Changes in Management Can Improve Returns from Cambodian Upland Crops

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Abstract

Farming systems research for wet-season non-rice upland crops in Cambodia is being conducted with the overall aim of poverty reduction and food security for farmers in the Provinces of Battambang and Kampong Cham. Some of these cash crops exhibit low and variable incomes, especially when grown in the early wet season. Cambodian farmers may borrow money to buy crop inputs and often sell their produce to companies and traders from neighbouring countries, hence they are price takers. Some new crop technologies are evaluated which relate to soil and crop fertility management interacting with climatic factors. The DSSAT crop simulation model is used to predict outcomes from alternative management strategies. Bio-economic analyses are conducted to assess the likely appeal of these technologies to Cambodian farmers in a return-on-investment context. The results show that management to adjust the nitrogen fertility available to corn, the use of rhizobium in soybean, and a delay in planting early-wet-season corn may all show substantial financial benefits. Further research and an associated farmer demonstration program involving local extension officers are recommended.

Key words. Upland crops, Cambodia, technology, economics, simulation, risk.

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1. Introduction

Poverty alleviation and food security are important issues in the upland cropping regions of Cambodia. This paper has its parentage in a project titled: ‘Farming Systems Research for Crop Diversification in Cambodia and Australia’, funded by the Australian Centre for International Agricultural Research. It is aimed at investigating soybean, mungbean, maize (corn), peanut, sesame and cowpea; upland crops grown for cash sale in a non-irrigated wet-season environment. The project aims to fill knowledge gaps about crop performance which lead to low yields and variable farm incomes. The purpose of the paper is to present results of a bio-economic analysis of potential new technologies from the viewpoint of the Cambodian farmer. The question is whether particular technologies, in specific farming systems contexts, are likely to be appealing enough to change management. The economic dimension of the comparison includes likely return on investment (ROI) from expenditure on crop inputs, and the trade-off between expected levels and variances of crop returns. Other (eg social, attitudinal and institutional) factors also impact farmer behaviour and management change.

The alleviation of poverty for upland farmers in Cambodia depends primarily on producing more of a crop in an efficient fashion, so that profits are improved. For all farmers there is a gap between potential and actual crop yields. Dillon and Hardaker (1993) listed biological (crop variety, weeds, pest, diseases, soil/water problems, and soil fertility) and socio-economic (costs and returns, traditions and attitudes, knowledge, input availability, institutions, and risk and uncertainty) factors which can constrain yields.

2. Context and methodology of the analysis

2.1 Areas of study

The Provinces of Battambang and Kampong Cham are contrasting upland cropping areas for study. They represent newer and more traditional areas respectively, and five districts were studied – Kamrieng, Sampov Lun and Rotonak Mondol (Battambang), and Chamkar Leu and Tboung Khmum (Kampong Cham) (Figure 1).

2.2 Information sources

Both biological and economic information was assembled for this study. A socio-economic survey and crop-check survey were conducted initially to generate information about farm and farm-family characteristics, and aspects of crop inputs, outputs and prices. Other crop economic data were also collected for this analysis. Typical crop activity budget information (Makeham and Malcolm 1986, Dillon and Hardaker 1993, McConnell and Dillon 1997) was generated by interviewing groups of farmers. Detailed farm information was recorded and crop activity budgets developed for typical farms in each district, and these were a starting point for these analyses.

The biological information came from on-farm trials in the project and crop simulations of proposed on-farm technologies. The trials tested alternative treatments in typical conditions for Cambodian upland farmers, and also facilitate demonstrations of results to local farmer populations. The crop simulation model results provide an idea of what is achievable if the major cropping constraints can be overcome. Some crop management questions are more suited to crop simulation analysis than farm trials.

The Decision Support System for Agrotechnology Transfer (DSSAT) family of models (Tsuji *et al.* 1998, Jones *et al*. 2003, Hoogenboom *et al*. 2004) was used in this study. DSSAT is a software package that contains crop growth models, database management programs, utility programs, and analysis programs, each easily executable from within a shell or capable of being run alone. An example of trade-off analysis using DSSAT is in Stoorvogel *et al*. (2004).

DSSAT requires climatic and soil characteristic inputs. Daily weather records for the various locations in Cambodia were either unavailable or limited in terms of duration and consistency. A weather generator program, MarkSim (CIAT 2004), was used to generate the data needed to run DSSAT simulations. MarkSim uses a third order Markov chain to estimate rainfall events, this is particularly important in South-East Asia. It estimates the altitude of a location from given latitude and longitude and then develops statistical parameters describing distributions of rainfall, temperatures and solar radiation. MarkSim was used to generate 89 years of weather records for this analysis. The soils used in the simulation were described as Labansiek and Kompong Siem soils (White *et al*. 1997). Soil analysis data were unavailable, so parameters were estimated from similar soil types (Vertosol, Kraznozem and Ferrosol) in Australia.

2.3 New technologies/crop management evaluated

Three types of crop technologies were evaluated based on a theme of soil and crop fertility interacting with climatic patterns. The first related to the application of nitrogen (N) fertilizer to corn. 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 crop yield. There is 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 fertilizer 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 wet season rains is an uncertain event in terms of date of first rains 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 corn.

2.4 Methods of analysis

Bio-economic analysis was used for this paper. We assume that the upland farmers in these districts are interested in crop economics, 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 weigh 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 (EWS) and main wet season (MWS)) 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. The issue appears to be mainly about individual-crop technology and management expertise; hence the economic comparisons are made at the crop-enterprise level.

2.5 Economic techniques

Comparison of with- versus without-management scenarios for a crop technology or management change can be conducted using partial or crop activity gross margin (GM) budgets. All economic results are presented in US dollars. The important investment question is whether the ROI will cover the cost of capital and provide a margin to compensate for attitudes to risk and reluctance to adopt new management. For questions of how much of an input, such as N, to use, marginal economic analysis is utilised 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. ROI considerations are also included.

We are also 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). In this paper we present distributional results for farmer decision-makers without making assumptions about their risk preferences.

2.6 Engendering farmer change

Abadi Ghadim *et al*. (2005) considered adoption to be a dynamic decision process involving information acquisition and learning-by-doing by growers. Their results highlight the primary economic character of the adoption decision, and also the importance of economic risk in the process. While not all of the factors important in engendering change might be associated with economics, it is likely that substantial profit changes are a necessary pre-condition for such changes to occur. Cambodian farmers often borrow money at 3% per month or more to purchase crop inputs. CIMMYT (1988) suggests that farmers would require a ROI of twice the cost of capital to consider making changes, but that for poor farmers considering a new technology a minimum of 100% was more realistic.

Apart from the financial benefits, technologies would also need to be capable of field demonstration. In Cambodia there are extension officers in the Provincial Departments of Agriculture and Forestry who are potentially important agents for change in the use of new crop technologies. These workers can be equipped to undertake field trial demonstrations and provide agronomic and economic information to farmers which allow them to form their own opinions.

2.7 Experimental design

For the question of how much N is profitable to use in corn, a yield response surface was generated by running DSSAT with 11 levels of N input (0, 25, 50, 75, … 250 kg N/ha) sown on the 1 April. These responses are to the total amount of nitrate (i.e. plant available) N available to the crop – whether from the soil or added as fertilizer. Then the profitability of N input was assessed using prices of 300 riel/kg ($75/t) for corn and 660 baht/50 kg bag of urea fertilizer ($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 EWS 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.

3. Results

3.1 Activity budgets

Interviews of groups of farmers were conducted in 2005 in each of the five districts, and consensus results for typical crop activity budgets are in Table 1. Generally, corn yields were highest and other yields were relatively low. Conversely the prices of other crops (especially sesame and mungbean) were relatively high and corn prices were the lowest. Activity GMs were generally lower in Rotonak Mondol and Tboung Khmum than in other districts, with a number of crop GMs being negative.

Farmers were questioned in the 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 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 GMs 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 1 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 EWS than MWS crops in all districts except Rotonak Mondol.

3.2 Nitrogen fertilization of corn

The marginal value product (N input demand function) 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 10^{th}, 50^{th} (median) and 90^{th} percentiles of the 89 crop-year simulations. 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 (units of 25 kg of plant available N) provides a change in gross corn 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.

3.3 Rhizobium inoculation of legume seed

A statistical analysis of the field experimental results was conducted and the interaction between N, inoculation and crop type on yield was tested (see Table 2). 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 2 are consistent with his findings.

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.

3.4 EWS crop planting rules

The results of these DSSAT simulations are in Table 3 and Figure 4. Average corn 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. Discussion

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 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 EWS crops generally have lower and more variable incomes than MWS crops. In terms of poverty alleviation and income security this is a strong reason for focusing effort on EWS crops and varieties which have a short growing season and are quick maturing. Sesame appears to be an important EWS crop. It is appealing to farmers because it can be planted dry, has a high price, and expenditure on crop inputs can be deferred or avoided depending on seasonal conditions and crop prospects.

The yield responses of corn to total 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 the rhizobium technology could be very successful 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 EWS corn 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. Field trials and an extension program need to be developed to further explore and promote this technology to the upland farmers.

5. Conclusion

The results show that there are large potential on-farm benefits from adding N fertilizer to corn, inoculating soybean seed with rhizobium and delaying EWS planting of corn. Local extension workers need the resources to develop an extension program to explore and promote these improvements. The development of a rhizobium industry should also be considered.

Table 1. Activity budgets: Cambodian upland crops 2005.

District	Crop	Yield t/ha	Price $/t	Variable Costs $/ha	Gross Margin $/ha
Kamrieng	EWS Sesame	0.375	600	186	39
	EWS Corn	4.5	75	257	81
	MWS Mungbean	1.44	425	233	379
	MWS Soybean	2.16	275	195	399
Sampov Lun	EWS Corn	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 Corn	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 Corn	5	120	336	264
Tboung 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

Table 2. Effect of rhizobium inoculation and fertilizer on legume yields.

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

Table 3. Simulated corn yield for three planting dates in Kamrieng.

Planting date	1-Mar	15-Mar	1-Apr	1-Mar	15-Mar	1-Apr
Fertilizer rate (kg/ha)	0	0	0	50	50	50
			Corn 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

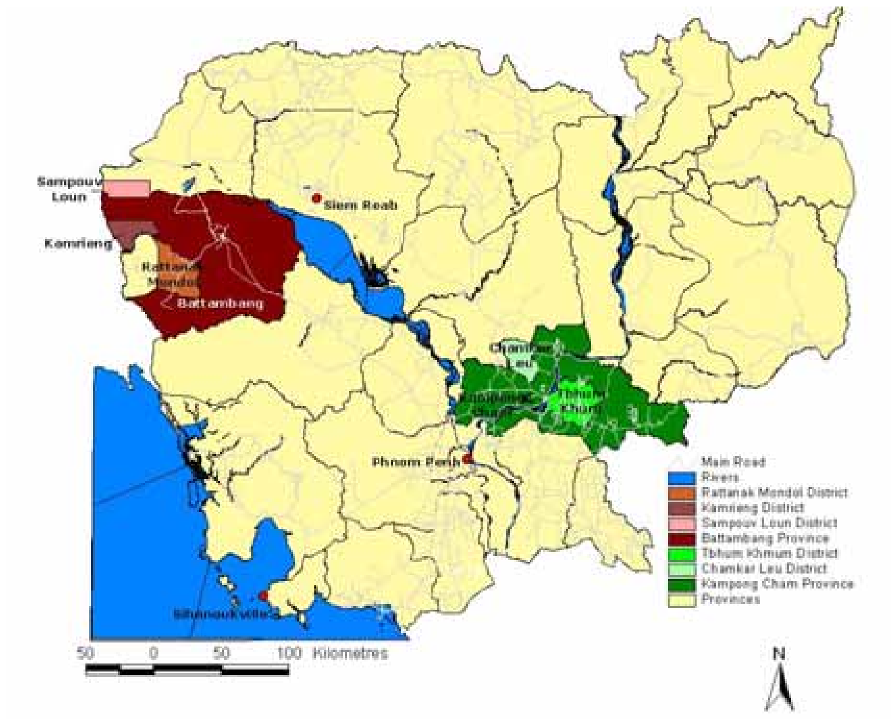

Figure 1. Districts and Provinces studied

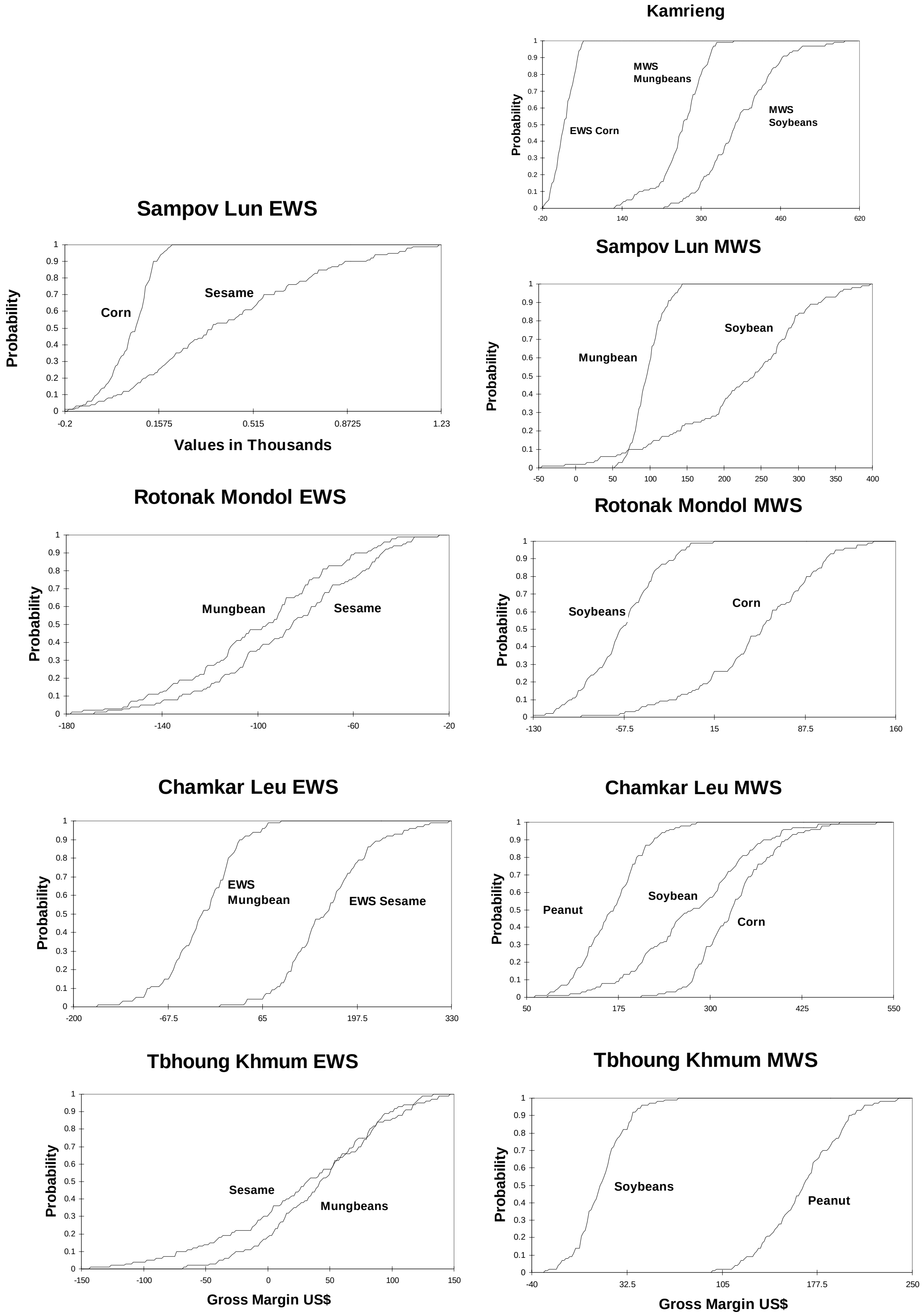

Figure 2. CDFs of activity budgets for EWS and MWS upland crops in Cambodia, 2005

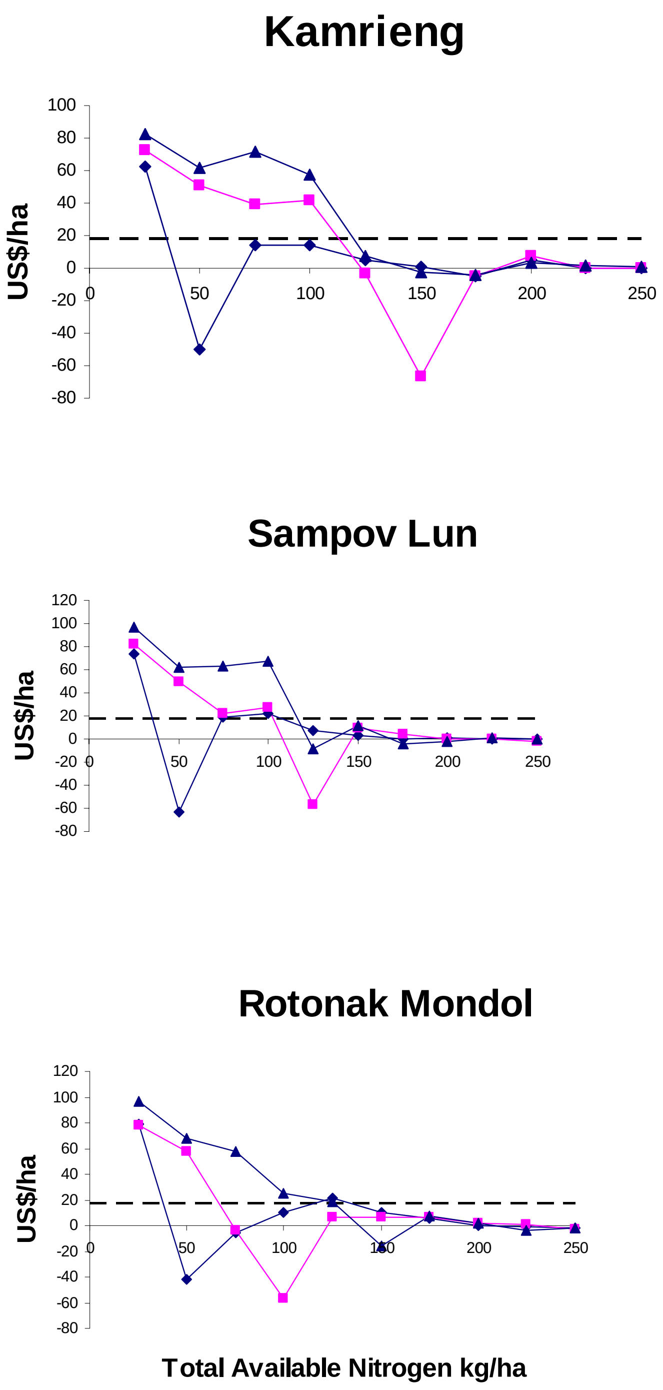

Figure 3. Input Demand and Marginal Cost Functions for Nitrogen in Corn. Triangles 90th percentile, squares 50th percentile, diamonds 10th percentile of climate outcomes. Marginal Cost of N dashed line

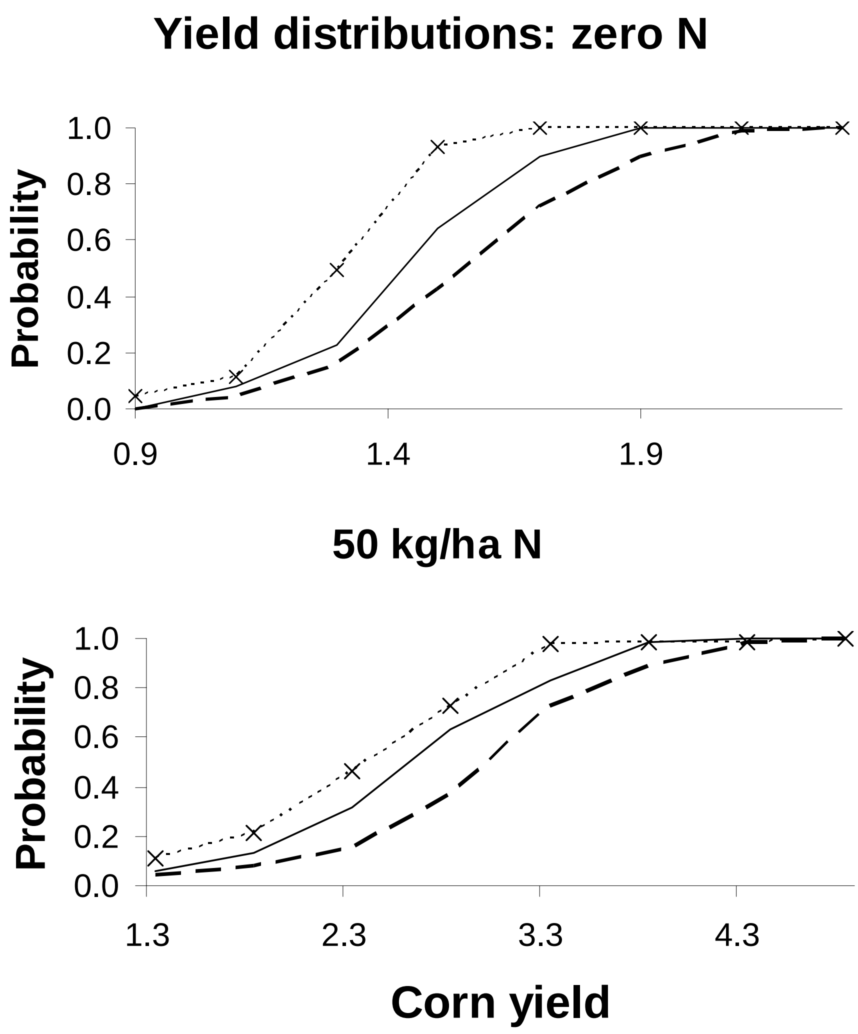

Figure 4. CDFs of corn yield as affected by fertilizer and planting date in Kamrieng

Dotted line 1 March, solid line 15 March, dashed line 1 April

References

Abadi Ghadim, A.K., Pannell, D.J. and Burton, M.P. 2005. Risk, uncertainty, and learning in adoption of a crop innovation. *Agricultural Economics*, 33, 1-9.

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

CIAT 2004. MarkSim: A Computer Tool that Generates Simulated Weather Data for Crop Modeling and Risk Assessment. See http://gisweb.ciat.cgiar.org/marksim/.

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.

Dillon, John L. and Hardaker, J. Brian 1993. *Farm management research for small farmer development*. FAO Farm Systems Management Series No. 6, Food and Agriculture Organization of the United Nations, Rome.

Hardaker, J.B., Huirne, R.B.M., Anderson, J.R. and Lien, G. 2004. *Coping with Risk in Agriculture*. 2nd 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.

Hoogenboom, G., Jones, J.W., Wilkens, P.W., Porter, C.H., Batchelor, W.D., Hunt, L.A., Boote, K.J., Singh, U., Uryasev, O., Bowen, W.T., Gijsman, A.J. du Toit, A., White, J.W., and Tsuji, G.Y. 2004. Decision Support System for Agrotechnology Transfer Version 4.0 [CD ROM]. University of Hawaii, Honolulu, HI.

Jones, J.W., Hoogenboom, G., Porter, C.H., Boote, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W., Singh, U., Gijsman, A.J. and Ritchie, J.T. 2003. 'The DSSAT cropping system model', *European Journal of Agronomy*. 18: 235-265.

McConnell, Douglas J. and Dillon, John L. 1997. *Farm management for Asia: a systems approach*. FAO Farm Management Report Series No. 13, Food and Agriculture Organization of the United Nations, Rome.

Makeham, J.P. and Malcolm, L.R. 1986. *The economics of tropical farm management*, Cambridge University Press, Cambridge.

Palisade Corporation 2000. *@RISK Industrial*. New York.

Stoorvogel, J.J., Antle, J.M., and Crissman, C.C. 2004. 'Trade-off analysis in the Northern Andes to study the dynamics in agricultural land use', *Journal of Environmental Management* 72: 23-33.

Tsuji, G.Y., Hoogenboom, G., and Thornton, P.K. (eds) 1998. *Understanding Options for Agricultural Production. Systems Approaches for Sustainable Agricultural Development*, Kluwer Academic Publishers, Dordrecht, the Netherlands. ISBN 07923-4833-8. 400 pp.

White, P.F., Oberthur, T., and Sovuthy, P. 1997. *The Soils Used for Rice Production in Cambodia: A manual for their identification and management*, International Rice Research Institute, P.O. Box 933, Manilla, Philippines.