultural change project" is increasingly diverse in terms of agendas, actors and approaches, all of the missions are underpinned by a normative desire for change among farmers – and thus are seeking farmer "adoption" in some sense. Any one project is likely to include aspects of various agendas and approaches to adoption and has to be understood within the context of other past and present adoption efforts. The original and arguably still dominant approach to farmer adoption is "extension".

Extension is a classical approach to farmer adoption. The process is that exogenous innovations are introduced to a farming population via information-based strategies. The goal is diffusion of innovation through the population in an epidemiological fashion. The primary barrier to diffusion is considered to be an information deficit – a lack of (trusted) knowledge of the innovation. Other farmer characteristics introduce barriers to their capacity or willingness to adopt. Adoption is imagined as an on/off switch - leading to quantitative measures of uptake (including rate of change). The classical theory of innovation diffusion from Rogers (2003) is shown in Figure 4.

A better (improved?) understanding of (barriers to) farmer adoption (Extension 2.0) has emerged in the literature. This includes a greater focus on context: that is, what pre-exists the intervention effort. A greater number and scale of factors are recognised as influencing adopters and the adoption process – beyond adoption as a matter of farmers' attitudes, behaviour, and choice. The innovations being sought are more enabling and flexible, and less prescriptive. There is evidence of critical thinking in terms of a participatory agenda: including farmers in some level of knowledge co-production; acknowledging the intrinsic and instrumental value of local knowledge; evidence of some systems thinking; and acknowledging farmers as diverse, dynamic, and inherently rational. The characteristics of an innovation are thought of as context-specific where farmers' systems are incorporated into the world of agricultural RD&E itself, with science practice as "local knowledge", and taking an agricultural information and knowledge systems approach.

Figure 4: Diffusion of innovation theory from Rogers (2003)



Lauren concluded that a better understanding of adoption thinking must acknowledge the "agricultural change project" as increasingly diverse in terms of actors, agendas, and approaches. But a similar normative desire for change – and frustration with the lack of it – underpins interventions with farmers. Any one adoption project is likely to include aspects of various approaches to adoption and has to be understood within the context of other past and present competing approaches, agendas, and actors involved. Conceptual pluralism can be a strength if it is transparent. The first step is reflexivity.

7.2 Focus group research

Dr. Chea Sareth presented the results of this field research, which appears to be the dominant model for assessing public perceptions, leading the SRA to incorporate the methodology in order to compare and triangulate findings from the interviews and ethnography. The project sought focus group data to investigate the social perspectives of Cambodian farmers in making decisions concerning adoption of new technologies and change to their farm management. The case studies include: Steung and Trapeang Chak villages in Tramkak District of Takeo Province which was the project area of improved rice establishment and productivity in Cambodia and Australia (CSE/2009/037), and O'Andoung village in Pailin Province and Kantuat village in Battambang Province which was the research sites of market-focused integrated crop and livestock enterprises for north-western Cambodia project (ASEM/2010/049) (see Table 4 and Figure 3). The two villages of Takeo Province are located under rainfed lowland condition where rice is the major crop. The two villages in Pailin and Battambang Provinces are rainfed upland farming systems which are favourable for non-rice crop cultivations.

In response to the project objectives and earlier work experiences of farm group discussion, between 8 and 10 experienced farmers was deemed the ideal number of participants for a productive workshop. The socio-economics team from CARDI consisted of five people to run the village workshops, with the assistance of village heads and Pailin Provincial Department of Agriculture (PDA) and Maddox Jolie-Pitt Foundation (MJP) staff members. One or two team members were to lead the discussions. Flipcharts were used to write all key discussion points in front of participants who were able to read the writing

and constantly commented on the written information while other team members also jotted down notes (Figures 5 and 6). The discussion was carried out based on the questions from Table 3, which align with wider research questions.

Figure 5: Farmer workshop conducted in Steung village, Takeo Province

Figure 6: Farmer workshop conducted in O'Andoung village, Pailin Province

7.2.1 Findings

Rice is the primary crop in Steung and Trapeang Chak villages for home consumption, with the surplus sold for cash income. Rice production was historically produced only for subsistence but it has been traded for cash since mid-1980s because of access to a rice market due to improved transportation. Increased rice production also has implications for the farmers, particularly with regards to material inputs. Daily household expenditure was the other main reason for paddy rice trading. The participants from both villages indicated that the production of rice in the future is expected to be more market oriented, and that the quantity sold is expected to increase. Peanut, mungbean, watermelon, and mixed vegetables were among non-rice crops produced mainly for cash income.

While rice is important, cassava is the primary crop in O'Andoung and Kantuat villages, despite its relatively new arrival to the area as a cash crop. Soybean, peanut, sesame, and mungbean were the longest crops beginning in 1998, but cassava has made substantial inroads into the agricultural economies in these areas. Maize was previously

cultivated by the majority, but is no longer as attractive in Kantuat, and was no longer cultivated in O'Andoung. Black pepper, longan, durian, and rambutan were perennial or strategic crops for Kantuat villagers. A very small number of households grew rice in O'Andoung, while approximately 80% of Kantuat households cultivated rice. Though their farming activities appeared to involve a cropping system, none of the four villagers understood the term 'farming systems'.

New rice varieties released by CARDI and IR50404 released by a Vietnam research institute were adopted in the two rainfed lowland villages. Fertilizer recommendation rates together with pesticide application to some extent were also practiced. Mechanization, including two-wheeled tractors, reapers, and combine harvesters, were accessible in both villages for rent, with a small number or no ownership of machinery amongst the smallholder farmers in these villages. Despite having no noticeable technology, the two upland villages have applied pesticides and materials/hormone for crop flower induction. Cassava growers in O'Andoung indicated the planting technique was influenced by Thai farmers. Seed, planting materials and other chemicals such as fertilizers and pesticides in both villages were also imported from Thailand and Vietnam.

Rice and non-rice crops could be sold to traders at the villages of Steung and Trapeang Chak, but the farmers also transported paddy rice and other farm produces to sell to nearby rice mills and markets respectively. Rice prices varied according to quality with lower quality rice having a lower farm gate price (US$0.22/kg) and fragrant rice having a higher price (US$0.35/kg) based on recent prices (03/2015). The price of crops such as mungbean and peanut was more stable, with watermelon more volatile. Cassava and maize cultivated in the two upland villages were sold to silos that were recently established in the areas. Soybean, mungbean, and sesame were collected by traders at each village and transported to Thailand. The farm gate price of cassava varied from US$0.03/kg to 0.06/kg of fresh cassava root and US$0.13/kg to 0.20/kg of dry cassava chip. The farm gate price also tended to fluctuate for soybean (US$0.38-0.68/kg) and mungbean (US$0.75 - 1.13/kg), but was said to be more steady for sesame (US$1.9/kg).

7.2.2 Challenges and factors improving farming systems

Water shortages, insects, and diseases were the primary challenges for rice and non-rice crop cultivation in the two rainfed lowland villages. Lack of green feed and diseases were experienced by cattle owners in the villages. Only Trapeang Chak village considered the absence of new technology as a farming constraint, though each focus group indicated a desire for technology. O'Andoung village indicated insects and irregular rainfall were the severe problems for the cultivations of cassava, maize, and soybean. Kantuat farmers also mentioned having rainfall at harvesting time was an obstacle but this village turned more attention to market forces, including crop price, road conditions, and transport costs. They complained that the harvest depended entirely on foreign markets; the establishment of prices by foreign traders, furthermore, was criticized. Additionally, poor road access and transport challenges were said to significantly affect market price. New innovations were also mentioned, but were the not primary concern of framers.

Irrigation was considered the top priority for the two rainfed lowland villages with regard to improving their farming practices and livelihoods. Sufficient organic and inorganic fertilizer supply was another factor of importance for enhancing crop production in Steung village. Despite indicating no technology requirement, this village implied crop intensification and diversification were important solutions to the current constraints. But Trapeang Chak villagers, apart from irrigation water, did identify technology for improving the cropping systems. Participants in O'Andoung believed that a reliable and regular rainfall was the primary factor needed to help their farm activities be more successful. Technology implication seemed to be more important to farmers in Kantuat. Other important factors included available markets and good prices to improve their farming businesses and livelihoods.

7.2.3 Conclusion

The participants were all drawn from active farm families, with experience in farming activities despite their wide range of ages. Many aspects of the households varied but family size and labour number were very similar amongst the four focus groups. The total village land areas were substantially different, but the area cultivated was relatively consistent. The average landholding per household varied between the two lowland villages and also between the lowland and upland villages, as was expected.

Crop cultivations were clearly influenced by favourable ecosystems – rice on lowland and non-rice crops on upland areas. The village settlement influenced the duration of cultivation between the two different environmental contexts, with the lowland villages cultivating rice long before the civil war while the upland villages commonly starting crop cultivations in 1998. Rice production was merely subsistence in the past for the lowland villages, but has gradually become a cash crop beginning in the mid-1980s. The purpose of crop cultivations was primarily commercially oriented in the upland villages.

All participants from the four villages consistently responded that the majority of villagers showed no intention to leave their farm in order to seek non-farm opportunity given a range of reasons. They either considered or intended to have children live outside the villages or earn income from non-farm business.

The two lowland villages have adopted certain new innovations including rice varieties, recommendations of fertilizer and pesticide application, and mechanized farming as well as agronomy practices. The use of seed, planting materials, chemicals, and fertilizers in the upland villages were seemingly influenced by traders and Thai farmers. The cropping system, including rice and non-rice crops, was constant or unchanged under rainfed lowland situation because rice cultivation was mainly for subsistence and part of the staple diet. Despite this, the decision on cropping system has been significantly influenced by market availability and crop prices.

The challenges of rainfed lowland farming were water shortage, insects and diseases, and lack of new technology. For the upland farming systems the primary challenge was to overcome unfavourable rainfall (irregular pattern and fluctuate amount), insects, roads and transport, market and farm gate prices. Broadly, irrigation source and agricultural technology were of central importance to lowland villagers. While one upland village group would like to have regular and reliable rainfall, the other group was interested in crop rotation and diversification for cropping systems, and market and price for post-harvest matter.

7.3 Ethnographic research

Dr. Nou Keosothea presented the results of the ethnographic research conducted by PNCA. Sothea's research team consisted of Seng Srey, Chan Phally, Eap Chemsileg and Phal Chenda.

The main ethnographic research was conducted in Takeo Province (Trapeang Chak village, Trapeang Kragnong Commune, Tramkak District and Stueng village Osaray Commune, Tramkak District) and Battambang (Kantuat village and O'Andoung village, Samlaut Commune).

The key questions for ethnographic research (Table 3) were: what are the farmer's goals, how do farmers involved in agricultural development in Cambodia interpret the 'agricultural system', what are the most significant challenges that inhibit the farmers from realizing their goals, what changes to the system does the farmer believe would help them realize their goals, and have they mentioned 'technology'? If not, ask directly. Ethnography is a combination of participant observation, semi-structured interviews, and focus groups. A pilot study was conducted to pilot the ethnography in Teukpos district, Kampong Chhnang Province.

7.3.1 Key findings: farmer goals

Farmers indicated that they want better cultivation techniques to obtain higher yields, to expand the farm to a bigger one, to have hand tractor to plough, to have rice fish farming, to raise more chickens with no disease, and wanted to learn growing black pepper.

“I want to grow peppers for another two hectares, but I cannot afford it now”.

7.3.2 Key findings: farmers involved in agricultural development (farming systems)

In terms of farming systems, farmers indicated that they were interested in rice fish farming, rice intensification that uses less seed, maize and cassava rotations, raising chickens and pigs, keeping their own rice seed, and inter-cropping (growing orchard and vegetables).

“I have a pond connected to my rice farm and I can raise fish to eat in rice farm to have more food and income”.

“I produce own rice seed and if my seed is not good I would exchange with other farmers for next growth”.

7.3.3 Key findings: challenges of farmers in achieving their goals

They indicated that their main challenges were lack of water, many rats and insects, low productivity and price is cheap, drought and flood, and lots of farmers are poor and lack of credit to buy agriculture inputs.

“Farmers around the dams upstream block the water for their personal use, the water cannot go far, and then I cannot get access to those water supplies. Moreover, I do not see any leaders come to solve this problem yet”.

7.3.4 Key findings: changes needed for farmers to achieve their goals

The farmers need simple and affordable agricultural technologies, they need irrigation, they need access to credit, and they need markets to buy their produce.

“The good point that farmers have discussed with his fellow farmers is that they have come up with good solutions and help share those techniques and methods to other farmers in the village. He can see that those farmers follow the ideas”.

7.4 Semi-structured interviews

There are a very small number of individuals and organisations who are extremely influential in the context of agricultural development in Cambodia. What those individuals think, how they rationalise what is done, and what they think should be done, is critical if we are to better understand the situation. Drawing on the ‘framing’ concept (see Figure 2 above), the interviews were conducted with the aim of exploring how central figures understood Cambodian smallholder farmers in the context of decision making concerning technology. The interviews, then, were designed to complement the focus group, ethnographic analyses, and economic modelling in order to compare how ‘experts’ interpret the situation.

Interviews were conducted with 18 individuals, including donor organisations, NGOs, government officers, scientific experts and consultants, commercial vendors, medium-scale farmers, and smallholder farmers. Broadly, the interviewees can be divided into groups connected, to varying degrees and in varying ways (see figure 2). Additionally, each of the groups showed similar ‘framings’ of smallholders and their decision making pertaining to technologies.

7.4.1 Cambodian University/Experts

The experts followed a technical understanding, presenting the issue as a problem of education. They viewed the farmers as unaware of the possible benefits of modern agricultural practices and felt that education and demonstration of practices would enlighten them. For example, a Cambodian expert explained that "we overuse technology which sometimes is not appropriate, but sometimes it's too cost and long term benefit, which sometimes farmer may not see as the benefit or they have a short term problem to solve. So that also can be challenge in extension as well." The scientists gave little consideration to the forces shaping the farmers (i.e., economic, political, cultural, historical); this is not to accuse the experts of dismissing those factors, but of relegating those factors to other researchers and activists for analysis and consideration. There was a belief that the decision to adopt technology, for them, could be isolated from wider challenges and forces. This had the benefit of allowing the experts to focus on the technical, modelled benefits that might result from adoption of specific technologies.

7.4.2 Donors

Donors were much more cognizant of the range of forces and influences on farmer decision making. Additionally, the donors appeared directly connected with the majority of the groups involved in agricultural RD&E. As a group, the donors grappled with what might be called 'Development', as opposed to more confined issues associated with agriculture. This difference was most pronounced with regard to the international organisations, which positioned themselves as having to respond to government directives, but with the need to balance their own agenda – typically wellbeing and poverty alleviation. As one donor explained,

> *"A very impressive increase in the rice crop and an ambition to export a million tonnes of milled rice by this year which is not going to happen, but still a very impressive increase in production. But it cannot continue and even if it did with rice prices falling, it's not a solution to poverty, because the prices are not going to continue increasing as they have done in the last few years. Which did indeed pull some farmers out of poverty, but it's not a sustainable development method."*

The donors struggled with the incompatibility of many competing agendas. With the smallholder farmer subject to many competing instructions and engagements, it was recognised that much contradictory information was being provided and that the farmers were, understandably, confused and suspicious of all individuals.

7.4.3 Government

Government respondents, like the donors, struggled with the Government's desire for rice exports, but framed their positions in the context of poorly funded government activities. For several of the respondents, the government's inability to fund extension or outreach activities meant that they were hamstrung by a lack of funds. There was a reserved sympathy for smallholders amongst this group, with one particular respondent stating:

> *"Because I have been working with the farmer more than 20 years. So when I graduated from university I started straight to the grass root level. I tried to understand what are the situation, how can we help them to improve these situations? So far, I still find that it very, very little improvement. A lot of work need to be done to help farmers."*

The government respondents also framed the issue of agricultural development as primarily involving donors, government, and the commercial sector. Interesting, and similar with most framing encountered during this analysis, farmers were not presented as central actors in decisions affecting the agricultural sector.

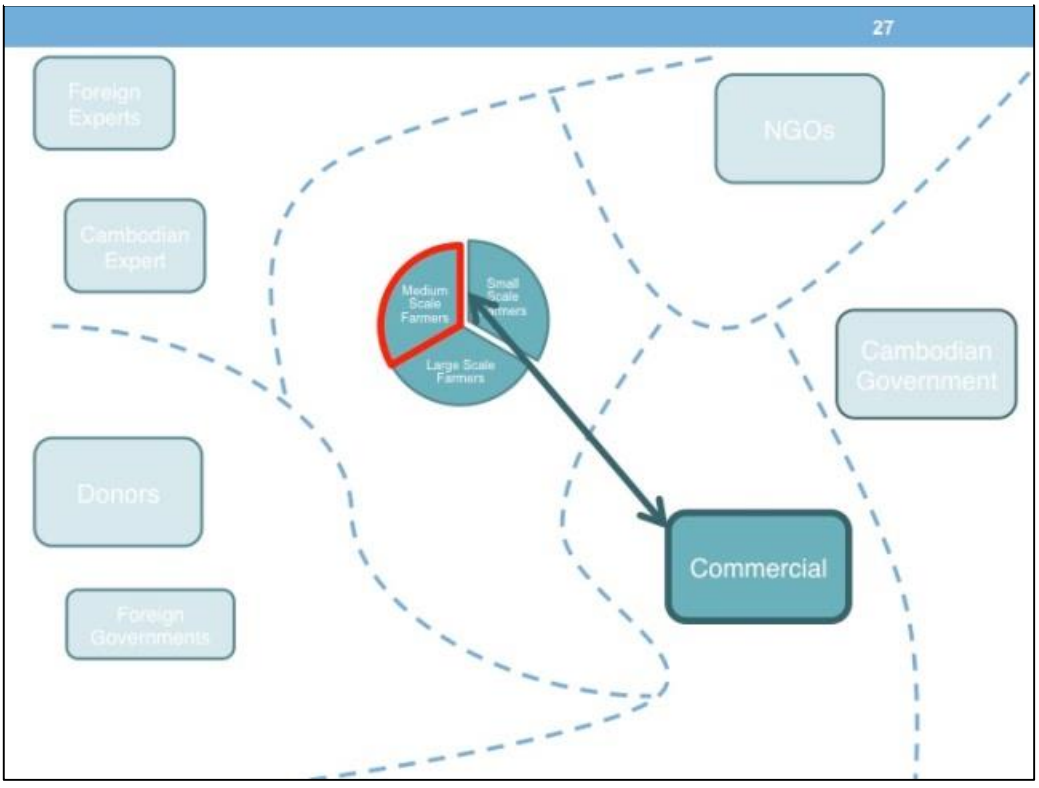
7.4.4 Farmers

In interviews with farmers, the decision to adopt a particular technology was presented, straight-forwardly, as a discussion involving the farmer and the local or travelling merchant. This finding, we feel, is important. It shows that despite the wide range of actors and agencies attempting to inform, support, and aid farmers, there is a fundamental disconnection between these actors and farmers. For example, in response to questions concerning how decisions are made, a farmers stated:

> *Interviewer: "So if he has a problem, a pest or something, who does he talk to for help?"*
>
> *Interviewee: [Interpreted] "He order from the company, buy from the market, company."*

This view was repeated with each interview of farmers, both smallholder and medium scale. For each question concerning farmer decision making, commercial actors were the primary source of information, credit, and supplies (Figure 7). While not confirmable, with follow-up questions exploring this claim, the farmers were asked whether they did not have access to NGOs, to local government support, or the micro-credit loans from NGOs. For each question the farmers answered in the negative, explaining that their farms were too distant from the city for such actors to visit them. This statement is difficult to accept, as there are countless NGOs looking to profit from their partnerships with farmers, but the farmers were clear with their views. Importantly, the factual basis of these claims, while important, should also be explored indirectly: why would the farmers express this view to interviewers? The answer may be that they desired support from us, though it was made clear that this was not forthcoming. The answer is, for now, unknown. Regardless, the potential disconnection between farmers and individuals seeking to expand and support farmers is an important finding in need of further analysis.

Figure 7: Connection and isolation of farmers



7.5 Economic analysis

Dr. Bob Farquharson presented the results of the economic research. The paper is titled: 'Financial and opportunity costs of agricultural labour in Cambodia: implications for rice production technologies'.

Economic development in Cambodia has been rapid in recent years, but still there is substantial poverty, especially in rural areas. Development of the domestic garment industry and construction work in Thailand have provided off-farm work opportunities for rural labour, at much higher wages than returns from farm work.

Subsistence rice production has been the traditional lowland rice farming activity, and it is still widespread. Cambodian Government rice policy has been to export 1 million tonnes rice by 2015, but to keep the rice price low for consumers. Rice farmers are now changing to grow rice for consumption plus some for sale, a semi-subsistence rice system.

Possible agricultural development strategies have been proposed – intensification, diversification and commercialisation. But the World Bank has queried whether rice is the answer to poverty reduction. Rice production is not generally a profitable activity (low yields and prices). What are the farmer incentives to grow rice or improve production? There is an apparent Government policy mismatch.

Cramb and Newby (2014) noted that ".. farmers in traditional rice-growing environments .. are responding to changing incentives by diversifying their farming systems .. and pursuing non-farm activities such as labour migration and rural business as part of a range of complex and dynamic livelihood strategies .., with significant implications for national and international research priorities".

There has been extensive work on rice production in Cambodia, but there is concern at apparently low levels of adoption of R&D outputs. Are there barriers or impediments to adoption? (Newman (2014)). Perhaps Cambodian rice farmers are rational to adopt a low-input low-yield cropping system that meets subsistence goals and allows use of household labour off the farm (Cramb (2014)). Jonathan Newby (personal communication 2014) stated that "*what's needed is an analysis that accounts for the full opportunity cost of farm-family labour*".

This economic analysis developed a model of lowland rice production in Cambodia to evaluate new rice production technologies and the options for farm-family labour. It is a bio-economic model (which includes yields, prices, and resources required – particularly land and labour). Constrained optimisation method (LP) was used to solve the model. This model accounts for the seasonal pattern of labour demand and supply.

The analysis extended the scope of interest from the farm to the farm household. "The livelihoods framework includes an increasingly diverse portfolio of assets and activities to survive and improve their standard of living" (Ellis 2000). Does the use of this framework have implications for adoption of new technologies? We considered the farm-level incentives and then expanded to the farm-family situation in a livelihoods framework. In doing so we accounted for the full opportunity cost of labour.

The research question was 'how are the incentives to change on-farm rice production and management methods in Cambodia affected by new labour (and mechanisation) options?' The analytical design is shown in Table 6.

Labour supply and use patterns are important in considering potential changes to farming systems. Nuthall (2011) noted that "the demand for labour in agricultural systems generally varies throughout the year. It is important to account for seasonal labour demand and supply in representing and analysing farming systems".

Table 6: Analytical design for economic analysis

Production technology	Labour supply and opportunities			
	No labour included (1)	Family labour (2)	Hired farm labour + (2) (3)	Non-farm work + (3) (4)
Traditional rice production	X	X	X	X
Add new rice production	X	X	X	X

Chea (2015) analysed typical lowland rice production in terms of labour required for land preparation, pulling and transplanting, tending crops and harvest/post-harvest activities. Labour periods for lowland rice were developed as shown in Table 7.

Table 7: Labour periods for Cambodian lowland rice production

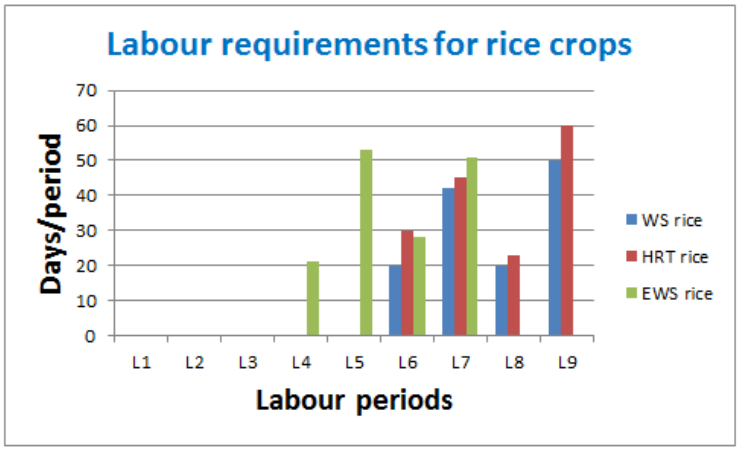
Period number	Dates	Number of days
1	1/1 - 15/1	14
2	16/1 - 23/1	7
3	24/1 - 23/4	89
4	24/4 - 20/5	26
5	21/5 - 14/6	24
6	15/6 - 31/7	46
7	1/8 - 30/9	61
8	1/10 - 15/11	46
9	16/11 - 21/12	45

From Chea's data the family labour supply is shown in Table 8 and Figure 7. Family members consisted of husband and wife, two adolescent children who could work off the farm, and two school-age children. The working week was assumed to be 6 days.

Table 8: Family labour supply based on four adult equivalents

Labour period name	Period days	Number of family workers		
		Adult	Adolescent	Total
L1	14	24	24	48
L2	7	12	12	24
L3	89	153	153	305
L4	26	45	45	89
L5	24	41	41	82
L6	46	79	79	158
L7	61	105	105	209
L8	46	79	79	158
L9	45	77	77	154
Total	358			

Figure 8: Labour requirements per period for rice crops



Rice production activities included in the economic model were traditional rice activities (Wet Season (WS) rice, and Early Wet Season (EWS). Both these were represented as semi-subsistence rice. An improved technology (Hypothetical Rice Technology HRT rice) with a 10% higher yield, having the same price and variable costs as WS, but requiring 20% more labour. Gross margin budgets for these activities were derived from Chea's thesis and are shown in Table 9. Also shown are Net Returns to Household Resources (NRHR) and Net Returns to Labour (NRL) calculations.

Table 9: Gross margin budgets and returns to labour and household resources

Item	Unit	WS rice	EWS rice	HRT rice
Yield	Kg/ha	2,195	2,612	2,415
Seed	Kg/ha	81	114	90
Output	Kg/ha	2,114	2,507	2,325
Farm Gate Price	US$/t	280	240	280
Gross Income	US$/ha	592	602	651
Input Expenses	US$/ha	90	123	90
Input Expenses	US$/t	41	47	39
NRHR	US$/ha	502	490	561
NRHR	US$/t	237	191	241
Total Household Labour	d/ha	132	153	158
NRL	US$/d	3.8	3.5	3.6

The results of the economic analysis are shown in Table 10. For the 2 ha farm without accounting for labour demand or supply (Scenario 1), the 'best' solution for semi-subsistence farms and traditional rice crops with an economic objective is to grow WS rice according to the financial figures (NRHR, NRL) in Table 9. Farm income is $1002 or about $3/day. When the HRT activity is introduced (Scenario 1) it is adopted and total farm income is $1,121, an increase of 12%.

When the seasonal labour demand for rice activities and family labour supply is included in the model (Scenario 2) HRT is still produced using family labour, because family labour is sufficient in each time period (i.e. not binding or constraining). When hired labour (at $7/d) is included as an option (Scenario 3) it is not used and the same rice production and farm income outcomes are observed as Scenario 2.

Finally, when off-farm work (at $3/d) is introduced as an option for adolescent labour (Scenario 4) the rice production changes to less HRT and some EWS rice because of the labour constraint in period 9. The adolescent labour in that period is better used off the farm and some unused labour in periods 4 and 5 are utilised to produce EWS rice. Total household income more than doubles

This economic analysis has shown what we might expect intuitively, that when off-farm work is included as an opportunity for family labour it is utilised to increase family income. But that decision has an impact on the choice of farm production activities.

The results of economic analysis are preliminary, being based on excellent data from Chea and hypothetical data for an improved rice technology. As expected, shifting to a livelihoods framework means that family income can rise but there are implications for labour use on farm, and rice activity choices. When assessing production decisions in a livelihoods framework (i.e. when labour demand and supply are included in the analysis and the opportunity costs of labour are fully accounted for) we find that:

- As off-farm work is undertaken by adolescent family members the farm-family income rises substantially,
- As labour for farm activities becomes less available in key periods, some land is used for EWS rice (which wasn't chosen before), and
- There is a predicted impact on rice activity choice as labour is used for off-farm income. A lower value crop may be grown, or a new technology not adopted because of the opportunity cost of labour.

Table 10: Economic results

Activity	**Unit**	**Resources used and outcomes**				
		Land only, no HRT	Land only, HRT	Land/family labour, HRT	Land/family labour/hired labour, HRT	Land/family labour/hired labour, HRT, off farm work
Scenario		1	1	2	3	4
WS	ha	2	0	0	0	0
	t	4.2	0	0	0	0
EWS	ha	0	0	0	0	0.7
	t	0	0	0	0	1.8
HRT	ha	0	2	2	2	1.3
	t	0	4.65	4.65	4.65	3.0
Total Farm income		$1,002	$1,121	$1,121	$1,121	
Household income						$2,340
Labour use						
P4 Adult	d	-	-	-	-	15
P4 Adol	d	-	-	-	-	0
P5 Adult	d	-	-	-	-	41
P5 Adol	d	-	-	-	-	0
P6 Adult	d	-	-	60	60	59
P6 Adol	d	-	-	0	0	0
P7 Adult	d	-	-	90	90	94
P7 Adol	d	-	-	0	0	0
P8 Adult	d	-	-	46	46	30
P8 Adol	d	-	-	0	0	0
P9 Adult	d	-	-	77	77	77
P9 Adol	d	-	-	43	43	0
Off-farm work						
P4 Adol	d					45
P5 Adol	d					41
P6 Adol	d					79
P7 Adol	d					105
P8 Adol	d					79
P9 Adol	d					77

7.6 Pesticide analysis

Ms. Angeliki Balayannis presented the results of the pesticide research. The paper is titled: 'A Toxic Crisis: Politicising pesticide in Cambodia'.

Background issues relate to (1) application of pesticides (absence of personal protective equipment, and calls for educating farmers on the appropriate practices), (2) bio-accumulation of pesticides in Phnom Penh (i.e., organochlorines in breast milk), and (3) Global South: 30% of pesticides in developing countries fail FAO quality and safety standards.

Cambodia is the worst case scenario (Environmental Justice Foundation (2002)): "the most hazardous pesticides are entering a country that arguably has the least capacity to manage the risks of the pesticides and the resultant harmful effects". Methods involved following the pesticide, examining the practices involved in manufacturing and using commodities across political borders, scales and actors, asking how commodities are made and used, and reconnecting commodities to their networks. Angeliki found that approximately 40% of pesticides sold in the Cambodian markets visited were illegal.

A major issue is uncertainty and knowledge. "*Everything is so interconnected and so vague and difficult to get a handle on because a lot of the information just isn't available - what's the quantity of pesticides that are being imported? What kind of pesticides are they? How are they used exactly? I don't think that there is any hard evidence in this country... I think the problem is probably so widespread that everybody is affected to some degree*" (FAO).

With respect to importing processes, "*The biggest issue facing Cambodia is actually Customs. They don't know what the active ingredient is, or what it's used for. The legislation is used to milk money, customs would have the biggest racket going. Those at the top control the borders, so they're the ones - something comes in, and they get paid. That's how it works*" (a pesticide seller).

With respect to farmers and pesticides, input sellers and other farmers are key sources of knowledge, farmers prefer the most toxic pesticides – they want fast, visible results, and farmers are aware of the health hazards. They would use less harmful methods if they had a similarly effective alternative.

Angeliki concluded that farmers' knowledge and practices are key concerns, and fundamental to any attempt to address emergent problems. However, without a consideration of the context surrounding pesticide use (particularly the role of manufacturers) a focus on farmers' knowledge can depoliticise an issue fundamentally grounded in questions of power. How do we envision a solution to a problem that cannot be grasped?

8 Discussion

Important early events for this SRA were the literature review and attendance at the ACIAR Policy Dialogue on Rice Futures in Phnom Penh. An 'Extension 2.0' picture emerged from the literature review of contemporary thinking of RD&E practitioners and observers. Extension 2.0 includes a greater focus on context (what already exists), recognition of a greater number and scale of factors influencing adopters and the adoption process, and innovations being sought to be more enabling and flexible, and less prescriptive. Evidence of critical thinking includes farmers in some level of knowledge co-production. The picture includes an acknowledgement of the intrinsic and instrumental value of local knowledge, evidence of systems thinking, and recognising farmers as diverse, dynamic and inherently rational. Characteristics of an innovation are thought of as context-specific, where farmers' systems are incorporated into the world of RD&E itself, science practice is 'local knowledge', and includes taking an agricultural information and knowledge systems approach.

Observations at the Policy Dialogue on Rice Futures were that for countries in the Mekong region, economic growth, off-farm work opportunities, farm labour migration, and wage remittances are now central considerations for smallholder decision making. They are more likely to take a livelihoods perspective of their situations, which can emphasise issues or considerations that fall outside more traditional appraisals. The increase in semi-subsistence agriculture means that a more explicit economic perspective is important; as smallholders use more purchased inputs and sell some of their produce in the market, costs and returns are raised, but outcomes are also more risky. The challenge is more complex than technical issues, there is a gap between information generated by scientists and what farmers need to produce their crops, and a need is for the RD&E community to adjust to the rapidly changing situation in Cambodia. Jonathan Newby (personal communication) observed that "what's needed is an analysis that accounts for the full opportunity cost of farm-family labour".

In light of these events the SRA proceeded in several ways. We conducted social field research (focus group workshops and ethnographic research) to find out about technology adoption in terms of context, local knowledge and systems thinking, we conducted semi-structured interviews of actors in the RD&E 'system', we developed a preliminary economic analysis of agricultural labour in a family livelihoods framework, and we conducted research on agricultural pesticides in Cambodia.

Results of the focus group workshops were that, for farmers growing mainly rice in lowlands and mainly non-rice crops in uplands, villagers did not want to leave their farms. Despite this, they accepted that their children would live outside the village and earn income from non-farm businesses. New innovations adopted in the lowlands were rice varieties, fertiliser and pesticide recommendations, mechanisation, and agronomic practices. In the uplands farmers were influenced by traders and Thai farmers for seed, planting materials, chemicals and fertilisers. Challenges in the rainfed lowlands were water shortages, insects and diseases, and lack of new technology (including irrigation). Challenges in the uplands were unfavourable rainfall (patterns and amount), insects, roads and transport, market, and farm-gate prices.

The implications from these results are that farmers expected their children (the next generation) to live outside the village and work in other industries. With respect to new technologies there was some emphasis on a desire for new technology but the main factors were weather, prices, and access to markets (like most farmers around the world).

Results of the ethnographic research were that farmer goals included higher crop yields, expansion of farm size, mechanisation, and farm activity diversification. Farmers were interested in farming systems issues (new activities) but challenges to achieving these goals included lack of water, rats and insects, low productivity and prices, drought and

flood, poor/lack of credit to buy inputs. According to farmers, to achieve their goals they require simple and affordable new technologies, irrigation, access to credit, and markets to buy and sell their products. Implications from these results were similar to the focus group workshops.

Results of the semi-structured interviews were that Cambodian university staff and scientific experts generally followed a technical understanding, presenting the issue as a problem of education, where farmers are unaware of possible benefits so that education and demonstrations would benefit them. Scientists gave little consideration to the forces shaping farmers; they believed that the decision to adopt could be isolated from wider challenges and forces so that they could focus on the technical effects. Discussions with farmers concerning their activities and options, as well as with reference to the specific technology of pesticide, suggest otherwise. Farmers were very knowledgeable, challenging the believe that they are ignorant or technologies or possible benefits and suggesting that other, more structural forces, dominate the decision to adopt technologies.

Donors were more cognizant of the range of forces and influences on farmer decision making. While donors appeared more directly connected with the majority of groups involved in agricultural RD&E, they also interpreted the issue as part of wider 'development' rather than just agriculture. In particular, they struggled with the incompatibility of many competing agendas. They recognised that farmers are (understandably) confused and suspicious of all individuals involved in the process. The donors were predominantly sympathetic to farmers, but beholden to the government and experts who influence the RD&E sector. There was appetite for different approaches, but few known alternatives and a constant desire to 'chip away' and contribute where possible.

Cambodian government respondents spoke of poorly funded government activities (extension). Some respondents also framed the issue of agricultural development as primarily involving donors, government and the commercial sector – farmers were not presented as central actors in decisions affecting the agricultural sector.

Farmers said the adoption decision involved the farmer and, almost exclusively, the local or travelling merchant. There was a fundamental disconnection between the other actors and farmers. Commercial actors were the primary source of information, credit, and supplies. Farmers were generally not involved with NGOs, nor with local government extension, and not generally in receipt of micro-credit loans from NGOs.

Preliminary findings from the semi-structured interviews are that there is an array of contradictory agendas and unequal power for research funding organisations to have greater impact – or make the most of existing knowledge – using a knowledge deficit model.

The economic analysis was a preliminary case study which developed a farm-level model of lowland rice production. An economic analysis was conducted of rice crop choice (traditional wet season/early wet season rice versus a hypothetical rice technology with higher yield and gross margin, but also requiring more labour). The whole-farm model was developed to represent detailed seasonal crop labour demands and family labour supply based on data from an unpublished PhD thesis. The new aspects of analysis were to include a detailed specification of farm labour demand and supply and to include the possibility of off-farm income for family labour members - this is the livelihoods framework. The results showed that the hypothetical new rice variety was chosen over traditional varieties when labour demand was fully met from the farm family. But when off farm work became an option it was used in the best strategy to increase family income, but the resultant labour shortage meant that the new variety was not fully utilised. The results showed that Cambodian farmers when faced with off-farm labour options with wages being remitted are rationally using off-farm wages and not adopting new rice technologies.

The pesticide research investigated the observed use of dangerous (and substantially illegal) chemicals by smallholders and drew a picture of the associated chemical

commodity trail from international manufacture across borders and to merchants, all without adherence to regulations about composition and safety. Farmers wanted fast effective results despite the (known) health risks.

From this preliminary research the view of RD&E and farmer technology adoption in Cambodia is of a contested system where various actors have different views of how the system should work, with different assumptions about the motivations and decisions of smallholder farmers. Smallholders are quite rational and behave in a reasoned manner when their livelihoods are considered. There is adoption of some new technologies and a desire for further improvements, but the current paradigm of scientific research and associated extension efforts appears disconnected from the everyday demands of farmers' lives and from their decision making.

9 Conclusions and recommendations

9.1 Conclusions

Major conclusions are that:

1. There are gaps in our understanding of the environment for RD&E in Cambodia and of the factors influencing Cambodian farmer technology adoption and management change;
2. Research questions arising from this observation relate to how social and economic factors and context influence Cambodian farmers as they consider new agricultural technologies. This raises the possibility that evidence from past agricultural development projects (with different levels of technology adoption 'successes') may help explain how social and economic factors have interacted with technologies in the context of successful adoption;
3. An objective of future work is to understand the role and importance of social and economic factors as determinants of past adoption decisions and develop a framework for determining how these factors can be integrated into future project scoping, planning, and dissemination of technologies, knowledge, and results;
4. A strategy for further work is to conduct detailed social and economic analysis of technology adoption experiences at the village level to increase understanding of the context for adoption. This is not an assessment of the level of project success (in terms of adoption), but rather an examination of the factors associated with (or determining) the level of success. The strategy includes applied research with Cambodian academic and institutional collaborators;
5. The methods will include focus group workshops, ethnographic research, semi-structured interviews, and farm-level economic analysis of representative farms and case studies using a livelihoods framework.

9.2 Recommendations

A proposal is drafted based on these findings with the aim of better understanding the social and economic imperatives for successful agricultural development and technology change. The project will use the above social and economic methods to assess perceptions, livelihoods, and needs of smallholder farmers associated with previous agricultural development projects, and then consider how potential productivity-enhancing technologies can be viewed in this context.

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10.2 List of publications produced by project

Robert Farquharson, Chea Sareth and Brian Cook (2015), Financial and opportunity costs of agricultural labour in Cambodia: implications for rice production technologies, Presentation to the Tropical Agriculture 2015 Conference, 16-18 November, Brisbane.

11 Appendixes

11.1 Focus group workshop report

Australian Government

Australian Centre for International Agricultural Research

Final Project Report

Smallholder Perspectives and Decisions about Technology Adoption in Agro-Ecological Zones and Farming Systems: Focus group discussion results

(September 2014 – June 2015)

Collaboration Project between University of Melbourne and Cambodian Agricultural Research and Development Institute

Smallholder Perspectives and Decisions about Technology Adoption in Agro-Ecological Zones and Farming Systems: Focus group discussion results

1. Introduction

Agricultural research in Cambodia particularly rice crop have been restarted with the establishment of Cambodia-IRRI-Australia Project (CIAP) and currently named Cambodian Agricultural Research and Development Institute (CARDI) since late 1980s after being completely destroyed by the Khmer Rouge regime controlled the country between 1975 and 1979. The research work has successfully developed new technologies ranging from rice varieties to post-harvest techniques significantly improved rice yield and contributed to the country's rice production increase since 1995. The research mainly funded by Australian Centre for International Agricultural Research (ACIAR) has also turned its attention to non-rice crops commonly cultivated on upland areas in early 2000s. Despite rice yield and production having overall increased, the majority of lowland farmers produced rice at subsistence level or even below subsistence. Apart from a small number of ACIAR funded projects, agricultural research on major non-rice crops in upland environment remained restricted. Therefore, the objective of this project 'Smallholder perspectives and decisions about technology adoption in agro-ecological zones and farming systems of Cambodia' was to investigate the social perspectives of Cambodian farmers in making decisions about adoption new technologies and change to their farm management.

2. Study locations

Because this short term project of smallholder perspectives and decisions about technology adoption in agro-ecological zones and farming systems of Cambodia is to investigate the social perspectives of Cambodian farmers in making decisions about adoption of new technologies and change to their farm management, Steung (1) and Trapeang Chak (2) villages in Tramkak District of Takeo Province which was the project area of improved rice establishment and productivity in Cambodia and Australia (CSE/2009/037) and O'Andoung village (3) in Pailin Province and Kantuat village (4) in Battambang Province which was the research sites of market-focused integrated crop and livestock enterprises for north-western Cambodia project (ASEM/2010/049) were selected for this study sites (Figure 1). The two villages of Takeo Province are located under rainfed lowland condition where rice is the major crop. The two villages in Pailin and Battambang Provinces are rainfed upland farming systems which are favourable for non-rice crop cultivations.

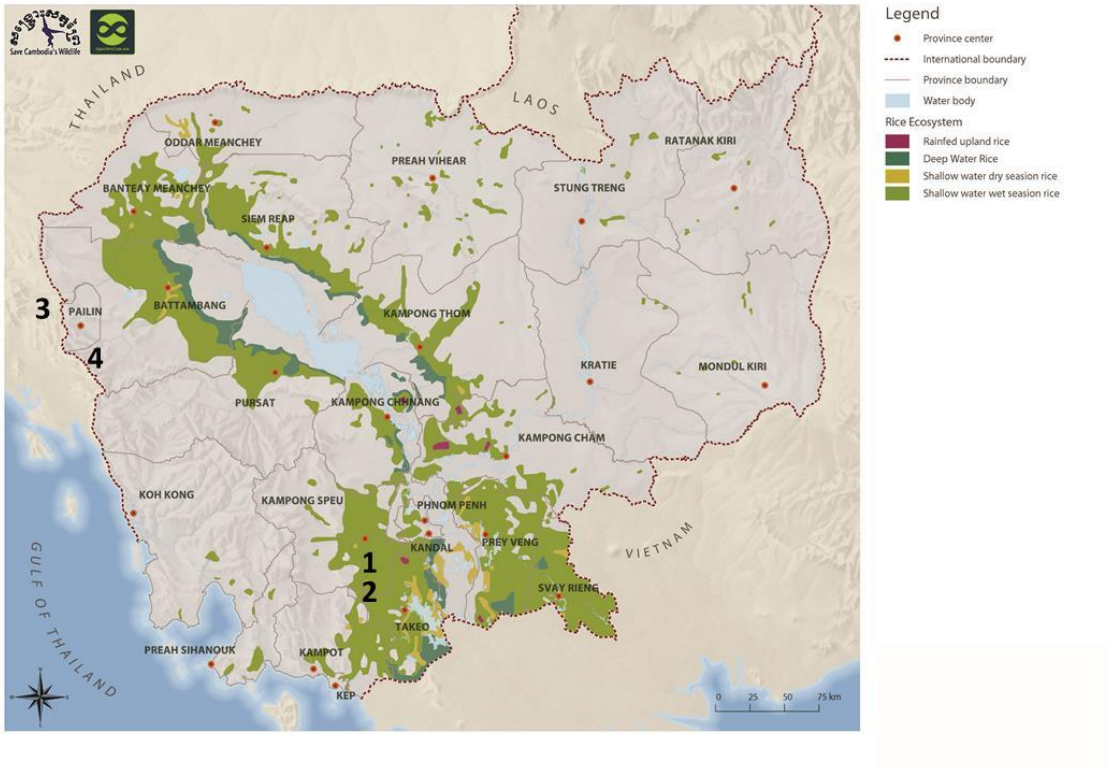

Figure 1: Different rice ecosystem in Cambodia

3. Workshop design

Based on the project objectives and earlier work experiences of farm group discussion, between 8 and 10 experienced farmers could be a productive workshop to generate necessary information. Socioeconomics team of CARDI consisted of five people to run the village workshops with the assistance from village heads and Pailin Provincial Department of Agriculture (PDA) and Maddox Jolie-Pitt Foundation (MJP) staffs. One or two team members were to lead the discussions. Flipchart was used to write all key discussion points in front of participants who were able to read the writing and constantly commented the written information while other team members also jotted down on their notebooks (Figure 2 and 3). The discussion was carried out based on the questions in Table 1.

Table 1: Questions for workshop discussions

Questions to guide the Focus Group Activities
1. What are the farmers' objectives/goals?
• How long have the individuals farmed? • Do they plan to always be farmers? • What would they like to do if they were not farmers?
2. How do farmers in Cambodia interpret the 'agricultural system'?
• What crops do the farmers produce? Why? • How long have they produced that crop? • What other crops have they produced? • What crops would they like to produce? • Will their families continue to farm in the future? • Who purchases their products? • Where do they sell these products? • What influences the price of their products?
3. What are the most significant challenges facing farmers?
• What are the biggest problems/challenges for farmers in Cambodia?   ○ In their region or village? • What are their experiences with those problems?
4. What changes to the system farmers think would help them be more successful?
• What changes would help farmers be more successful? • How would those changes help them?
Have they mentioned 'technologies'? If not, ask directly.

• Are they aware of any technologies that would help them be more successful?
  ○ New breeds of rice?
  ○ Pesticide?
  ○ Tractors?
  ○ ?

Figure 2: Farmer workshop conducted in Steung village, Takeo Province

Figure 3: Farmer workshop conducted in O'Andoung village, Pailin Province

4. Workshop participant information

The socioeconomics team contacted with the heads of Steung and Trapeang Chak Villages in advance to brief them the workshop activities which would hold in their villages and to request them to invite farmers in their villages. A day before the workshop, the team visited the village heads again to explain the purpose of workshop and confirm of invited participants and planned locations. Pailin PDA and MJP staffs assisted to gather farmers for the workshops in Pailin and Samlot respectively with similar communications were made before coming to the workshop days.

Except for O'Andoung Village with 16 attendants, the number of participants in other three villages ranged from 8 to 11 people (Figure 4 to 7). The discussions did go well for the three smaller groups but the largest group was frequently interrupted because some of them who were not the main responsible people for farming activities did not pay attention to the discussion but just came to the workshop expecting for some free gifts. The Pailin PDA staff might not clearly explain the villagers of the workshop. Many invited farmers in Kantuat did not appear at the time of workshop and therefore the MJP staffs had to call them again. The workshops in Steung and Trapeang Chak villages were organized with the assistance from the village heads and it was really well arranged. The question guide for discussion (Table 1) could not be able to obtain a lot of information from the participants because they can be simply answered by one short sentence therefore the workshop facilitators had to raise various questions prepared in advance in order to generate more information from the participants.

The age of participants widely ranged from 23 to 77 years old in all groups with an average between 40 and 53 years among the four villages. The gender of participants was fairly good balance between male and female with the female participants ranging from greater than 30 to nearly 70%. Table 2 to 5 present the information of participants of the focus group workshops.

Table 2: Participants in Steung village

No.	Name	Age	Sex	Relationship to household	Main occupation	Contact number
1	Haas Nob	47	Male	Household head	Farmer	0717108062
2	Kan Sokchea	53	Female	Household head	Farmer	092124232
3	Kang Chenda	48	Female	Household head	Farmer	098471120
4	Saem Chrel	41	Male	Household head	Farmer	0883447876
5	Ouch Sarom	35	Female	Wife	Farmer	0884654311
6	Pok Sokhim	35	Female	Wife	Farmer	0977201093
7	Ouch Dara	28	Male	Household head	Farmer	0977651300
8	Tob Em	50	Female	Wife	Farmer	n/a
9	Hun Hi	27	Male	Household head	Farmer	n/a

Figure 4: Participants in Steung village, Takeo Province

Table 3: Participants in Trapeang Chak village

No.	Name	Age	Sex	Relationship to household	Main occupation	Contact number
1	Im Yath	60	Female	Household head	Farmer	n/a
2	Pal Mom	26	Female	Wife	Farmer	0967191257
3	Touch Nim	49	Male	Household head	Farmer (vice village chief)	0719253403
4	Chan Seak	37	Male	Household head	Farmer	0887353867
5	Ouk Sambunthen	46	Male	Household head	Farmer	017472005
6	Koam Thea	40	Male	Household head	Farmer	0884911766
7	Chen Tha	50	Female	Household head	Farmer	n/a
8	Mode Tharn	53	Male	Household head	Farmer	n/a
9	Koam Oun	46	Male	Household head	Farmer	0884637241
10	Cham Krit	43	Female	Wife	Farmer	n/a
11	Long Say	46	Male	Household head	Farmer	0977732994

Figure 5: Participants in Trapeang Chak village, Takeo Province

Table 4: Participants in O'Andoung village

No.	Name	Age	Sex	Relationship to household	Main occupation	Contact number
1	Mak Kosal	45	Female	Wife	Farmer	0976256367
2	Krang Reun	59	Female	Mother	Farmer	n/a
3	Kean Sok	70	Female	Mother	Farmer	n/a
4	Saem Sokha	28	Female	Wife	Farmer	0975492474
5	Veoun Mao	43	Female	Wife	Farmer	n/a
6	Seam Lout	30	Male	Son	Farmer	0972027580
7	Veoun Ken	54	Male	Household head	Farmer	n/a
8	Chhaem Prok	47	Male	Household head	Farmer	n/a
9	Seng Sokthida	49	Female	Wife	Farmer	0965830035
10	Sok La	42	Female	Wife	Farmer	n/a
11	Vaen Sopheavy	25	Female	Wife	Farmer	0963100968
12	Peang Sok	70	Female	Household head	Farmer	n/a
13	Phat Chreb	38	Female	Wife	Farmer	012906343
14	Keo Chharm	58	Male	Household head	Farmer	017942795
15	Un Pheoun	61	Male	Household head	Farmer (village chief)	0978073840
16	Him Veoum	45	Female	Wife	Farmer	n/a

Figure 6: Participants in O'Andoung village, Pailin Province

Table 5: Participants in Kantuat village

No.	Name	Age	Sex	Relationship to household	Main occupation	Contact number
1	Run Aem	57	Female	Household head	Farmer	0883424691
2	Hang Phot	59	Male	Household head	Farmer	n/a
3	Svay Phat	56	Female	Wife	Farmer	095298937
4	Keb Kob	61	Male	Household head	Farmer	0719177146
5	Duk Sophoan	28	Male	Household head	Teacher	095682451
6	Prum Sari	64	Female	Wife	Farmer	0718971269
7	Von Vany	23	Male	Son	Farmer	012397975
8	Chey Chham	77	Male	Household head	Farmer (village chief)	0179446131

Figure 7: Participants in Kantuat village, Samlot district of Battambang Province

5. Profiles of target villages

The profiles of the four selected villages including population, sex, family, house, family size and labour were presented in Table 6. Population among the six villages widely varied from less than 500 to above 2,100 people with female number having a little higher proportion except for Steung village with a greater female population. Therefore, the larger population village had larger number of farm families and smaller village had lesser number of farm families ranged from 100 to 460. Because some married children still shared the houses with parents despite registering as independent families, the number of houses were smaller than number of families. Family size and labour which comprised 5 and 4 respectively were quite consistent among the four villages but Trapeang Chak had 2 family members more than other and O'Andoung had a family labour smaller than other.

Table 6: Village profiles

	Steung	Trapeang Chak	O'Andoung	Kantuat
Population	2,126	630	469	950
Female	1,313	340	235	480
No. families	461	145	97	224
No. houses	324	123	83	203
Family size	5	7	5	5
Family labour	4	4	3	4

Under two distinct ecological zones, there are different land types between the two lowland villages – Steung and Trapeng Chak and the two upland villages – O'Andoung and Kantuat. Table 7 presents the figures of village sizes consisting of residential space, farming land, and paddy field with and without irrigation source. The total village area ranged from only 228 ha (Trapeang Chak) to 1,409 ha (O'Andoung).

Residential area was common for every village but the village head of Steung was not able to estimate the housing land size because there was such land record for his village and also the settlement of houses were spread across the village territory. Kantuat had the largest land for housing because every house attached to an area for annual cropping and fruit trees. The residential land was granted to the former Khmer Rouge families by Khmer Rouge authority shortly before handing over the Khmer Rouge controlled zone to the elected Cambodian government.

Paddy land was available in all villages but it is very marginal in O'Andoung (13 ha) while Kantuat villagers had access to large rice land (125 ha) despite being upland condition. Depending on rice cultivation, the two rainfed lowland villages had far larger rice fields than the two uplands. More than half of paddy field in Steung could access to irrigation systems. Farmland referring to the upland villages was between 330 and 530 ha and upland for non-rice crops referring to the lowland villages was only 20 ha in Steung and unavailable in Trapeang Chak. Hillside or bush land was small compared to the largest forest area of upland villages but this land type was not granted to any villager. The forest land in Kantuat village was not under the management of local authority but environmental group.

Table 7: Village areas and accessible farming lands (ha)

	Steung	Trapeang Chak	O'Andoung	Kantuat
Total area	1,010	228	1,409	703
Residential area	-	25	15	46
Paddy field	345	223	13	125
Irrigated land	200	n/a	n/a	n/a
Farm land/upland	20	n/a	329	532
Hill side/bush land	15	17	1,050	-

An average landholding per household calculated by summing residential land, paddy field and non-rice crop land, and dividing with the total number of family in the village was 0.8 ha and 1.7 ha in Steung and Trapeang Chak and 3.7 ha and 3.1 ha in O'Andoung and Kantuat respectively. Table 8 presents farm land holding based on the estimations of participant. The majority of farm households in Steung owned less than 2 ha with 60 % below 1 ha and in Kantuat occupied between 1 and 3 ha which was consistent with the overall figures. Only few households had large paddy land. The estimation of land holding in upland villages was also somewhat consistent with the average figure despite showing high percentage of 1 ha family in O'Andoung. The participants also agreed that a number of family owned very large farmland. However there were between 10 and 20 landless families in every village.

Table 8: Farm household land holding

	Steung		Trapeang Chak		O'Andoung		Kantuat	
	ha	%	ha	%	ha	%	ha	%
Small size	<1	60	≤1	41	1	30	<1	5
Medium size	1-2	37	>1-3	54	>1-5	40	3-4	50
Large size	>2	3	>3	1	>20	5	>7	10

6. Farming history and future direction

Under rainfed lowlands environment, despite experiencing Khmer Rouge regime between 1975 and 1979, the farm households in Steung and Trapeang Chak claimed their farming activities referring particularly to rice cultivation have continued from their parents because there was no interruption for farming activities but farmland and production were strictly controlled by the state. Rice cultivation had been carried out under collective system during the Khmer Rouge period and after the collapse of the darkness regime. Considering the participants' age variation, they have farmed from 10 to 50 years. O'Andoung and Kantuat villages located in the upland areas bordering Thailand had different history of farming because the lands where they were densely forest zones have not been cultivated before and during the civil war. The farming land allocation was carried out in 1998 shortly before the integration of Cambodian Government and former Khmer Rouge military. Though they also had cultivated crops during the civil war after the defeat of Khmer Rouge regime retreating to settle in the mountainous areas along Cambodia-Thailand border, it was also under the collective farming society. Therefore, the participants considered the commencement of their farming activities were rather in 1998.

The participants in Steung village indicate they had no intend to leave farming work because their livelihood relied entirely on rice cultivation but additional sources of income from the activities of farm, off-farm or non-farm jobs were necessary. Minority of villagers would wish to abandon farming and to look for non-farm work opportunity but they were old-age people and had no other skill therefore they have continued rice cultivation. They anticipated that many young people would quit farming activity in the future. Trapeang Chak farmers raised three major factors which have kept them continue farming. Firstly, both farmland and farming experiences were inheritance from their parents therefore they did not want to abandon the bestowal. Secondly, lack of other skills to pursue non-farm jobs was also not rejected. Thirdly, financial layout for other business was also constraint. However, good non-farm income and skill development would encourage the farmers to leave farming work. The villagers in O'Andoung stressed that farming was their livelihood and land was accessible resource as the main reasons. No other alternative and no capital for investment also were also barriers to move out of the farms. They would prefer to have additional income in the village other than leaving the farms if there was an option. But young family members may want to quit farming activities. The participants in Kantuat suggested that their rich land resource and available markets for farm outputs were strong motivation for farming. However, they wanted their children to seek non-farm opportunities.

7. Crop cultivations influenced by available technology and market

Rice was the main crop in Steung and Trapeang Chak villages for home consumption and the surplus for cash income. Rice production was previously produced only for subsistence and it has been traded for cash since mid-1980s because rice market

became available together with accessible roads, further the production also increasingly required material inputs. Daily household expenditure was also other main reason for paddy trading. The participants from both villages indicated the production will shift to more market oriented that is the quantity for sale will increase. Peanut, mungbean, watermelon and vegetables were among non-rice crops mainly produced for cash income.

But cassava was the major crop in O'Andoung and Kantuat villages despite being adopted at different year. The latter indicated that it was scaling out from the former. Soybean, peanut, sesame and mungbean were the longest crops starting from 1998 and they were still being planted. Maize which was previously cultivated by the majority has been decreasingly planted in Kantuat and was no longer cultivated in O'Andoung. Black pepper, longan, durian and rambutan were perennial crop or strategic crops called by Kantuat villagers. Very small number of households grew rice in O'Andoung but as many as 80% of Kantuat households cultivated rice. Though their farming activities appeared to be well cropping system, none of the four villagers understood the term 'farming systems'.

Many new rice varieties released by Cambodian Agricultural Research and Development Institute (CARDI) and IR50404 released by Vietnam research institute were adopted in the two rainfed lowland villages. Fertilizer recommendation rates together with pesticide application to some extent were also practised. Trapeang Chak indicated the practice of young and less seedling per hill for transplanting method technically recommended. Mechanization including two-wheeled tractor, reaper and combine harvester were accessible in both villages regardless small number or no ownership of machinery in the villages. Despite having no noticeable technology, the two upland villages have applied pesticides and materials/hormone for crop flower induction. Cassava growers in O'Andoung indicated the planting technique was influenced by Thai farmers. Seed, planting materials and other chemicals such as fertilizers and pesticides in both villages were also imported from Thailand and Vietnam.

Rice and non-rice crops could be sold to traders at the villages of Steung and Trapeang Chak but the farmers also transported paddy rice and other farm produces to sell to nearby rice mills and markets respectively. Rice price varied according to quality with low quality rice having low farm gate price (USD 0.22/kg) and fragrant rice having higher price (USD 0.35/kg) based on recent obtaining prices. The price of such crops as mungbean and peanut was more stable but watermelon was more volatile. Cassava and maize cultivated in the two upland villages were sold to silos rapidly established in the areas. Soybean, mungbean and sesame were collected by traders at the villages and transported to Thailand. The farm gate price of cassava varied from USD 0.03/kg to 0.06/kg of fresh cassava root and USD 0.13/kg to 0.20/kg of dry cassava chip. The farm gate price also tended to fluctuate for soybean (USD 0.38-0.68/kg) and mungbean (USD 0.75 to 1.13/kg) but more steady for sesame (USD 1.9/kg).

8. Challenges and factors improving farming systems

Water shortage, insects and diseases were the major challenges for rice and non-rice crop cultivations in the two rainfed lowland villages. Lack of green feed and diseases were experienced by cattle owners in the villages. Only Trapeang Chak village considered the absence of new technology as their farming constraint. O'Andoung village indicated insects and irregular rainfall were the severe problems for the cultivations of cassava, maize and soybean crops. Kantuat farmers also mentioned having rainfall at harvesting time was an obstacle but this village turned more attention on market, crop price and

roads and transport. They complained that the harvest depended entirely on foreign market; traders were only party to set the price for farm produces; and the condition of poor road access significantly affected market price. New innovations were also mentioned but were the not key factors because of rich soil fertility in Kantuat.

Irrigation system was priority for the two rainfed lowland villages to improve their farming situations. Sufficient organic and inorganic fertilizer supply was other factors required for enhancing crop production in Steung village. Despite indicating no technology requirement, this village implied crop intensification and diversification were important solution to the current constraints. But Trapeang Chak villagers apart from irrigation water did select technology for improving the cropping systems. Participants in O'Andoung believed that a reliable and regular rainfall was the only factor helping their farm activities for more successful. Technology implication seemed to be more impressed by the Kantuat participants. The practice of crop rotation could improve soil fertility and crop diversification could minimize the large scale of crop losses or entire losses. Other important factors such available markets and good price could also make their farming business more successful.

9. Conclusion

The participants from all villages were active farm family members and well experienced in farming activities despite having wide range of ages. Number of household and population broadly varied but family size and labour number were very close within the four villages. The total village land areas were greatly different but cultivated areas became smaller gap among the four villages. The average landholding per household clearly varied between the two lowland villages and also between the lowland and upland villages.

Crop cultivations were clearly influenced by favourable ecosystems – rice on lowland and non-rice crops on upland. The village settlement had connection to the duration of cultivation between the two different environmental villages with the lowland villages cultivating rice even long before the civil war while the upland villages commonly starting crop cultivations in 1998. Rice production was merely subsistence in the past for the lowland villages but has gradually turned to partially cash generation since mid-1980s. The purpose of crop cultivations was commercially oriented in the upland villages.

All participants from the four villages consistently responded that the majority of villagers showed no intention to leave their farm in order to seek non-farm opportunity given a range of reasons. They either considered or intended to have children lived outside villages or earned income from non-farm business.

The two lowland villages have adopted certain new innovations including rice varieties, recommendations of fertilizer and pesticide application, and mechanized farming as well as agronomy practices which were the impact of agricultural research for nearly three decades. The uses of seed, planting materials, chemicals and fertilizers in the upland villages were seemingly influenced by traders and Thai farmers. Cropping system, rice-non-rice crops, was constant or unchangeable under rainfed lowland situation because rice cultivation was mainly for subsistence and rice was also staple diet but the decision on cropping system has been significantly influenced by market availability and crop prices because of largely commercial crop production in the upland areas.

The challenges of rainfed lowland farming were water shortage, insects and diseases, and lack of new technology and the upland farming systems had to overcome unfavourable rainfall (irregular pattern and fluctuate amount), insects, roads and transport, market and farm gate prices.

Two villages located under rainfed lowland ecosystem and another two under upland environment with each village having particular conditions and typically practising farming activities required different appropriate factors to make the farming systems more successful. Irrigation source and agricultural technology were key solutions to lowland villages. While one upland village would like to have regular and reliable rainfall, the other was interested in crop rotation and diversification for cropping systems, and market and price for post-harvest matter.

11.2 Economics research report

Financial and opportunity costs of agricultural labour in Cambodia: implications for rice production technologies

Abstract

This paper illustrates an approach to analysing the question of adoption of new technologies by smallholders in developing countries when the full financial and opportunity costs of labour are accounted for. The analysis extends the traditional whole-farm approach to a livelihoods framework when opportunities for off-farm work are included in an optimizing model. Linear Programming is used as the analytical method. We expect, *a priori*, that including the opportunity cost of labour will have an impact on choice of 'best' farm management, and there is evidence in the results that this is the case. However, this is a preliminary analysis using, in part, hypothetical data. Further work to fully investigate this approach to such questions is warranted.

Introduction

Economic development in Cambodia has been rapid in recent years, with an annual average growth rate in the economy of 7.8% over the period 2000 to 2012 (Hatsukano and Tanaka (2014)). But still there is substantial poverty, with the poverty headcount ratio at US$1.25/d reducing from 44.5% to 22.8% over the same period, and the GINI coefficient of income inequality being 38.3% and 37.9% in 1994 and 2008, respectively (Hatsukano and Tanaka (2014)).

Associated industry developments in Cambodia have included growth in garment and other manufacturing, and employment opportunities have also developed in construction and other industries in Thailand. These have provided employment options for Cambodian farm families and rural workers.

Agriculturally, subsistence rice production is still the main activity although this industry is also experiencing substantial change. The Cambodian Government established a rice export policy in 2010, with the goal of exporting 1 million tonnes of rice by 2015 (Hatsukano and Tanaka (2014)).

Agricultural development policy in South-East Asia is based on three strategies of intensification, diversification and commercialisation (Johnston 2014). But the World Bank has recently queried whether rice is the answer to poverty reduction (Wade 2014). Rice production in Cambodia is not generally a profitable enterprise, with low rice prices and yields. Hence farmer incentives to grow rice are low and they would prefer to grow higher-value and more profitable crops, i.e. diversifying away from rice. Farmer incentives to grow rice don't match with Cambodian Government policy for targets to export rice and maintenance of low domestic consumption prices.

There are increasing health concerns about excessive rice consumption associated with obesity in human populations, for food with high carbohydrate content and high Glycaemic Index. There are associated effects on the consumption of staple goods as incomes rise, with both the proportion of income spent on food and the proportion spent on the traditional staple declining. At some stage rice becomes an 'inferior good' so that consumption per capita declines as income rises (Pingali 2004).

Associated with these economic developments in non-agricultural Cambodia is the availability of off-farm work for substantially higher wages than farm returns (up to US$100/month (Wade 2014)). This has reduced the supply of agricultural labour for rice production (a very labour-intensive activity), and increased farm labour wage rates. It has also led to a rapid increase in mechanisation (Newman 2014).

Cramb and Newby (2014) outlined the trajectories of rice-family households in South-East Asia. They commented that ".. farmers in traditional rice-growing environments .. are responding to changing incentives by diversifying their farming systems .. and pursuing

non-farm activities such as labour migration and rural business as part of a range of complex and dynamic livelihood strategies. Moreover, the growth of agribusiness investment has led to new modes of land utilisation, from contract harvesting to large-scale plantations, with significant implications for national and international research priorities". These trajectories are the result of deliberate decisions or livelihood strategies by farm households.

The Australian Centre for International Agricultural Research (ACIAR) invests substantial research and development (R&D) funds in rice production technologies in the Mekong Region, and is interested in optimising outcomes from this important research (Robins 2014). Funding bodies are concerned at apparently low levels of adoption of R&D outputs, and this issue has been characterised as due to the presence of barriers or impediments to adoption (Newman 2014). But farmers do adopt new technologies when there is a clear advantage in doing so, for example a shortage of farm labour and rising labour costs has led to the rapid increases in mechanisation in rural Cambodia. Given the contemporary economic and policy context, Cambodia rice farmers may be quite rational to adopt a low-input, low-yield cropping system that meets their subsistence goals and allows them to use household labour to earn higher returns off the farm (Cramb (2014)).

The 'adoptability' of new technologies has been considered by Rogers (2003) and Pannell et al. (2006), where attributes of a technology, from the adopters point of view, are considered in the context of whether adoption is likely. These attributes are relative advantage, compatibility, complexity, trialability and observability. Farquharson et al. (2013) evaluated the adoption intentions of Cambodian upland farmers with respect to rhizobium inoculation of legume seeds and found that, statistically, relative advantage was the most important characteristic, followed by observability. Compatibility, complexity and trialability were not significant. Relative advantage is substantially a measure of economic merit.

In this paper we develop a model of lowland farm rice production in Cambodia to evaluate new rice production technologies and use of farm family labour. It is a bio-economic model in which the potential economic advantages of technology adoption and change are included. The model is used to assess the financial and opportunity costs of agricultural labour in Cambodia in terms of adoption and change. This follows Cramb's (2014) observation that policies and technologies need to be assessed at the farm household level in a livelihood context.

Research question and analytical approach

Given the above issues and context, an important question relates to the incentives for lowland rice producers in Cambodia to change their production, or adopt new technologies.

The research questions addressed in this paper are:

1. How are the incentives to change on-farm rice production and management methods in Cambodia affected by new labour and mechanisation options?

2. Are the economic perspectives of smallholders changed when a rural livelihoods framework and labour use options are considered?

The objective of this paper is to provide new insights to the incentives for rice producers to adopt new rice production technologies. We are primarily considering labour as a resource for rice production, and evaluating the financial and opportunity costs of agricultural labour in lowland rice production systems.

The audience is R&D funding bodies, governments making policy about agricultural production and exports (the Royal Government of Cambodia), and agencies conducting R&D and extension (CARDI, Department of Agricultural Extension Cambodia).

We conduct an analysis at the farm level, since this is where agricultural production and management decisions are made. We use a whole-farm analysis since we consider

farming systems issues to be important. We develop a representative farm model (a whole-farm model (WFM)) to find information that is relevant to the wider population of lowland rice farmers.

However, given the importance of rural livelihoods for farm family decisions (Cramb (2014)) we develop the WFM to assess farm income and then extend to a farm-family analysis in a livelihoods framework. In this way the farm-family labour resource is considered within the full opportunity set of farm and off-farm work.

Rural Livelihoods

Cramb and Newby (2014) discussed rural appraisal within a rural livelihoods framework to assess the family situations of poor, average and better-off households in central Vietnam. Rural livelihood diversification is "the process by which rural households construct an increasingly diverse portfolio of activities and assets in order to survive and to improve their standard of living" (Ellis (2000), p.15). Rural livelihoods analysis has been developed by Scoones (1998), Ellis (2000) and others. Ellis (2000, p.10) defines a livelihood as comprising "the assets (natural, physical, human and financial and social), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household".

In this analysis the focus is on farm-family labour as an asset that can be diversified into non-farm income in order that the family unit can survive and improve in standard of living. The research question is whether such diversification changes the incentives for farmers to change rice crop management and adopt new rice production technologies. By expanding focus of the analysis from the farm to the farm family in a livelihoods context while maintaining the economic framework for analysis we consider the farm-level incentives for rice production when the full opportunity cost of labour is accounted for.

Characteristics of the problem

Lowland rice production in Cambodia has traditionally been conducted for subsistence purposes, where rice production is solely for family consumption and no sales or cash transactions were undertaken. Recently the Cambodian government has developed a rice export target and encouraged rice farmers to produce some rice for sale. There is now more semi-subsistence farming where an amount of rice is produced for year-round family consumption and the excess is sold in a market (Chea 2015).

In this case economic aspects of rice production become more important. This may be allied with desire for improved quality of life through consumer goods (improved diet, child education, family health, and television), transportation (motorcycles) and communication (mobile phones)). Economics includes an accounting for inputs, outputs and their relative prices. We consider that an economic objective for farm families is relevant in assessing farm-level decisions for semi-subsistence rice production.

The typical lowland rice farming system comprises a wet season rice crop (WS) with the potential for an early wet season rice crop (EWS) and other dry season crops, e.g. vegetables, depending on availability of supplementary water sources (Chea 2015). These crops are generally labour intensive, although there has been increased use of mechanisation in recent years. There are patterns of labour demand associated with these crops so that the choice of crops depends on wet season rainfall, supplementary water sources in the dry season, and labour availability.

For the purposes of this analysis a hypothetical rice activity representing a new technology (HRT) is constructed. Based on the WS rice activity, the HRT has a 10% yield increase, receives the same price, has the same variable costs, and requires 20% more labour.

Associated with this issue of labour availability and cost have been autonomous developments in ownership and use of machinery on Cambodian farms. Two-wheeled tractors are being increasingly used for cropland preparation, and contractors are

becoming more common with harvesting machines for rice. There are commercial incentives so that the pricing of contract harvesting is competitive compared to the daily hired labour rates and the number of person-days required to harvest a hectare of rice.

There are opportunities to hire farm labour (non-family labour) and for family members to work off farm. Therefore labour has an opportunity cost and the issue for this paper is whether these financial (hired labour) and opportunity (off-farm work for family labour) costs affect the incentives for choice of farm rice production methods (including new technologies).

Labour supply and use patterns

Nuthall (2011, p.277) noted that the demand for labour in agricultural systems generally varies throughout the year. It is important to account for seasonal labour demand and supply in representing and analysing farming systems.

A study of the lowland rice activities by Chea (2015) for Trapeang Run village showed that the main lowland rice activities can be divided into Land Preparation (ploughing, harrowing and fertilising), Pulling and Transplanting (pulling seedlings and transplanting), Tending Crops (manuring and weeding) and Harvest/Post Harvest (harvesting, threshing and transport). These activity types are consistent for lowland WS and EWS rice.

From Chea's detailed labour budgets a set of labour periods was devised to suit the main rice activities for use in the WFM analysis. Details of rice labour periods are in Table 1.

Table 1: Labour periods for Cambodian lowland rice production

Period number	Dates	Number of days
1	1/1 - 15/1	14
2	16/1 - 23/1	7
3	24/1 - 23/4	89
4	24/4 - 20/5	26
5	21/5 - 14/6	24
6	15/6 - 31/7	46
7	1/8 - 30/9	61
8	1/10 - 15/11	46
9	16/11 - 21/12	45

In this analysis the farm family is assumed to consist of 6 people, a husband and wife, plus 2 young adults who provide full time work opportunity (both on and off the farm), and 2 younger children of school age who do not provide any labour. The farm labour supply is therefore 4 adult equivalents, 2 of which are assumed to be able to undertake off-farm work. Estimates of farm family labour supply are given in Table 2, based on family labour being available on 6 days per week (Table 2).

Table 2: Family labour supply based on adult equivalent numbers

Labour period name	Period days	Number of family workers		
		Adult	Adolescent	Total
L1	14	24	24	48
L2	7	12	12	24
L3	89	153	153	305
L4	26	45	45	89
L5	24	41	41	82
L6	46	79	79	158
L7	61	105	105	209
L8	46	79	79	158
L9	45	77	77	154
Total	358			

The estimated labour requirements over these periods for WS, EWS and HRT rice are shown in Figure 1.

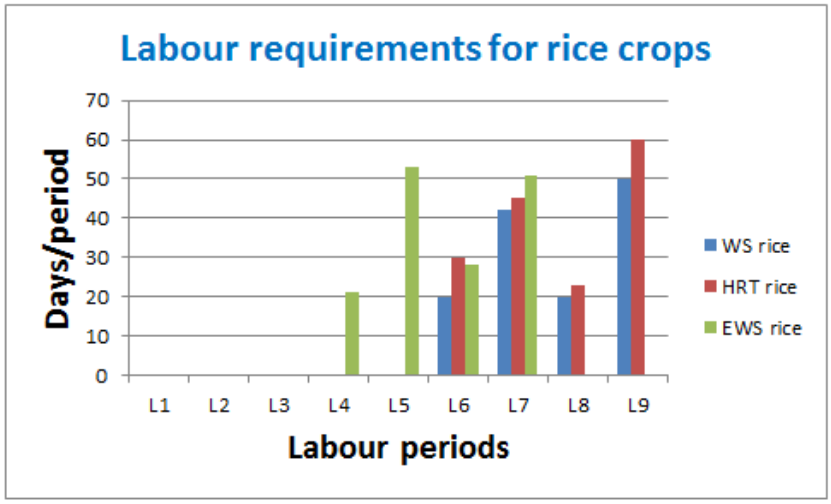

Figure 1: Labour requirements per period for rice crops

Recently in Cambodia the availability and price of local hired farm labour has changed with the availability of non-farm work (e.g. garment manufacturing and construction). The author collected a time series of hired labour prices in upland Cambodia, and these data are in Figure 2. In the Pailin district of north-east Cambodia the labour price has risen from 6,000 riel/day to nearly 30,000 riel/day (US$1.5 – 7/d) over the period 2006-2014.

Figure 2: Farm labour price: Pailin district in Cambodia

For this analysis a labour price of US$7/d was used for the hired labour activity.

Analyses to test research questions

The two important aspects of this research are choice of farm production technology and use of family labour; these are set out in the research questions above. The analytical design to address these choices is in Table 3.

Table 3: Analyses of crop and labour activities to test research questions

Production technology	Labour supply and opportunities			
	No labour included	Family labour	Hired farm labour + (2)	Non-farm work + (3)
	(1)	(2)	(3)	(4)
Traditional rice production	X	X	X	X
Add new rice production	X	X	X	X

Using a whole-farm-family model, for each cell in Table 1 the farm-family income and optimal allocation of farm and labour activities are estimated. Scenarios (1), (2) and (3) focus on farm-level decisions and scenario (4) is the livelihoods analysis. Comparison of these results allows the research questions to be addressed.

Economic framework and method

Since there are seasonal labour requirements according to crop choice and since family labour is in fixed supply a constrained-optimising WFM approach is used. The WFM is used to account for the interactions between the farming system (crop activity choice) and labour availability.

The economic framework, and budgeting in particular, considers the benefits and costs of alternative actions or decisions. Analyses can be undertaken for the farm as a whole or for separate activities within the farm. Analysis using a WFM accounts for farming systems interactions (Dillon 1976).

Important farm management economic questions include which products should be produced and in what quantities, given the resources available and the decision maker's objective. In assessing and developing improved farming systems when economic objectives are important for decision makers, budgeting is a simple analytical technique (Dent et al. (1986), Makeham and Malcolm (1986), Nuthall (2011)) which provides the basis for more detailed analyses.

All farm costs can be divided into fixed (or overhead) and variable (or working) costs. Fixed costs for a farm remain constant regardless of the varying levels of output and changing patterns of production. Examples of fixed costs in developing countries include minimum cash living expenses, schooling and clothing costs for the farm family, or finance costs such as interest and fixed-loan repayments (Makeham & Malcolm 1986). Variable costs for a farm are those that vary with the levels of output and changing patterns of production. Examples include fertiliser and weeding costs.

In developing countries many smallholder farms have non-cash inputs, such as rice seed retained from the previous crop for planting, organic fertiliser (manure), and labour provided by family or other sources in kind.

Farm activity analysis

Chea (2015) conducted economic analyses of farm activities based on conventional farm management economics modified for semi-subsistence rice production in Cambodia. For a farm activity the Gross Margin (GM) per ha is the gross value of production (estimated crop yield multiplied by the farm-gate price) less paid-out costs or cash expenses. This is termed the net return to household resources (NRHR). NRHR can be calculated per ha or per tonne.

Since household labour is considered to be a resource that can be allocated to farm, off-farm or non-farm activities, the ratio of NRHR to total labour input to the farm activity is calculated and termed the net return to household labour (NRL).

Crop GM and labour budgets for WS, EWS and HRT are in Appendix I and summarised in Table 4.

Table 4: Crop GM budgets

Item	Unit	WS rice	EWS rice	HRT rice
Yield	Kg/ha	2,195	2,612	2,415
Seed	Kg/ha	81	114	90
Output	Kg/ha	2,114	2,507	2,325
Farm Gate Price	US$/t	280	240	280
Gross Income	US$/ha	592	602	651
Input Expenses	US$/ha	90	123	90
Input Expenses	US$/t	41	47	39
NRHR	US$/ha	502	490	561
NRHR	US$/t	237	191	241
Total Household Labour	d/ha	132	153	158
NRL	US$/d	3.8	3.5	3.6

Whole-farm analysis and opportunity costs of resources

For a farm economic objective the choice of farm activities, and of the best use of farm resources, must be made by fully accounting for the opportunity costs of such use (Dent et al. (1986)). The cost of undertaking a farm activity is the value of the best alternative action that has to be foregone. This concept applies to the use of resources, such as land and labour, as well as to the choice of farm activity.

The marginal value product (MVP) is the increase in profit associated with the use of one more unit of a resource that is in limited supply. For land, the MVP can be thought of as the extra profit that could be made if one more unit of land was available, or the maximum yearly amount of money the farmer could afford to pay for the use of additional land without reducing farm profit. In a whole-farm context the MVP will depend on the new optimal combination of farm activities.

Paris (1991) noted that this value of marginal product is the shadow price, or imputed price of the input. It is the marginal sacrifice that an economic agent must bear because of the presence of the constraint. Dent et al. (1986) note that “the terms shadow price, opportunity cost and MVP are often used synonymously when referring to resources” (p.77).

Linear Programming (LP) (Pannell, DJ 1997) was used to conduct the analysis in this paper since both the choice of farm activity (change or adoption of new methods to improve profits) and the best use of labour (on- or off-farm in a livelihoods framework) are the important research questions. The optimising LP method fully accounts for the opportunity costs of resources used. The model was solved with Microsoft Excel Solver. An LP matrix is shown in Appendix II.

Results

Results of analyses conducted according to Table 3 are presented. The LP models were specified according to parameters in Tables 1, 2 and 4. Table 5 includes crop choice results with only the land constraint (2 ha farm size) for traditional WS and EWS rice production, and when HRT is included (option (1) in Table 3). For traditional rice production WS is optimal and farm profit is $1,002. When HRT is included it is optimal and farm profit rises to $1,120.

When crop labour period requirements and family labour supply are included (option (2) in Table 3) the results are as in Table 6. HRT is still the best crop and adult and adolescent labour is supplied in periods 6, 7, 8 and 9. Farm profit remains at $1,120 since there are no financial or opportunity costs for family labour in this model.

Table 5: Crop choice with only land available

Activity	*Optimal solution values*		
	ha	t	$
Traditional rice production			
WS	2	4.2	
EWS	0	0	
Farm profit			$1,002
Tradition rice and new technology			
WS	0	0	
EWS	0	0	
HRT	2	4.65	
Farm profit			$1,121

Table 6: Crop choice with land and family labour available

Description	*Activity*	*Optimal solution values*			
		ha	t	d	$
Crop choice	WS	0	0		
	EWS	0	0		
	HRT	2	4.65		
Family labour in period	6 Adult			60	
	6 Adolescent			0	
	7 Adult			90	
	7 Adolescent			0	
	8 Adult			46	
	8 Adolescent			0	
	9 Adult			77	
	9 Adolescent			43	
Objective function	Farm profit				$1,121

When hired labour is made available to the farm (option (3) in Table 3) at a price of US$7/d the results were that no hired labour was used and farm profit remained at $1,120 (Table 7).

Table 7: Crop choice with land, family labour and hired labour available

Description	*Activity*	*Optimal solution values*			
		ha	t	d	$
Crop choice	WS	0	0		
	EWS	0	0		
	HRT	2	4.65		
Family labour in period	6 Adult			60	
	6 Adolescent			0	
	7 Adult			90	
	7 Adolescent			0	
	8 Adult			46	
	8 Adolescent			0	
	9 Adult			77	
	9 Adolescent			43	
Hired labour in period	6			0	
	7			0	
	8			0	
	9			0	
Objective function	Farm profit				$1,121

Finally off-farm work was included (option (4) in Table 3) for the 2 adolescent family members with the model now representing a farm-family livelihoods framework. Off-farm work was included at a value of US$3/d based on a garment factory wage of US$100/month. The results are in Table 8. Off-farm work is included in the optimal solution and farm-family income rises to US$2,340. In this result the labour constraint is now binding so that 0.7 ha of EWS and 1.3 ha of HRT are included.

Table 8: Crop choice with land, family labour, hired labour and off-farm work available

Description	***Activity***	***Optimal solution values***			
		ha	t	d	$
Crop choice	WS	0	0		
	EWS	0.7	1.8		
	HRT	1.3	3.0		
Family labour in period	4 Adult			15	
	4 Adolescent			0	
	5 Adult			41	
	5 Adolescent			0	
	6 Adult			59	
	6 Adolescent			0	
	7 Adult			94	
	7 Adolescent			0	
	8 Adult			30	
	8 Adolescent			0	
	9 Adult			77	
	9 Adolescent			0	
Hired labour in period	6			0	
	7			0	
	8			0	
	9			0	
Off-farm work in period	4 Adolescent			45	
	5 Adolescent			41	
	6 Adolescent			79	
	7 Adolescent			105	
	8 Adolescent			79	
	9 Adolescent			77	
Objective function	Farm family livelihood				$2,340

The shadow prices (opportunity cost or MVP) of land and labour are shown in Table 9. In the farm model when labour is not constrained or limited in supply in any period, the shadow price of land is $560. If another ha of land was available the (optimal) HRT crop grown yields 2.325 t/ha at a price of $241/t.

In the livelihoods model the labour supply to grow HRT becomes constrained because the 43 d of adolescent labour previously used to grow HRT rice in period 9 (Table 7) is now better used in off-farm work. Adult labour in periods 4 and 5 is used to grow EWS rice, with adjustments in adult labour used in other periods. Adolescent labour to produce rice is now a constraint on farm income and the shadow price is the $3/d for off-farm work except in period 8. In that period the use of labour for rice production now becomes binding and the shadow price of an extra unit of labour is reduced.

The shadow price of land in the livelihoods model is $478, being the best use of an extra ha which would grow EWS rice (for a yield of 2.507 t/ha and a price of $191/t).

Table 9: Shadow prices of farm land and labour resources

		Farm level analysis	Livelihoods level analysis
Shadow prices	**Unit**		
Land	$/ha	560	478
Adult labour 4	$/d	0	0
Adol labour 4	$/d	0	3
Adult labour 5	$/d	0	0
Adol labour 5	$/d	0	3
Adult labour 6	$/d	0	0
Adol labour 6	$/d	0	3
Adult labour 7	$/d	0	0
Adol labour 7	$/d	0	3
Adult labour 8	$/d	0	0
Adol labour 8	$/d	0	1.36
Adult labour 9	$/d	0	1.36
Adol labour 9	$/d	0	3

Discussion

The results presented are preliminary, being based on detailed rice crop labour and GM budgets for one Cambodian village developed by Chea (2015) and a hypothetical new rice technology. Further work is required to develop models and parameters to investigate the approach of using constrained optimisation with an economic objective applied to semi-subsistence rice farms in Cambodia. These results show that the choice of rice crop technology can change when resource constraints are fully accounted for. In these results the use of LP for farm and farm-family analysis (extending the farm framework to a livelihoods analysis) can show optimal farm management choices when the resource supplies of land and labour are fully accounted for. Such an approach can indicate whether 'new technologies' are likely to be adopted when the full financial and opportunity costs of farm family and hired labour are included in the analysis.

The research questions posed in this paper are whether and how the incentives to change on-farm rice production and management methods in Cambodia are affected by new labour and mechanisation options, and whether the economic perspectives of smallholders are changed when a rural livelihoods framework and labour use options are considered. Although these results are preliminary, there is evidence that the choice of rice production method is influenced by off-farm work options when a labour constraint is binding. And the farm family welfare impact of taking a rural livelihoods framework is clear when comparing the family livelihood result, which more than doubles compared with the farm income amount. Further work to collect data and specify livelihood models of farm production is warranted.

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Appendix I: Crop activity gross margin and labour budgets

Table I-1: Crop Activity Budget, WS Rice, Trapeang Run

Item	Unit	Value
Yield	Kg/ha	2,195
Seed	Kg/ha	81
Output	Kg/ha	2,114
Farm Gate Price	US$/t	280
Gross Income	US$/ha	592
Input Expenses	US$/ha	90
Input Expenses	US$/t	41
NRHR	US$/ha	502
NRHL	US$/t	237
Total Household Labour	d/ha	132
NRL	US$/d	3.8

Table I-2: Crop Activity Budget, EWS Rice, Trapeang Run

Item	Unit	Value
Yield	Kg/ha	2,612
Seed	Kg/ha	114
Output	Kg/ha	2,507
Farm Gate Price	US$/t	240
Gross Income	US$/ha	602
Input Expenses	US$/ha	123
Input Expenses	US$/t	47
NRHR	US$/ha	490
NRHL	US$/t	195
Total Household Labour	d/ha	153
NRL	US$/d	3.5

Table I-3: Crop Activity Budget, HRT Rice

Item	Unit	Value
Yield (+10% from WS)	Kg/ha	2,415
Seed	Kg/ha	90
Output	Kg/ha	2,325
Farm Gate Price	US$/t	280
Gross Income	US$/ha	651
Input Expenses	US$/ha	90
Input Expenses	US$/t	39
NRHR	US$/ha	561
NRHL	US$/t	241
Total Household Labour	d/ha	158
NRL	US$/d	3.6

Table I-4: Labour requirements for WS Rice

Activity	d/ha	Category	Total
Seedbed activities	5	Land Preparation (LPW)	
Ploughing	11	LPW	
Harrowing	3	LPW	
Fertilising	1	LPW	20
		Pulling/Transplanting	
Pulling seedlings	10	(PTW)	
Transplanting	32	PTW	42
Manuring	6	Tending crops (TEW)	
Weeding	14	TEW	20
		Harvest/post-harvest	
Harvesting	33	HPHW	
Threshing	12	HPHW	50
Transport	5	HPHW	
TOTAL Labour	132		132

Table I-5: Labour requirements for EWS Rice

Activity	d/ha	Category	Total
Seedbed activities	7	LPE	
Ploughing	10	LPE	
Harrowing	3	LPE	
Fertilising	1	LPE	21
Pulling seedlings	21	PTE	
Transplanting	32	PTE	53
Manuring	6	TEE	
Manuring	6	TEE	
Weeding	16	TEE	
Harvesting	33	HPHE	28
Threshing	13	HPHE	51
Transport	5	HPHE	
TOTAL Labour	153		153

Table I-6: Labour requirements for HRT Rice

Activity	d/ha	Category	Total
Seedbed activities		Land Preparation (LPW)	
Ploughing		LPW	
Harrowing		LPW	
Fertilising		LPW	30
		Pulling/Transplanting	
Pulling seedlings		(PTW)	
Transplanting		PTW	45
Manuring		Tending crops (TEW)	
Weeding		TEW	23
		Harvest/post-harvest	
Harvesting		HPHW	
Threshing		HPHW	
Transport		HPHW	60
TOTAL Labour (+20% from WS)			158

Appendix II: Example LP matrix

This matrix does not include the hired labour activities.

ACTIVITY	WS	SWS	EWS	SEWS	HRT	SHRT	LP4	LC4	LP5	LC5	LP6	LC6	LP7	LC7	LP8	LC8	LP9	LC9	OW4	OW5	OW6	OW7	OW8	OW9		
OBJ FN		237		191		241													3	3	3	3	3	3	MAX	
YIELDWS	-2.114	1																							LE	0
YIELDEWS			-2.507	1																					LE	0
YIELDHRT					-2.325	1																			LE	0
LAND	1		1		1																				LE	2
L4			21				-1	-1																	LE	0
L5			53						-1	-1															LE	0
L6	20		28		30						-1	-1													LE	0
L7	42		51		45								-1	-1											LE	0
L8	20				23										-1	-1									LE	0
L9	50				60												-1	-1							LE	0
PL4							1																		LE	45
CL4								1											1						LE	45
PL5									1																LE	41
CL5										1										1					LE	41
PL6											1														LE	79
CL6												1									1				LE	79
PL7													1												LE	105
CL7														1								1			LE	105
PL8															1										LE	79
CL8																1							1		LE	79
PL9																	1								LE	77
CL9																		1						1	LE	77