



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Upland crop technologies in Cambodia: economic evaluations and some adoption issues

Bob Farquharson^{A,B}, Fiona Scott^A and Chea Sareth^C

^ANSW Department of Primary Industries, Tamworth Agricultural Institute, 4 Marsden Park Road, CALALA, NSW 2340, AUSTRALIA

^BCorresponding author bob.farquharson@dpi.nsw.gov.au

^CCambodian Agricultural Research and Development Institute, PO Box 01, Phnom Penh, CAMBODIA

Abstract:

Agricultural research and development (R&D) has been conducted in the upland districts of Cambodia to develop new farming systems and crop management technologies. Levels of farm income in these areas are relatively low due to small farm sizes and low crop productivity. Work is also planned to encourage the process of adoption of these technologies, and here we investigate how this process can be facilitated. A literature review identifies two important technology characteristics, 'relative advantage' and 'trialability', for successful adoption. Minimum or target rates of return on investment in new technologies are discussed as a means of investigating how much improvement in relative advantage might be enough to encourage successful adoption of the technology. A number of economic assessments of new crop methodologies in Cambodian upland districts and farming systems are presented. Some technologies show an encouraging return on investment from the viewpoint of the Cambodian farmer – rhizobium inoculation of soybean seed had an indicated return of up to 600% on the investment depending on the cost to the grower. Other issues are also likely to be important in discussing change to farming systems, for instance social issues in the village/community context. We present a proposal for a participatory learning process in which economic and social issues are highlighted, to encourage adoption of new crop technologies in local Cambodian contexts.

Key words: New technology, adoption, upland crops, Cambodia, economic assessment, social

52nd Annual Conference of the Australian Agricultural and Resource Economics Society, Canberra, Australian Capital Territory, 5 – 8 February 2008

Disclaimer: the views expressed in this paper do not necessarily reflect those of the NSW Department of Primary Industries or of the Cambodian Agricultural Research and Development Institute.

Upland crop technologies in Cambodia: economic evaluations and some adoption issues

1. Introduction

Poverty and food security in developing countries continue to be issues addressed by development and aid agencies, such as the Australian Centre for International Agricultural Research (ACIAR). Inherent problems of inadequate social and economic institutions, lack of infrastructure, low levels of public health and education, low levels of human and social capital, and lack of government services are major issues faced by indigenous communities in Cambodia. Many poor and disadvantaged Cambodians live in rural areas, and agricultural development is seen as a way of addressing these issues.

Recent R&D in Cambodia has been conducted to generate new information in an agricultural cropping context and to develop new technologies, farming methods and marketing systems or institutions for local communities. The central question of this paper is to consider how adoption of improved crop technologies by Cambodian upland farmers can be encouraged to reduce poverty and improve food security. How can social welfare in Cambodian upland districts be improved for farm families and villagers who grow cash crops such as maize, soybean, mungbean and peanut?

It is one thing to conduct research to develop improved technologies and marketing systems for a target group of farmers based on perceptions of the problem and a solution, but it is quite another to see these improvements successfully adopted and leading to enduring beneficial change. In this paper we consider the case of a particular area of project work where R&D has been conducted to develop improved technologies for Cambodian upland cropping districts, and where the question now is how to build on this work to generate change on a large scale. Can a consideration of the adoption question lead to enhancement of future research and project efforts?

We consider that such a review is timely and beneficial and we proceed via a distillation of the main issues that the adoption literature has highlighted. We then use these messages from other authors to draw out some key activities for further project work. The main characteristics of a new technology for successful adoption are considered to be 'relative advantage' and 'trialability', but these must be consistent with farmer goals and relevant social contexts (Pannell *et al.* 2006). Some previous economic evaluations of these new technologies have shown potentially-large returns on investment for farmers. We discuss how to include social and other adoption considerations into a participatory and co-learning process for assessing and promoting new crop technologies to improve social welfare.

2. What can other authors suggest to us about adoption?

There is a voluminous literature on adoption of new technologies. Here we review some articles from agricultural economics and other disciplines. The review is primarily of economic issues relating to new agricultural technologies and adoption, but some recent writing has considered these in a broader social context and this focus is found to be valuable for our purposes.

An early approach which considered the economic incentive as a primary driver for adoption of hybrid corn in the US was demonstrated by Griliches (1960). He found

that the pattern of diffusion of hybrid corn could be represented by an S-shaped growth curve, although there were marked differences in adoption rates according to geographical regions. His conclusion was that American farmer behaviour with respect to hybrid corn was consistent with the idea of profit maximisation. Lindner (1987) also concluded that the actual benefits of adoption to potential adopters primarily determined the rate and ultimate level of adoption.

A number of authors have presented conceptual frameworks for adoption of agricultural innovations. Abadi-Ghadim and Pannell (1999) concluded that risk and the dynamic nature of adoption decisions (involving changes in farmer perceptions and attitudes) needed to be considered. They concluded that information collection and learning-by-doing were important for changing the perceptions of risk-averse growers about the riskiness of an innovation.

Risk, uncertainty and learning for adoption were also themes of Marra *et al.* (2003). The core elements of their approach for adoption were:

- Learning which improves the farmer's ability to implement the new technology;
- Learning which allows the farmer to make better decisions about the new technology;
- Perceptions of the farmer about the present and future probability distributions of economic returns from the new technology;
- Perceptions of the farmer about the covariance of economic returns between new and old technologies;
- The strength and direction of risk attitudes of the farmer (i.e. risk averse, neutral, preferring); and
- The option value of delaying where fixed costs of adoption occur.

A focus away from economic issues was followed in a cross-disciplinary approach to understanding adoption of conservation practices by Pannell *et al.* (2006). They considered that adoption depends on personal, social, cultural and economic factors and on the characteristics of the innovation. Adoption is related to achieving personal goals. They found that innovations were more likely to be adopted where they have high relative advantage and when they are readily triable.

Pannell *et al.* (2006) defined relative advantage as 'the degree the innovation is perceived to be better than before'. This will depend on landholder goals and the biophysical, economic and social context. Relative advantage for agricultural practices depends on short-term factors (costs, yields, prices and profits); medium- to long-term profits; impacts on other parts of the farming system; impact on riskiness of production; compatibility with existing practices and farm resources; the complexity of the innovation; government policies; compatibility with existing beliefs and values; impact on family lifestyle; self-image and brand loyalty; and perceived environmental credibility.

Trialability relates to characteristics of the innovation itself which affect how easily the farmer can learn about its performance and management. Pannell *et al.* (2006) considered that trialing provides information that reduces the uncertainty about relative advantage. They observed that trialability is affected by divisibility (can it be used on a small scale?), that observability of results promotes diffusion of the practice (also 'over the fence' learning), that longer time lags are associated with less

trialability, that the complexity of an innovation is negatively related to trialability and adoption, that costly trials are negatively related to adoption, that there can be threats to a trial (drought, disease, pests), and that trials need good implementation.

For Pannell *et al.* (2006) these two aspects of adoption had implications for research:

- We should be conscious of the types of innovations that can be adopted more readily (i.e. those with high relative advantage and high trialability);
- We should encourage a participatory approach;
- We should look constructively at what farmers do already; and
- We should provide information about the trial performance of familiar reference land uses or practices (i.e. current farmer practice) in conjunction with information with information about the performance of the innovation.

And for extension:

- Changed management won't occur unless it is consistent with farmer goals;
- The main contribution of extension will be through raising awareness, and perhaps changing perceptions of the relevance and performance of an innovation;
- For many innovations, extension will contribute to accelerate the adoption process rather than lift the final level of adoption;
- Extension (and science) does not have automatic legitimacy and credibility, these have to be earned; and
- Extension agents need to be trusted (this is strongly related to understanding the goals of the farmer).

And for policy:

- If a practice is not adopted in the long term it is because farmers are not convinced that it advances their goals sufficiently to outweigh its cost;
- Innovations need to be 'adoptable';
- We need to invest time and resources in attempting to ascertain whether an innovation is adoptable before proceeding with extension to promote its uptake.

Pannell (2007) distinguished 3 groups of factors that influence potential adopters:

- (a) social, cultural and personal factors (eg peer pressure, government awareness-raising programs, attitude of the potential adopter towards risk);
- (b) features of a practice that influence its relative advantage (i.e. its contribution to achievement of the adopter's goals, such as profitability or environmental benefits); and
- (c) features of a practice that influence its trialability (eg ease of observing its performance in a trial).

He also considered the adoption process in terms of phases as follows:

- (i) Awareness of the problem or opportunity. In this context 'awareness' means not just awareness that an innovation exists, but that it is potentially of practical relevance to the landholder;
- (ii) Non-trial evaluation: reaching stage (i), the point of awareness, is a trigger that prompts the landholder to begin noting and collecting information about the innovation in order to inform the decision about whether or not to go to the next step of trialing the innovation;
- (iii) Trial evaluation: trials contribute substantially to both the decision making and skill development aspects of the learning process;

- (iv) Adoption: depending on the trial results, use of the innovation may be scaled up;
- (v) Review and modification; and
- (vi) Non-adoption or dis-adoption.

Pannell (2007) suggested a relationship between the factors influencing potential adopters and the phases of adoption, as shown in Table 1. He noted that ‘in general, social factors are most important in the early phases, but as the landholder gains personal experience through trialing the practice, its perceived relative advantage becomes more important’. He further considered that ‘participatory research, bringing together researchers and potential adopters, can be an effective way of injecting “adoptability” thinking into the research process at a certain point’.

Table 1. Adoption stage and factors influencing adoption (Pannell 2007)

	Social, cultural, personal factors	Relative advantage of the practice	Trialability of the practice
Awareness	✓✓✓		
Non-trial evaluation	✓✓✓	✓	✓✓
Trial evaluation	✓✓	✓✓	✓✓✓
Adoption	✓	✓✓✓	✓
Review and modification	✓	✓✓✓	✓
Non- or dis-adoption	✓	✓✓✓	

3. Can we use relative advantage as a means of screening new technologies prior to extension?

If our ultimate aim is successful and widespread adoption of new technologies can we use a measure of relative advantage to screen technologies prior to embarking in an extension program? If we accept the message of Table 1 that perceived relative advantage is more important later in the adoption process, then we can consider setting a (high) target level of relative advantage for possible new technologies to screen out those which perform poorly for this attribute.

There is little mention here of the capital requirements with respect to new technology. In the Cambodian situation any technology that required a considerable investment in capital would be problematic due to the general poverty levels, even if there was a considerable relative advantage. In the literature cited the concept of relative advantage implicitly takes capital requirements into account.

Such an approach has been adopted by at least one Australian Cooperative Research Centre that focuses on developing new farming technologies. The Future Farm Industries CRC (see <http://futurefarmcrc.com.au>) aims to explore beyond incrementally-changing technologies to those that offer substantial potential for profit improvements. By selecting projects that in pre-experimental modelling and analysis show a large expected improvement (eg the objectives of one pasture grazing project were to produce a 50% increase in ‘profit’ and a 50% reduction in leakage to

groundwater), the CRC is essentially setting targets for expected relative advantage as a pre-requisite for the project prior to funding approval.

Thus pre-experimental modelling and analysis together with a minimum level of improvement in expected relative advantage can be used to select technologies with enhanced chances of successful and widespread adoption. This approach can contribute to the probability that funded projects meet the objective of funding agencies for widespread adoption, i.e. achieving value for money in their funding decisions.

4. How much relative advantage is enough for widespread adoption by Cambodian farmers?

If we consider the issue of relative advantage as a driver or motivation for change, the question appears to come down to ‘how much of a change might be necessary to encourage poor Cambodian farmers on small farms to try something new?’ In other words, how big an improvement in relative advantage might we consider necessary before Cambodian farmers are interested in change, and before researchers and extension officers recommend a new technology or management practice?

CIMMYT (1988) considered these issues and stated three premises for assessing on-farm experiments in developing recommendations for farmers:

1. Farmers are concerned with the benefits and costs of particular technologies;
2. They usually adopt innovations in a stepwise fashion; and
3. They will consider the risks involved in adopting new practices.

These premises relate directly to the relative advantage and trialability attributes discussed above. In addition, the adoption of a technology will depend in part on how familiar farmers are with the technological innovation. If it is similar to something else they already have then it is more quickly understood and adopted than a totally new or complicated technology.

The question of ‘how much economic improvement might be enough to motivate change’ was considered by CIMMYT (1988). In economic terms this involves comparing between agricultural experimental treatments according to changes in benefits and costs. In other words we can compare the relative advantage of alternative improved crop technologies with themselves and with current farmer practice.

The main method of considering relative advantage by CIMMYT (1988) in answering the ‘how much’ question was via the measure of return on investment. The economic methodology involves:

- Calculating the net economic benefit of changing technology via a partial budget;
- Calculating (again by a partial budget) the total costs that vary; and
- Expressing the ratio of net benefit to total costs that vary as a percentage, the marginal rate of return to investment in the new technology.

For example, consider \$1 invested in nitrogen fertiliser for a maize crop where this investment returns \$1.75 after paying the other expenses necessary to grow and harvest the higher-yielding crop (labour, transport etc). After accounting for the \$1 investment the return is 75%. Is this a sufficient return for the farmer given the

riskiness of applying nitrogen in a variable climate and where other factors (eg weed control) might affect the crop performance? How sure are we (as research and extension officers) of the biological (yield) response to added nitrogen, and the associated cost changes, in a typical farmer's field so that a positive return on investment is expected? And how large a return might be enough for that farmer to induce adoption?

The size of this return on investment can be compared to the cost of capital or set according to some minimum or target rate that accounts for issues such as the risk attitudes of indigenous farmers. While acknowledging that in most cases it is not possible to provide an exact figure for a minimum rate of return, CIMMYT (1988) suggested possible target rates of (a) twice the cost of capital or (b) higher rates such as 50 to 100%. Based on experience in development work CIMMYT (1988, p.37) suggested that the figure will rarely be below 50%, even for technologies that represent only simple adjustments to farmer practice, and is often in the neighbourhood of 100%, especially when the proposed practice is new to farmers.

Farquharson *et al.* (2006a) found from a Cambodian upland farm survey that interest rates in Cambodia could be as high as 3% per month. On an annualised basis twice this capital cost is in the range of 70-80%.

We propose that a minimum return on investment of 100% be used for deciding which improved crop technologies be included in the set of technologies promoted to Cambodian upland farmers.

4.1 On-farm economic evaluation methods

Economic analysis can be undertaken for profit-conscious farmers when making various types of decisions. One decision is of which combination of farm enterprises (a whole-farm plan) to choose for the relevant planning period (eg which crops to grow in the next year over the whole farm). Another decision relates to the choice of management action or technology to use (eg how much of an input to use). These questions can be inter-related if the use of appropriate technology improves a particular enterprise return enough for it to be now included in the optimal farm plan.

Economic analysis can be conducted at the whole-farm level. Whole-farm analysis was perhaps originally conducted to choose the best farm plan (eg see Rickards and Passmore 1977), but it is now often used to assess new technologies for their impacts on farm profitability (Malcolm, Makeham and Wright (2005). However, if the enterprise choice does not depend on the technology (eg if a crop rotation or livestock production system is pre-determined in the short term) then technology evaluations can be conducted within the farm enterprise context.

There are a number of different economic methods available to consider these questions. Whole-farm analysis can be conducted using optimisation (eg linear programming) or simulation methods (eg gross margin budgets constructed using spreadsheets). Enterprise analysis can be conducted using gross margin, partial, and cash flow or capital budgets, with deterministic or stochastic characteristics. All these methods are based on the assumed farmer goal of maximising a financial objective subject to a set of constraints and including the principles of opportunity cost and equi-marginal returns.

4.1.1 Farm enterprise choice and gross margin analysis

On-farm economic evaluation methods should be consistent and follow some fundamental guidelines in order to avoid errors that will confound the trial or demonstration economic results. This is to ensure the comparisons are valid. Farmers need accurate information on the profitability of new agronomic technologies for upland crops so that they can assess the economic benefits of adopting the new technologies on their farms.

In on-farm trials and demonstrations usually one or more inputs are changed to ascertain what the effect is upon yield and therefore income. It follows that only the factors being tested should be altered between the treatments where practicable. There may be instances where extra inputs are required due to the nature of the treatments. An example of this is when a low or zero fertiliser rate is being compared to fertiliser of one or more rates. The addition of fertiliser may make weeds grow more as well as the crop, requiring extra weeding to the treatment with added fertiliser. Therefore extra hand-weeding or spraying may be needed to prevent the weeds competing for moisture with the crop. In this case the extra cost should be accounted for in the economic analysis and explained in the analysis.

Gross margin analysis is one of the most common methods of on-farm economic evaluation of different cropping technologies. A gross margin is the *gross income* from a crop less the *variable costs* incurred in growing it. Gross margins are generally quoted per unit of the most limiting resource, which is usually land, so on a per hectare basis (Malcolm, Makeham and Wright 2005).

The income amount is determined from the yield of the crop and the price received for the crop. Price is often influenced by crop quality. Income per hectare is calculated by multiplying the yield per hectare (in kilograms or tonnes) by the price (per kilogram or tonne). In addition to this, the yield listed in the budget figures should indicate for some crops how the yield has been measured. One example of peanuts, where yields can be reported either as 'nut-in-shell' or threshed nuts out of the shell. The price for each is very different, so it is very important to say what the yield being measured is so the correct price may be applied.

Variable costs are those costs directly attributable to a crop and which vary in proportion to the area or yield of crop grown. For example, if the area of soybeans sown doubles, then the variable costs associated with growing it, such as seed, chemicals, and fertilisers will also double.

Table 2 outlines all the considerations for variable costs. All of these factors cost money and should also be measured/recorded if a gross margin is to be estimated.

The calculation of a gross margin enables comparison of the profitability expected from similar crops and is a starting point in choosing an overall combination of crops. Gross margins can also be used to analyse actual crop performance by monitoring costs and returns.

The gross margin information collected may then be used for other techniques such as the CIMMYT partial budgeting and marginal rate of return approach discussed above.

However, gross margins need to be used carefully. Because overhead costs are excluded, it is advisable to only make comparisons of gross margins between enterprises which use similar resources or that are sown at the same time. The gross margin is not total profit because it does not include fixed or overhead costs such as depreciation or interest payments on loans which have to be met regardless of crop area.

If major changes are being considered, more comprehensive budgeting techniques are required to properly account for changes in resource use. Other more comprehensive, types of budgets include partial budgets which include capital investment, discounted cash flow budgets and whole farm budgets.

Table 2. Key considerations for construction of gross margin budgets

Income	What was the yield per hectare and in what units was it measured? (For example bare grain, nut-in-shell, on the cob, in the pod). Apply the correct price per unit for the unit the crop was measured in. What was the crop quality like? Was it acceptable or was the price discounted due to poor quality or were bonuses received for very good quality?
Crop type and variety of seed	What was the seed rate per hectare? For instance seed costing US\$1 per kilogram, sown at 20 kg per hectare, costs \$20 per hectare. And what was the cost per hectare of sowing it? For instance, how many people were needed over how many days to hand-sow 1 hectare?
Fertiliser	What fertiliser was used? What was the rate of fertiliser per hectare? What was the cost of applying it? (eg at sowing with seed or separately before sowing, which costs extra in labour).
Herbicides	What was applied? At what rate was it applied? eg litres per ha and cost per litre. And what was the cost per hectare of applying it?
Pesticides	As for herbicides (name, rate, cost, how applied).
Irrigation	How much water per hectare was applied and how much did it cost to pump?
Machinery costs	What machinery was used and what was the cost per hectare? For example, for ploughing.
Harvesting costs	Include costs for labour for harvesting, cost of threshing, as well as consumables such as bags and fees such as transport of the produce to market. These costs will vary with yield per hectare.

When comparing experiments or demonstrations, it is important to standardise costs in order to accurately measure the treatment effect. For example, if crop variety demonstrations are on neighbouring farms, and one neighbour was able to get a cheaper rate for ploughing which has nothing to do with the trial, then it is not correct to put in the two different ploughing costs, because this will confuse how much extra profit was due to the better variety or due to the saving in ploughing costs.

4.1.2 Assessing technologies within crop enterprises

Comparison of with- versus without-management scenarios for a crop technology or management change can be conducted using partial or crop activity (gross margin) budgets. The important investment question is whether the return on investment (ROI) will cover the cost of capital and provide an extra amount to compensate for attitudes to risk and reluctance to adopt new management. For questions of how much of an

input, such as N fertiliser, to use, marginal economic analysis can be used to compare the marginal value product (input demand) of crop output with marginal costs as the input level increments. This allows development of a profit maximizing level of the input, and ROI considerations can also be included.

We may also be interested in the risks and returns associated with alternative technologies, hence comparison of distributions of outcomes are conducted. There are a number of ways to make such comparisons, including the development of Expected Value – Variance trade-off graphs (Hardaker *et al.* 2004) and Stochastic Dominance Analysis (Anderson *et al.* 1977).

4.2 Previous evaluations of upland crop technologies in Cambodia

In this section we present some results of previous survey work and economic analysis which describes the Cambodian upland farm and farm-family context, and includes some previous evaluations of the ROI for some of the technologies being considered in the project work. It is anticipated that a review and reassessment of the economic evaluations would need to be considered for future project work.

4.2.1 Characteristics of upland farms and crop returns

Non-rice crops are an important source of household income for Cambodian upland farmers and they comprise around 4% of Gross Domestic Product (Asian Development Bank (ADB), 2007). The major crops include maize, mungbean, soybean, peanut, sesame and cowpea, cultivated mainly in the northeast and in certain areas of central Cambodia where soils are more favorable than in the rainfed lowlands. Upland crop production has increased substantially in recent years - around 100,000 tonnes of maize, 10,000 tonnes of mungbean, 3,000 tonnes of soybean and peanut each and 1,000 tonnes of sesame were produced in early 1980s, but these have increased to 273,000, 28,530, 82,260, 25,740 and 42,070 tonnes of the recent production respectively (Ministry of Agriculture, Forestry and Fisheries (MAFF) Statistics, 2005). Per upland family farm production levels exceed those family farms producing rice.

Upland crops are cultivated in most provinces of the country and farms in three Provinces - Kampong Cham, Battambang and Takeo (see Figure 1) - were surveyed by Farquharson *et al.* (2006a). Average farm sizes in the upland areas are commonly larger than in the rainfed lowlands, and the systems of operating land are also different. The average total household land area surveyed was 2.7 ha in Kampong Cham, 6.3 ha in Battambang and 2.6 ha in Takeo. The largest average District farm area was 9.5 ha in Sampov Lun (in Battambang) while the smallest was 1.8 ha in Tboung Khmum (in Kampong Cham). Besides their own land, upland farmers also rented land out and in for farming purpose although this was generally small compared to owned area.

Apart from land, farmers owned farm machinery and equipment such as tractors, disc and mould board ploughs, spray units, pumps, tubewells, threshers, oxcarts and draft animals. Substantial percentages of interviewed farmers in the Banan and Sampov Lun Districts of Battambang and the Ou Reang Ov and Tboung Khmum Districts of Kampong Cham owned tractors (2- or 4-wheeled). Spray units were also commonly owned by farmers in most districts. Cattle were kept by many households to supply draft power especially for those with small farms and no other machinery. Further,

upland farmers substantially invested in seed, since hybrid varieties were generally used, with associated costs of fertilizers and pesticides. The overall investment in capital for upland crop production was relatively high compared with other types of agricultural production.

Rainfed upland farming systems can be clearly distinguished from rainfed lowland conditions in Cambodia. In the rainfed lowlands rice is the single, or main, crop with limited crop alternatives due to soil types, but the farming systems in uplands integrate a broad variety of crops including legumes, cereals, fruit trees and industrial plants, with rice in the minority. The main wet season starts from late May, but particular upland crops can commence as early as February to utilize early wet season rainfall. Therefore upland farming systems have more diversified cropping patterns with a varied cropping calendar. Even though many varieties of non-rice crops have been cultivated in uplands, typical crops of the surveyed locations were maize, soybean, mungbean, peanut, sesame, cowpea and chilli. Farmers choose the crops to grow from year to year depending on productivity resulting from both agronomic and climatic factors, and also on market demand. Farmer decisions on crop cultivation or cropping systems are strongly influenced by market returns and risks associated with those returns (Young and Westcott (1996), as cited by Katsvairo and Cox (2000)).

Some crop activity budgets from 2005 are shown in Table 3 for the Kamrieng, Sampov Lun and Rotonak Mondol districts of Battambang Province and the Chamkar Leu and Tboung Khmum districts of Kampong Cham Province. Average maize yields were far higher than other crops, above 4 t/ha versus 1-2 t/ha for soybean and peanut and less than 0.5 t/ha for mungbean and sesame. In contrast, maize was sold at the lowest price among the crops, around US\$70-100/t against US\$200-400/t for soybean, peanut and mungbean, and US\$600/t for sesame. Soybean, mungbean and maize generally produced the best income, although income varied between districts and seasons.

4.2.2 Upland crop technology evaluations

Three types of crop technologies were evaluated by Farquharson *et al.* (2006b), based on a theme of soil and crop fertility interacting with climatic patterns. The first related to the application of nitrogen (N) fertilizer to maize. Survey information indicated that farmers often considered their soils to be moderately fertile but few applied fertilizer. Given the experience of farmers in Australia of long-term soil fertility decline through cropping without replenishing soil nutrients (eg Dalal and Mayer 1986), the question of how much N fertilizer to apply appears to be relevant.

The second analysis related to rhizobium inoculum of legume seed to improve nodulation, subsequent atmospheric N absorption and legume crop yields. There is currently no rhizobium industry or practice in Cambodia, and the hypothesis is that legume crops would respond to this technology. Field trials in 2004 were designed to investigate the effects of rhizobium inoculation and N fertiliser applications on legume crop yields.

The third management alternative involved the investigation of crop planting rules at the beginning of the wet season. The onset of early wet season rains is an uncertain event in terms of date of first rain and the amount of follow-up rainfall. Mini droughts

may occur after the first rain, and farmers who plant early often lose crops which are planted, germinate and then die. Three planting dates were investigated for maize.

Table 3. Activity budgets: Cambodian upland crops 2005 (from Farquharson *et al.* (2006b)).

District	Crop	Yield t/ha	Price US\$/t	Variable Costs US\$/ha	Gross Margin US\$/ha
Kamrieng	EWS Sesame	0.375	600	186	39
	EWS Maize	4.5	75	257	81
	MWS Mungbean	1.44	425	233	379
	MWS Soybean	2.16	275	195	399
Sampov Lun	EWS Maize	5.5	75	244	169
	EWS Sesame	0.67	600	277	125
	MWS Mungbean	0.65	350	172	56
	MWS Soybean	2.4	225	167	373
Rotonak Mondol	EWS Sesame	0.3	375	179	-67
	EWS Mungbean	0.3	375	207	-95
	MWS Maize	4	88	251	101
	MWS Soybean	1	200	255	-55
Chamkar Leu	EWS Mungbean	0.8	300	229	11
	EWS Sesame	0.5	625	194	119
	MWS Peanut	2	250	376	124
	MWS Soybean	1.75	235	200	211
	MWS Maize	5	120	336	264
Tbounng Khmum	EWS Sesame	0.35	650	174	54
	EWS Mungbean	0.3	325	89	9
	MWS Soybean	0.65	200	131	-1
	MWS Peanut	2.1	200	225	195

4.2.2.1 Methods of analysis

Bio-economic analysis was used to evaluate these technologies. The upland farmers in these districts were assumed to be interested in crop profitability, because the socio-economic survey results showed that farmers often borrow money to finance crop inputs and sell the produce for cash.

Cambodian upland farmers will consider evidence of potential change for individual crop enterprises, but they may also consider whole-farm or farm-family issues. In general the latter will be important if there are changes in the farming system contingent on changes at the enterprise level. In Cambodia, changes in wet-season cropping activities do not seem to have major implications for the whole farm. The farming system is relatively simple – farmers try to grow two crops (early wet season and main wet season) with family and purchased inputs. Hired labour, fertilizer, machinery services, and finance, are often available so that there are no major resource constraints to the types of changes evaluated here. However, farm sizes are relatively small. The issue appears to be mainly about individual-crop technology and management expertise; hence the economic comparisons are made at the crop-enterprise level.

4.2.2.3 Experimental design

For the question of how much N is profitable to use in maize, a yield response surface was generated by running a crop simulation model with 11 levels of N input (0, 25, 50, 75, ... 250 kg N/ha) sown on 1st of April. These responses are to the total amount of nitrate (i.e. plant available) N accessible to the crop at planting – whether from the soil or added as fertiliser. Then the profitability of N input was assessed using prices of 300 riel/kg (US\$75/t) for maize and 660 baht/50 kg bag of urea fertilizer (US\$0.72/kg N). For rhizobium inoculation of legume seed, field trials in 2004 for mungbean and soybean comprised a design of 0, 40 and 80 kg/ha of N, with and without rhizobium inoculation. Eight experiments were conducted for the two crops on two soils types in two Provinces. All were planted in July and harvested in late October, and soybean was priced at \$200/t. The early wet season planting date analysis for corn was conducted by simulating a hybrid corn variety planted on 1 March, 15 March and 1 April with 0 and 50 units of N added to the basal soil N level.

4.2.2.4 Risk analyses

Farmers were questioned in group interviews about potential variability in yield and price of each crop - the minimum, most likely and maximum values that they had experienced for each. In terms of yield and price correlation, they consistently indicated that in high yielding years the prices offered were low, and vice versa. When these triangular distributions and a negative correlation (-0.75) were applied to the Gross Margins in Table 1, a simulation of outcomes using @RISK (Palisade Corporation 2000) produced the Cumulative Distribution Functions (CDFs) in Figure 2. These CDFs confirm the differences in expected crop incomes from Table 3 and add a dimension of income variability. A number of crops show a large degree of variability with a Coefficient of Variation (CV) greater than 100%. The CVs for income distributions are higher for early- than main-wet-season crops in all districts except Rotonak Mondol.

4.2.2.5 Nitrogen fertilisation of maize

The marginal value product (input demand function) for N (Farquharson 2006) and marginal N cost functions in Battambang Province are shown in Figure 3. Input demand functions for N (in increments of 25 kg) are plotted for the 10th, 50th (median) and 90th percentiles of the 89 crop-year simulations. These percentiles represent different climatic outcomes of very dry, median and very wet seasons. The marginal cost of applying 25 kg of N is \$18. For Kompong Siem soils in these districts, the value of applying N fertilizer in infertile situations (i.e. a total of 25 kg of plant available N) provides a change in gross maize revenue of \$60-90 or \$2.4–3.6/kg N, implying an ROI of 230-400%. As more N is added the marginal value falls, and the pattern depends on the seasonal outcome. In very low rainfall years it is not economic to have more than 25-30 kg N/ha available to the plant. In Kamrieng and Sampov Lun the median responses indicate that 100 kg or more of N could be targeted. In Rotonak Mondol the median response indicates 60-70 kg of N, whereas in very good years N costs are covered up to 125 kg of N in all districts.

Using a 100% minimum ROI the marginal cost of 25 kg of N is effectively \$36, and the indicated levels of N to target in median years are 100 kg/ha in Kamrieng, and 60-70 kg/ha in both of Sampov Lun and Rotonak Mondol. The plots in Figure 3 give an idea of the likely spread of N responses as climate varies.

4.2.2.6 *Rhizobium* inoculation of legume seed

A statistical analysis of the field experimental results was conducted and the interaction of N, inoculation and crop type on yield was tested (see Table 4). The average response to inoculation in mungbean was 6% and for soybean 20%. Herridge (2005) reviewed the results of experiments and field trials of inoculation in Asia. He reported that for a total of 149 site-years, average yield responses to inoculation were 12% for lentil, 15% for cowpea, 17% for pigeon pea and mungbean, and 19% for black gram. The soybean results in Table 4 are consistent with his findings.

Table 4. Effect of rhizobium inoculation and fertilizer on legume yields (from Farquharson *et al.* (2006b)).

N (kg/ha)	Rhizobium inoculation	Yield (t/ha)	
		Mungbean	Soybean
0	Nil	0.691	0.895
40	Nil	0.737	1.155
80	Nil	0.739	1.148
0	Plus	0.733	1.072
40	Plus	0.743	1.249
80	Plus	0.748	1.098

Least Significant Difference at 5% = 0.0643 t/ha

There were no significant yield effects in mungbean. For soybean, there was a significant yield effect associated with rhizobium inoculation with zero added N, and also for applying 40 kg/ha of N without inoculation. The ROI for the latter case was 81%, doubtful in terms of the minimum 100% ROI criterion. In contrast, using rhizobium without N fertilizer returned an increased yield valued at \$35/ha. The cost of inoculating is likely to be less than \$5/ha (even if rhizobium is imported), giving an ROI of at least 600%. Therefore inoculation could be very attractive for soybean. There are no data on the yield of subsequent crops following inoculation with rhizobia.

4.2.2.7 *Early wet season crop planting rules*

The results of the crop simulations are in Table 5 and Figure 4. Average maize yields were consistently higher for 50 kg added N than zero added N. In both cases mean yield increased as the planting date was delayed. For zero N the CV increased slightly with increased yield, but when N fertilizer was added the CV declined as yield increased with delayed planting. The CDFs for 1 April stochastically dominate those for 15 March, which in turn dominate those for 1 March. As expected the predictions of increased yield from adding 50 kg/ha of N were profitable for each planting date – ROI in excess of 150% in all cases.

4.2.2.8 *Discussion of crop technology evaluation results*

The results presented here provide an idea of some likely risk and return trade-offs associated with existing and alternative upland crop technology management in Cambodia. The crop activity budgets and triangular yield and price distributions from existing farmer discussion groups indicate a range of economic performance of crops within and between districts. Some crop activities appear to be unprofitable most of the time. The risk simulations indicate that early wet season crops generally have lower and more variable incomes than main wet season crops. In terms of poverty alleviation and income security this is a strong reason for focusing effort on early wet

season crops and varieties which have a short growing season and are quick maturing. The results in Table 1 show that potentially the returns from early wet season crops can be as high as main wet season crops, depending on the district.

Table 5. Simulated maize yield for three planting dates in Kamrieng (from Farquharson *et al.* (2006b)).

Planting date	1-Mar	15-Mar	1-Apr	1-Mar	15-Mar	1-Apr
Fertilizer rate (kg/ha)	0	0	0	50	50	50
	Maize yield (t/ha)					
10 th percentile	1.17	1.28	1.33	1.53	1.85	2.37
50 th percentile	1.40	1.53	1.63	2.70	2.91	3.29
90 th percentile	1.57	1.77	2.00	3.42	3.80	4.14
Mean	1.38	1.53	1.66	2.60	2.87	3.24
CV	0.12	0.13	0.16	0.27	0.24	0.22

The yield responses of maize to available N fertilizer were simulated for very dry, median and very wet years. Using the 100% minimum ROI criterion, the median response on Kompong Siem soils in Battambang Province indicates that from 60-75 up to 100 kg/ha of N is the range of optimal N fertility levels, depending on locations. The existing levels of soil fertility need to be considered in developing farmer recommendations.

Inoculation of legume seed with rhizobium was considered using farm trial results. The yield response in soybean was sufficient to consider that a rhizobium technology investment could be very profitable in Cambodia, as it is in other parts of Asia. Institutional arrangements for the development of a rhizobium industry and practical ways of storing and renewing rhizobium in villages between wet seasons need to be considered.

When planting of early wet season maize is delayed to late March or April on fertile soils (or when N fertilizer is added) there appears to be an increase in expected yield and a reduction in yield variability. Reduced cultivation to preserve soil moisture could also reduce the risk of early sowing.

5. What about trialability, farmer goals and information provision?

From the above literature review the issue of generating new technologies for adoption and change by groups of farmers is likely to succeed or fail depending on whether such technologies are consistent with farmer goals and aspirations. The perceptions and attitudes of the farmers will be context-sensitive, hence the need to think about technologies within the local social framework for indigenous farmer groups.

The development of information as a basis for decision making by farmers and scientists will be vital in the technology evaluation process. For scientists, an understanding of farmer goals and context and, for farmers, the process of observation and learning by doing will be vital. The trialability of the technology is important.

Further in a decision-making process, the risk attitudes of farmers and the perceived riskiness of new technologies versus current approaches are likely to be important.

Hence in the social context, an investigation of the goals of farmers in the local context and an evaluation of their attitudes to risk will be valuable. The perceived riskiness of new versus old technologies will be another dimension of relative advantage that can be investigated using research methods.

5.1 Trialability for Cambodian upland farmers

Of the new upland crop technologies in Cambodia some will be easier than others for farmers to trial and adopt. New crop varieties (eg hybrid corn) and fertiliser should be readily available from local providers or grain trading companies. Other technologies, such as rhizobium for legume seed, will be more problematic. A concerted effort will be required to supply rhizobium on an interim basis and to assist the development of a sustainable rhizobium supply industry in the longer term. Changes in tillage and ground cover (stubble mulching) may not occur until appropriate equipment becomes available. Changing crop planting dates in the early wet season should be readily trialable, but there may be strong social pressures which mitigate such changes.

6. A proposal for further project work

Two previous ACIAR projects, “Farming Systems Research for Crop Diversification in Cambodia and Australia” (project no. ASEM/2000/109) and “Improving the Marketing System for Maize and Soybeans in Cambodia” (project no. ASEM/2003/012), have conducted R&D into upland cropping in Cambodia including scientific and production economic research with associated extension activities and investigating marketing systems for maize and soybean. Further project work is now planned with the objective of achieving adoption and change in agricultural and marketing practices to improve social welfare. We now propose a focus and methodology for that work based on the discussions above. The new work will include aspects of agricultural production and marketing in an extended value chain which includes transmission of market information.

Key activities in the new project could include:

- Using focus groups (co-learning processes) in representative upland villages to
 - Develop a shared understanding of farmer goals and risk attitudes, and the social and institutional decision-making contexts for indigenous communities,
 - Documenting or mapping typical farming systems and the agricultural value chain for marketing crops, and
 - Discuss important locally-perceived constraints or problems in agricultural production and marketing that can be addressed by the new project;
- For agricultural production issues
 - Conduct a detailed investigation of potential improvements in relative advantage (broadly defined) for a suite of new technologies and then select those considered most suitable to promote to local farmers and villages, and
 - Investigate issues of trialability or adoptability for these technologies or crop management practices;
- For marketing issues

- Investigate the use of locally-relevant means of transmitting marketing and price information between farmers and grain buyers (silo managers), and
- Determine other issues in the value chain that can be addressed within the new project;
- Associated on-farm trials or demonstrations of new crop production technologies and village- or district-level trials of new marketing methods and market information transmission mechanisms; and
- A continuing evaluation and review of these steps as they contribute to measured adoption or change in social welfare at the farm, district and provincial level.

The economic component of the project can consist of a detailed evaluation of the dimensions of relative advantage of potential new crop technologies versus current farmer practice (including perceived riskiness of the alternatives). Information from such evaluations can provide input to the process of choosing possible crop technologies for promotion and extension campaigns, as well as the promotion and extension activities to achieve adoption and change.

Hardaker *et al.* (2004, p.5) define *uncertainty* as imperfect knowledge and *risk* as uncertain consequences, so that 'to take a risk is to expose oneself to a significant chance of injury or loss'. Relative advantage, as defined by Pannell *et al.* (2006) includes perceived risk in relation to farmer goals. Hence the economist's role can include a consideration of farmer goals (including the degree of risk aversion) and a quantification of the perceived relative riskiness of new and existing technologies in the farming system context. Such considerations can add to the simple ROI role suggested above.

6.1 A focus on rhizobium?

In the above analyses of relative advantage the ROI for rhizobium inoculation of legumes was potentially very high, depending on the costs to farmers of obtaining the inoculant. Given this apparent improvement in relative advantage issues of availability, trialability and crop management then become important.

Rhizobium strains are readily available in Thailand (Dr D Herridge, NSW Department of Primary Industries, personal communication) and further work is currently being conducted to establish rhizobium production in Vietnam and Myanmar. A major issue for establishing rhizobium production in new countries is implementing the necessary quality control.

For establishing widespread adoption of rhizobium inoculation in north-west Cambodia an approach of importing rhizobium from Thailand may be better than trying to establish a domestic industry. If rhizobium is available from north-east Thailand then the issue becomes one of marketing and distribution to provide the technology as widely as possible. Issues of storage of rhizobium on farms or in villages prior to use will require attention.

If rhizobium does become commercially available to Cambodian farmers then a remaining issue is to ensure that farmers use it appropriately. Farmers will need to be trained in how to use rhizobium in a farming systems context, i.e. not only to apply it correctly to seed prior to sowing but also to ensure that other aspects of management

(such as weed and disease control) are adequate so that expression of the rhizobium benefit is not compromised by other management failings.

7. Conclusion

A review of literature relating to the adoption of agricultural innovations has suggested that the degree of improvement in relative advantage with respect to farmer goals and trialability on a small scale will enhance the information available to farmers and improve their decision-making capacity. In this paper we suggest that to encourage change and enhance adoption it is necessary to evaluate and select technologies based on these characteristics to improve the likelihood of widespread and sustained change to achieve improved social welfare. The economist's role can include investigating (with other researcher and extension workers) farmer goals and social contexts and then evaluating (with researchers, extension officers and farmers) alternatives to current practice in terms of relative advantage. A multi-disciplinary and co-learning approach is proposed for new project work.

References

Abadi-Ghadim, A.K. and Pannell, D.J. (1999), 'A conceptual framework of adoption of an agricultural innovation', *Agricultural Economics* 21, 145-154.

ADB, 2007. "Economic Trends and Prospects in Developing Asia: Southeast Asia - Cambodia". In Asian Development Outlook 2005
<http://www.adb.org/Documents/books/ADO/2005/cam.asp>.

Anderson, J.R., Dillon, J.L. and Hardaker, J.B. 1977. *Agricultural Decision Analysis*. Iowa State University Press, Ames, Iowa.

CIMMYT 1988. *From Agronomic Data to Farmer Recommendations: An Economics Training Manual*. Completely revised edition. Mexico D.F.

Dalal, R.C., and Mayer, R.J. (1986), 'Long-term Trends in Fertility of Soils under Continuous Cultivation and Cereal Cropping in Southern Queensland. I Overall Changes in Soil Properties', *Australian Journal of Soil Research*, 24, 265-79.

Farquharson, R.J. (2006), 'Production response and input demand in decision making: nitrogen fertilizer and wheat growers', *Australian Agribusiness Review*, Volume 14, Paper 5, <http://www.agrifood.info/review/2006/Farquharson.html>.

Farquharson, R., Chea S., Chapho, S., Bell, R., Seng, V., Vance, W., Martin, R., Ung, S., Scott, F. (2006a), 'Contemporary practices, constraints and opportunities for non-rice crops in Cambodia', *Cambodian Journal of Agriculture*, 7(1): 1-12.

Farquharson, R.J., Chea, S., Chapho, S., Martin, R.J., Haigh, B.M., Scott, J.F., Ung, S., (2006b), 'Changes in Management Can Improve Returns from Cambodian Upland Crops', *Paper presented at the 26th Conference of the International Association of Agricultural Economists*, Gold Coast, Australia, August 12-18.

Griliches, Z. (1960), 'Hybrid corn and economics of innovation', *Science* 132, 275-280.

Hardaker, J.B., Huirne, R.B.M., Anderson, J.R., and Lien, G. (2004), *Coping with Risk in Agriculture* Second Edition, CABI Publishing, Wallingford UK.

Herridge, D.F. (2005), 'Soil and Agronomic Management for Improvement in Biological Nitrogen Fixation in Food Legumes', Paper presented to International Food Legume Research Conference, New Delhi, 18-22 October.

Katsvairo, T. W. and Cox, W. J., (2000), 'Economics of Cropping Systems Featuring Different Rotations, Tillage, and Management in Soil and Crop Management', *Agronomy Journal*, Vol. 92. pp 485-493.

Lindner, R.K. (1987), 'Adoption and diffusion of technology: an overview', in Champ, B.R., Highly, E., Remenyi, J.V. (eds), *Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics*, ACIAR Proceedings No. 19, Australian Centre for International Agricultural Research, Canberra, pp, 144-151.

MAFF Statistics, (2005) *Agricultural Statistics*, Statistics Office, Department of Planning and Statistics, MAFF, Phnom Penh Cambodia.
<http://www.maff.gov.kh/statistics/crops.html#a4>.

Malcolm, Bill, Makeham, Jack and Wright, Vic (2005), *The Farming Game, Agricultural Management and Marketing*, 2nd Edition, Cambridge University Press, Melbourne.

Marra, M., Pannell, D.J. and Abadi Ghadim, A. (2003), 'The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?', *Agricultural Systems* 75, 215-234.

Palisade Corporation (2000) *@RISK Industrial*, New York.

Pannell, D.J., Marshall, G.R., Barr, N., Curtis, A., Vanclay, F. and Wilkinson, R. (2006), 'Understanding and promoting adoption of conservation practices by rural landholders', *Australian Journal of Experimental Agriculture* 46, 1407-1424.

Pannell, D.J. (2007), 'Influences on technology adoption in different phases', Pannell Discussions No. 103, June, available at www.general.uwa.edu.au/u/dpannell/pd/pd0103.htm, accessed 21 December 2007.

Rickards, P.A. and Passmore, A.L. (1977), 'Planning for Profit in Livestock Grazing Systems', *Professional Farm management Guidebook No. 7*, Agricultural Business Research Institute, University of New England, Armidale.

Young, C. E., and Westcott, P. C., (1996), *The 1996 US Farm Act Increases Market Orientation*, USDA-ERS Agric. Info. Bull. no. 72. U.S. Govt. Print. Office, Washington, DC.

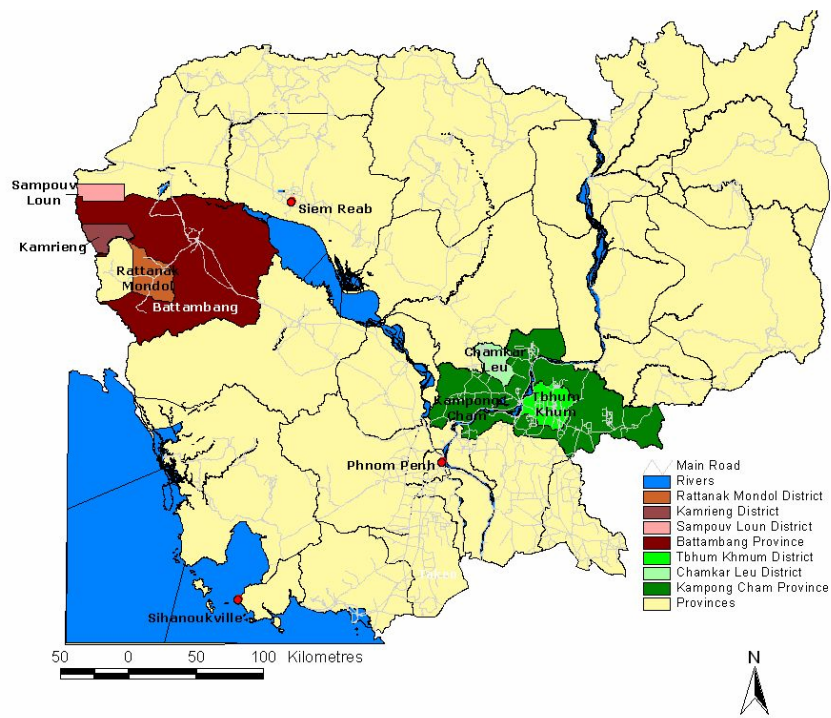


Figure 1. Districts and Provinces studied by Farquharson *et al.* (2006b).

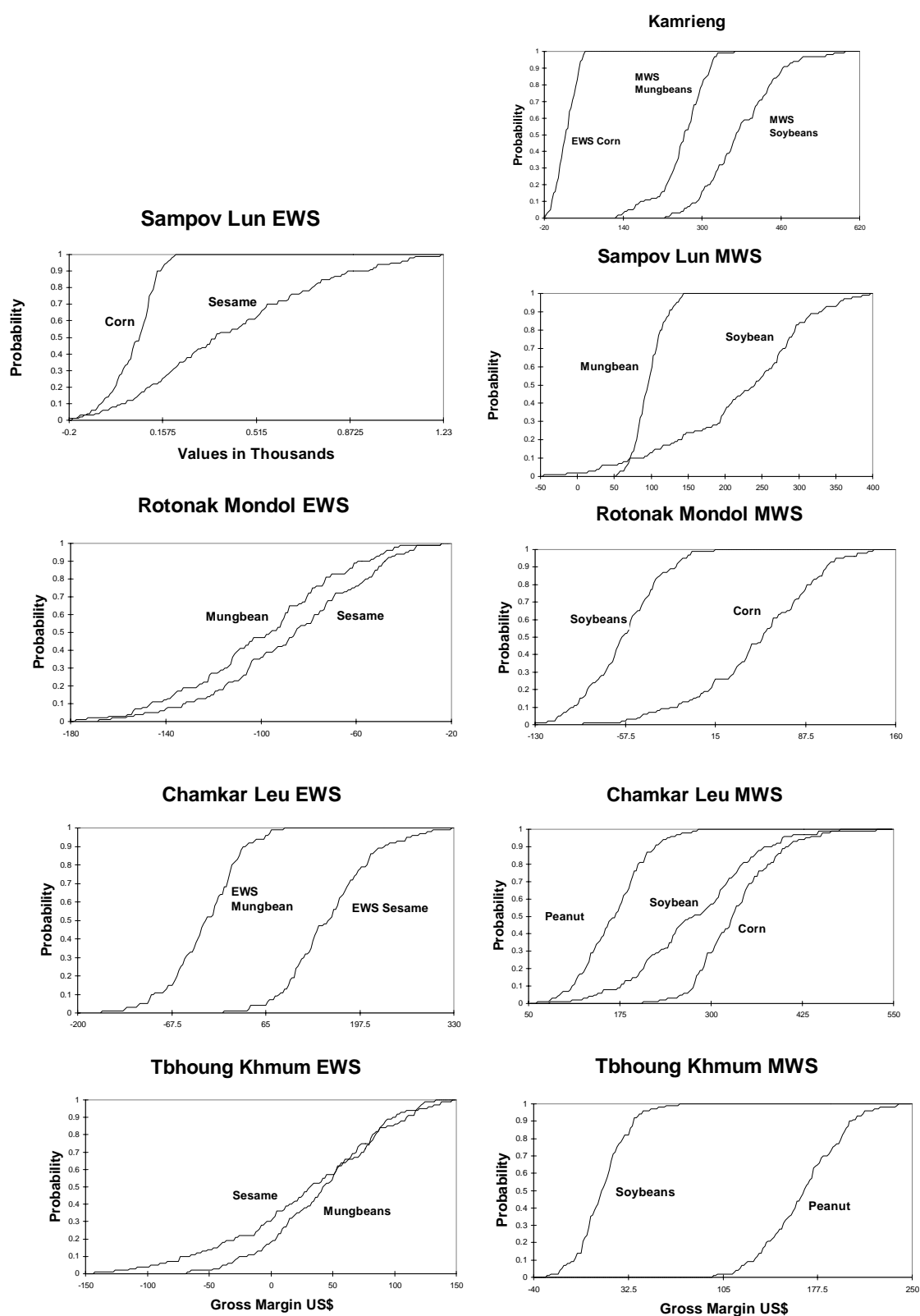
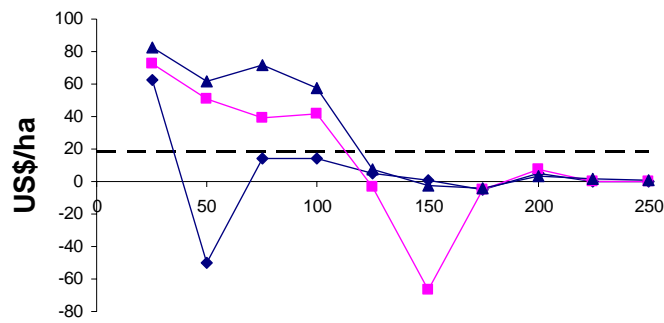
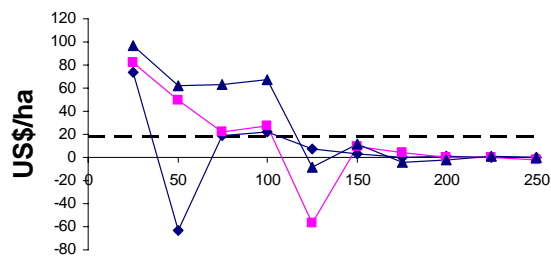


Figure 2. Cumulative Distribution Functions of activity budgets for early and main wet season upland crops in Cambodia, 2005 (from Farquharson *et al.* (2006b)).

Kamrieng



Sampov Lun



Rotonak Mondol

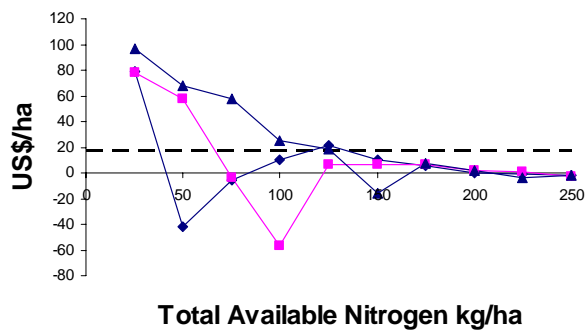
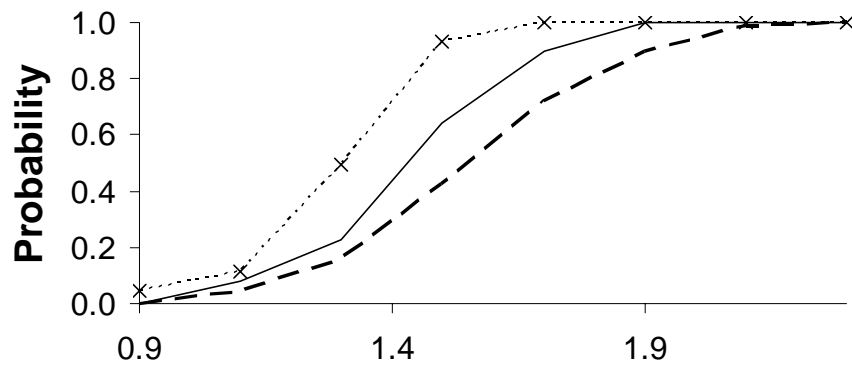


Figure 3. Input Demand and Marginal Cost Functions for Nitrogen in Maize. Triangles 90th percentile, squares 50th percentile, diamonds 10th percentile of climate outcomes. Marginal Cost of N dashed line (from Farquharson *et al.* (2006b)).

Yield distributions: zero N



50 kg/ha N

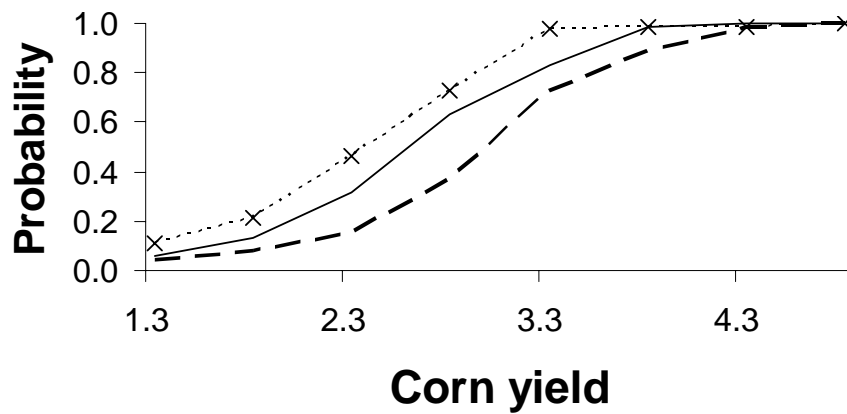


Figure 4. Cumulative Distribution Functions of corn yield as affected by fertilizer and planting date in Kamrieng (from Farquharson *et al.* (2006b)). Dotted line 1 March, solid line 15 March, dashed line 1 April