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National Agriculture and Forestry Research Institute

Intensification of lowland rice-based farming systems in Laos in the context of diversified rural livelihoods

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Contributed paper prepared for presentation at the 57th AARES Annual Conference, Sydney, Australia, 5th-8th February, 2013

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AUSTRALIAN AGRICULTURAL & RESOURCE ECONOMICS SOCIETY

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Abstract

The cultural and economic importance of paddy rice production for households in the lowlands of Lao PDR cannot be overstated. Annual rice production is viewed by households and the Government alike as an indicator of poverty and food security. Over the past decade the adoption of new technologies has resulted in productivity improvements in lowland rice systems, yet further gains are being sought to maintain national rice self-sufficiency. The Government of Laos has established optimistic yield targets for both the lowland rainfed and irrigated rice production systems. However, survey evidence shows that, despite the adoption of improved technologies, most rainfed farmers remain subsistence-oriented and there is a significant yield gap between the current situation and the proposed targets. The diversification of household livelihoods through wage migration has reduced farm labour availability and increased farm wages. At the same time, price fluctuations due to supply shocks and government responses have created a further disincentive to the intensification of rice production systems. An economic analysis of rainfed rice production suggests that given current conditions we are likely to continue to see the adoption of low-input, labour-efficient, and relatively stable rice production systems for most households, with small areas of high-input, commercially-oriented systems in favourable conditions. We argue that research and extension efforts should recognise this diversity of production systems and household livelihood strategies.

Key Words: Rainfed lowland rice, fertility management, risk analysis, Lao PDR,

Introduction

The cultural and economic importance of paddy rice production for households in the lowlands of Lao PDR (Laos) cannot be overstated. The cultivation of glutinous rice remains the platform on which rural livelihoods in the lowlands are based. Lowland households strongly identify with paddy rice production and will typically answer questions regarding their employment or livelihood by saying they are "paddy rice farmers" (*sao na*) or "grow paddy rice" (*het na*), despite the diversity of farm and non-farm activities in which they are engaged. The rainfed lowland ecosystem is more important in Laos than in other countries in mainland Southeast Asia, accounting for around 70 per cent of total rice area; only 13 per cent of total area is irrigated (Eliste and Santos 2012). Furthermore, with policies to stabilise and eradicate shifting cultivation in upland areas and to promote cash crops in both the uplands and the lowlands, productivity improvements in the rainfed lowlands will be an important determinant of both household- and national-level food security.

Rice production in the rainfed lowlands faces a number of biotic and abiotic constraints at the farm level, including poor soil fertility, droughts and floods, and various pests and diseases (Schiller et al. 2001; Linquist and Sengxua 2001; Fukai and Ouk 2012). Furthermore, factors beyond the farm boundary, such as rising input costs, fluctuating output prices, and uncertain trade policy, continue to limit farmers' incentive to intensify production beyond that required to achieve household self-sufficiency. Hence in recent years labour and capital have been redirected into a range of other farm and non-farm activities rather than into intensifying rice production (Manivong et al. 2012). With high levels of yield- and price-risk, and limited opportunities for consumption smoothing through market mechanisms (credit, insurance), households adopt income-smoothing strategies by adopting low-input production systems and income diversification, most notably through migration of family members to earn wages.

While the constraints are numerous, lowland rice production systems have been evolving over the past two to three decades. The traditional farming system that relied on draught animal power, traditional varieties, and organic fertiliser now accounts for a very small proportion of the country's rice area, with widespread adoption of mechanised land preparation, improved varieties, and low levels of inorganic fertiliser. Despite the achievements of these green revolution technologies in terms of increased output, lowland rice production remains an economically marginal activity, providing limited economic incentive for farmers to intensify production beyond household consumption needs. This poses a challenge for the Government that seeks to keep the price of rice affordable for urban consumers (and net buyers of rice in rural areas), while providing incentives for farmers to intensify production to achieve food security objectives. Attempts to maintain national food security, equated with rice self-sufficiency, have included the setting of official yield targets – 4 tons/ha for the rainfed wet-season crop and 5 tons/ha for the irrigated dry-season crop – that are high relative to the current situation, as well as ad hoc trade restrictions prompted by seasonal shortfalls and price spikes. However, in many cases the strategies fail basic economic viability tests at the household level and have created further market uncertainty.

The limited intensification of lowland rice systems reflects the relative resource endowments and livelihood objectives of farm households. Induced innovation theory predicts that farming systems will respond both to changes in resource endowments and to growth in product demand, with new technologies developed that facilitate the substitution of relatively abundant and low-cost factors for those that are relatively scarce (Hayami and Ruttan 1985). In practice, this depends on the extent to which farmers' circumstances and national government policies align, and the ability of farmers to influence research and development priorities. In considering the economic and institutional constraints to improved fertility management, Pandey (1999) classifies rice production systems using a matrix of population density and the stage of economic development (income levels). He argues that, in situations with low population density and low income levels (in which he includes Laos), farms tend to be subsistence-oriented, with limited demand for improved nutrient management technologies that increase yields and returns to land. Such technologies will only be adopted if they also help save labour, the relatively scarce resource. He further argues that, in order to stimulate the demand for yield-increasing technologies, policies need to focus on improving the profitability of rice production. This may include the development of export markets and improved market infrastructure, factors that lie outside the farm boundary. Nevertheless, in rainfed regions, production risk will continue to influence the demand for fertility management technologies.

In this paper we aim to explain farmers' decisions regarding intensification of rainfed lowland rice systems in the context of current resource endowments, product demand, and production and market risk. We first describe the current rice production system in two major lowland provinces in central and southern Laos – Savannakhet and Champasak. We demonstrate that while the rainfed production system remains largely subsistence-oriented, farmers have selectively adopted a range of new technologies and continue to respond to changing incentives. However, to date this has largely involved the adoption of low-input, more labour-efficient, and more stable production systems rather than commercially oriented, high-input, high-yield systems. We use activity budgeting and risk analysis to explore the economic performance of several input scenarios, ranging from farmers' practice to input levels required to achieve Government policy targets. This analysis can be used to reassess aspects of rice policy for the rainfed lowlands in Laos.

Methods

Savannakhet and Champasak are two of the most important rice-producing provinces in Laos. In 2009 they accounted for around 40 per cent of the national wet-season harvested paddy area and a similar proportion of total production (Ministry of Planning and Investment 2010). A diagnosis and assessment of farming systems in these two provinces was one of the objectives of the integrated research project "Developing improved farming and marketing systems in rainfed regions of southern Lao PDR", funded by the Australian Centre for International Agricultural Research (ACIAR). This paper is based on the analysis of data collected in several phases of field work, including key informant interviews with district agricultural staff, village group discussions, household surveys, and household case studies.

The project fieldwork was conducted along transects reflecting different farm types, from irrigated lowland through rainfed lowland to upland. However, only data from lowland villages are considered here; the upland villages surveyed in the east of Savannakhet have been excluded from the analysis. Thus for present purposes the study region included six villages in Outomphone, Phalanxai, and Phin Districts in Savannakhet (Figure 1) and six villages in Phonthong and Sukhuma Districts in Champasak (Figure 2). A household survey was carried out with 30 randomly selected households in each village, making 360 households in all. Information was sought regarding household composition and assets, cropping practices, livestock practices, off-farm and non-farm employment, migration and remittances, forest collection and hunting activities, access to water, access to credit, group membership, information sources, and rice security. Case studies were conducted with 13 households in Savannakhet and 18 households in Champasak.

Survey and case study data were supplemented with project and historical agronomic trial results in order to construct model budgets for various input scenarios. These include data from fertiliser response trials conducted by IRRI and NAFRI over more than a decade (Linquist and Sengxua 2001; Linquist and Sengxua 2003; Heafele et al 2010). Official yield data were not used as these tend to overestimate actual farm yields (Pandey and Sanamongkhoun 1998), presumably a reflection of the pressure to show progress in achieving policy targets. Sensitivity analysis, threshold analysis, and risk analysis (using the @Risk software package) were conducted for each scenario.

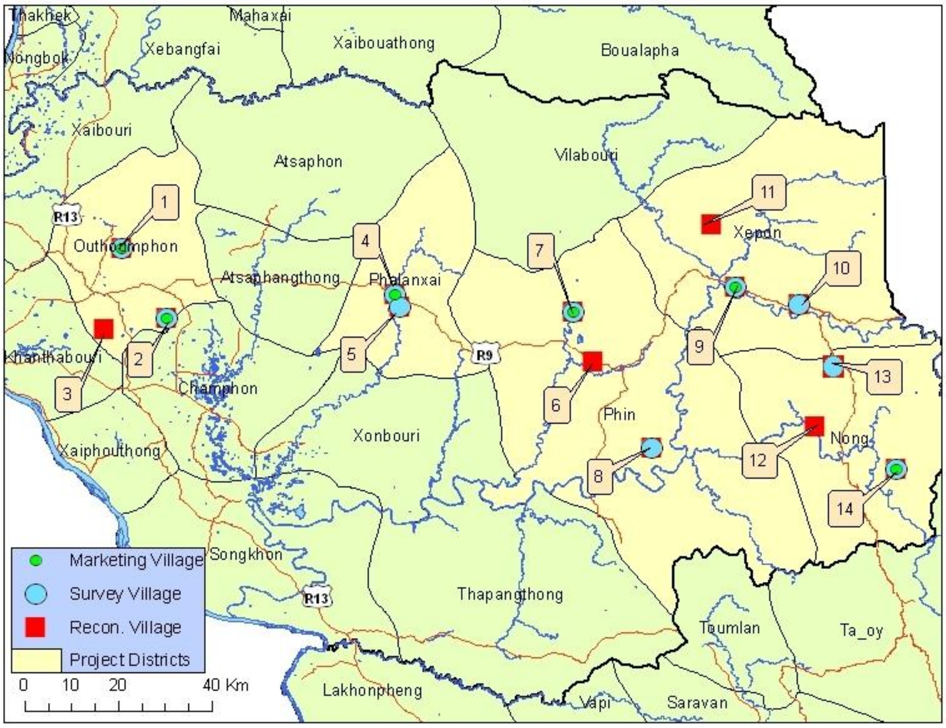

Figure 1 Location of socio-economic activities in Savannakhet Province. Villages 1-8 have been included in this analysis. Group discussions were conducted all villages. The household survey was not conducted in villages 3 and 6.

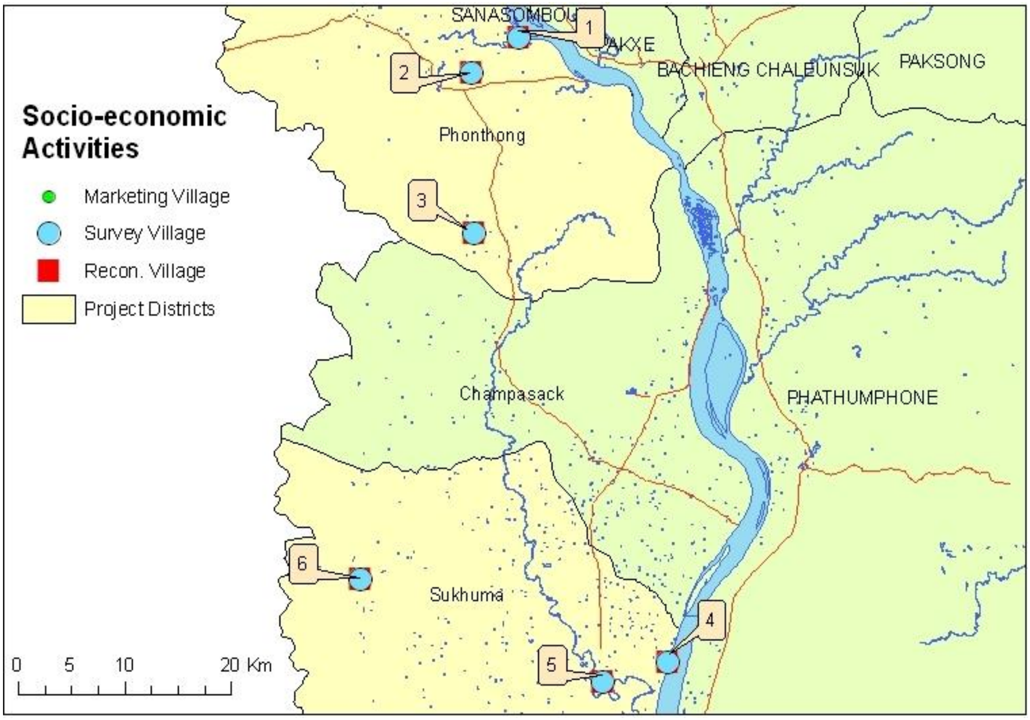

Figure 2 Location of socio-economic activities in Champasak Province

The Status of Lowland Rice Farming in 2010

The cultivation of paddy rice remains an important livelihood activity for the majority of households in the lowland regions of Laos and creates the platform on which other activities and household decisions are based. Decisions regarding labour utilisation and migration, livestock management, even religious and cultural festivals, are all made with reference to the paddy production cycle. Around 96 per cent of surveyed households in the lowland and transitional[1] villages surveyed cultivated paddy rice in the wet season of 2010. Household access to paddy land varied within and between villages, from less than a hectare to over 10 ha with an average across all villages of around 2 ha (Table 1). There was a similar proportion of households with 1 ha or less (33%), 1-2 ha (34%), and over 2 ha (33%). Beyond farm size, other factors such as soil type, position in the toposequence, and access to water sources all affected the productivity of the land even before any management decisions were overlayed. The stability of the livelihood platform thus varied between households and seasons.

The wet season of 2010 was considered by farmers and researchers to be a drier than normal year, with reported yields (calculated from farmers' estimates of cultivated area and production) somewhat lower than in previous years (Table 1). Droughts and floods are a common occurrence in the region, with large areas impacted by these climatic shocks. According to Schiller *et al.* (2006), over a period of 37 years (1966-2002) the central region (which includes Savannakhet) was affected by extreme events in 32 years, while the

[1] Transitional villages are located in the 'transitional zone' between rainfed lowland rice production and upland rice production. Many households in these villages cultivate both paddy and upland rice.

southern region (which includes Champasak) was affected in 22 years. These events have a profound impact on household rice self-sufficiency, given that many operate close to a subsistence threshold. Nevertheless, this means that the 2010 yields were not greatly different from the normal run of seasons. It is significant that they were below official yield data for the same season, and well below the official target of 4 t/ha.

Table 1 – Factors affecting household rice status in surveyed villages, 2010 (n=360)

District and village	% of households who grow paddy rice	Mean household size	Mean WS cultivated area (ha)	Mean yield (kg/ha)	Mean % of production sold
Outomphone	100	6.6	2.5	1,466	9.7
Nagasor	100	6.1	2.1	1,618	8.2
Phonegnanang	100	7.0	3.0	1,314	11.2
Phalanxai	98	6.2	1.9	1,572	3.8
Phanomxai	100	6.8	1.3	1,987	2.1
Phontan	97	5.7	2.6	1,157	5.5
Phin	88	7.2	1.2	1,740	7.2
Khamsa-e	87	7.3	1.2	2,545	14.1
Geang Xai	90	7.0	1.1	965	0.5
Phonethong	97	7.0	2.8	1,582	24.5
Phaling	97	7.3	2.4	1,718	22.3
Oupalath	97	7.0	2.4	1,933	27.0
None Phajao	97	6.8	3.5	1,100	24.1
Soukhuma	98	6.3	1.8	1,996	22.6
Boungkeo	100	6.7	1.4	2,219	26.2
Khoke Nongbua	100	6.5	1.7	2,109	24.1
Hieng	93	5.8	2.4	1,645	17.1
Mean	**96**	**6.7**	**2.1**	**1,689**	**15.3**

Households produced limited surplus rice for sale in the 2010 wet season, averaging only 15 per cent across the 12 villages (Table 1). Only 40 per cent of surveyed households who were growing paddy rice sold any rice, with the rest either producing rice exclusively for home consumption or buying rice to cover a deficit. However, sellers included some households that had access to irrigation water for the subsequent dry season (particularly in Bounkeo and Phaling in Champasak).[2] The proportion of households selling rice, just self-sufficient, and buying rice varied significantly between the villages (Figure 3). There was also a group of households that sold rice immediately after harvest to pay off debt and re-entered the market later in the year to make up shortfalls. These households received low paddy prices when they sold their rice after harvest and incurred higher prices when they re-entered the market to make purchases.

[2] Wet-season rice remained largely rainfed in these villages unless subsidies were given for irrigation fees during drought years.

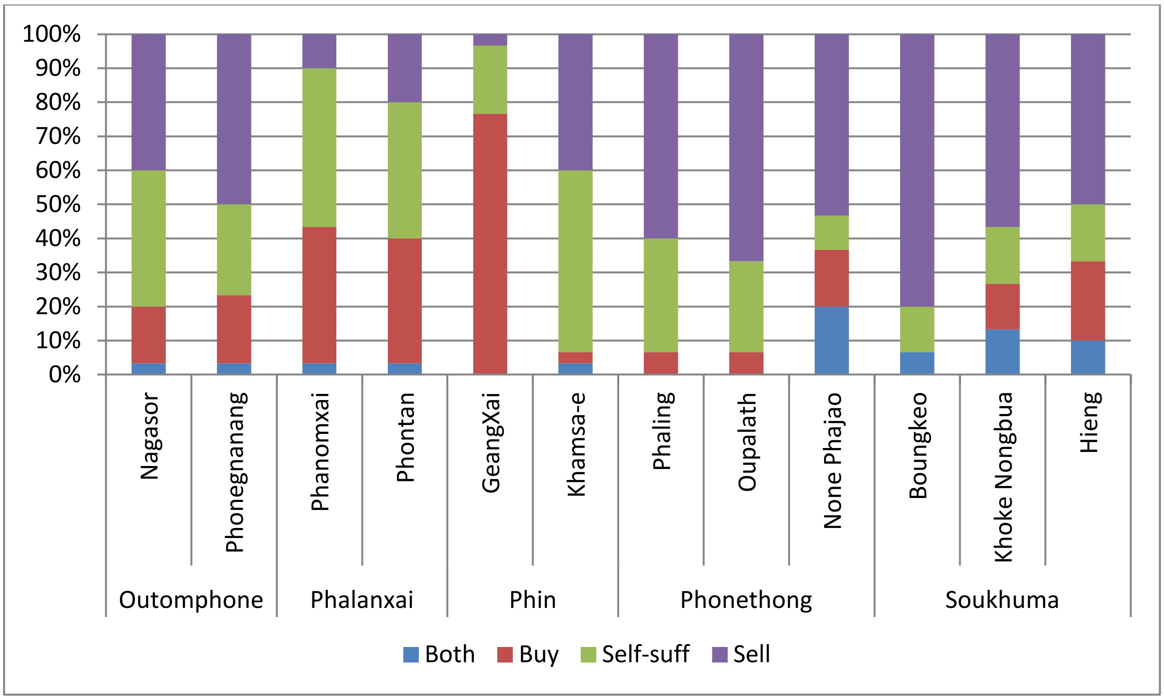

Figure 3 – Household rice status for 2010, by district and village

The household's rice status is a function of the number of household members (or, strictly, the number of people who share the harvest); the area of paddy land available for cultivation; and the yield of the rice crop (Table 1). Given that yields fluctuate between years and many households are close to subsistence levels, the household's rice status is likely to change from year to year. Hence households formulate their livelihood strategy each year depending on crop performance. For example, the migration patterns of young people in some case-study households were determined by the performance of the wet-season rice crop and whether cash income would be required to make up shortfalls.

The average household size in the survey was 6.7 members, but this is complicated by household dynamics throughout the year. Members of the household may migrate for periods of the year and not consume from the household's rice stock. On the other hand, sometimes the rice harvest is shared beyond the immediate household, including relatives who have moved away from the village. Similarly, there are other social obligations involving sharing rice with others, including offerings to monks. Despite these nuances, the national criterion for self-sufficiency is 350 kg of paddy (i.e., unmilled) rice per household member per year.

Figure 4 shows the yield required for an average household to achieve self-sufficiency for a range of paddy areas. The "self-sufficiency curve" indicates the large difference in required yield as land size varies. For example, a household with 2 ha of paddy land only requires a yield of around 1.2 t/ha to achieve household self-sufficiency, while a household with only 1 ha would require a yield of close to 2.5 t/ha. The scatter plot presents the yield and area combinations for the 2010 wet season. Self-sufficient households tend to track the "self-sufficiency curve", suggesting that households are trading off yield and paddy area, pursuing higher yields only when farm size is limited. As expected, most net purchasers of rice fall below the "self-sufficiency curve" in Figure 4 and most net sellers are above the curve (remembering that actual family sizes vary between points). Some households remain net purchasers of rice, despite relatively large paddy area, due to low yields, while other households achieve relatively good yields but, due to area constraints, still fail to meet household requirements.

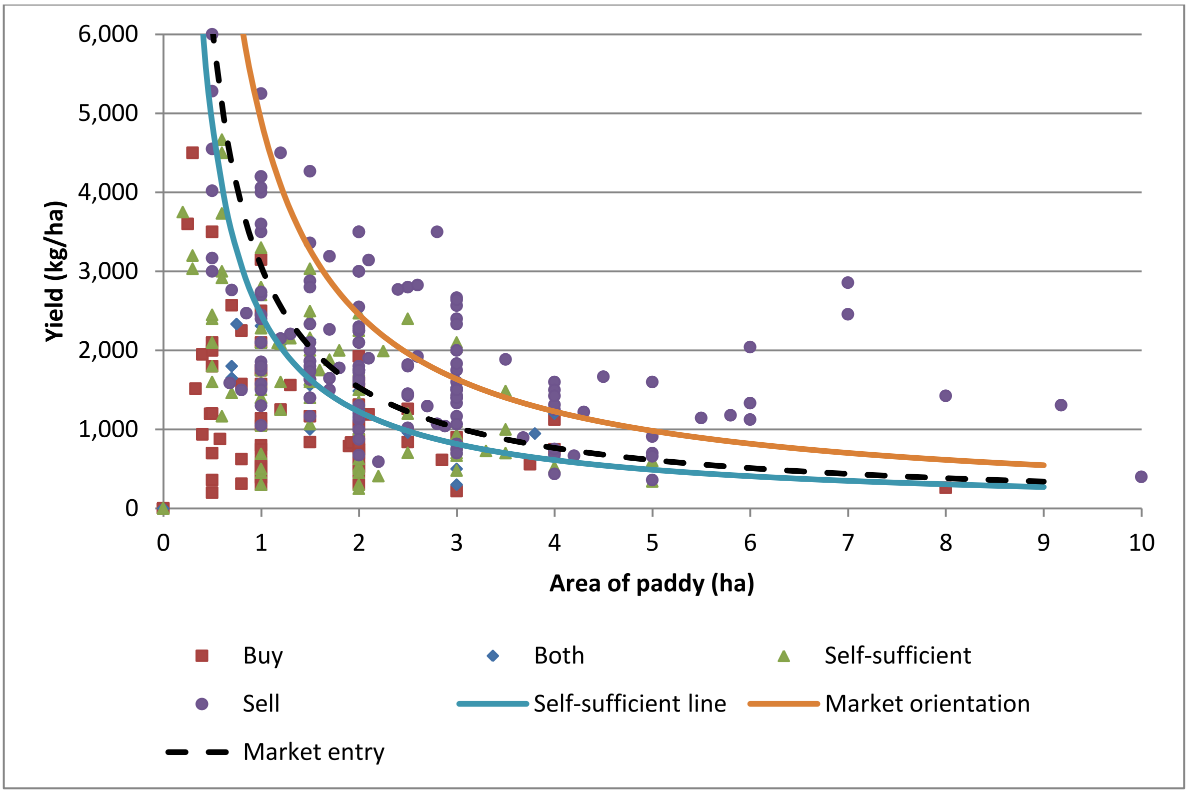

Fig 4 – Yield-area combinations by household rice status

The “market-oriented curve” in Figure 4 shows the yield-area combinations enabling the average household to sell 50 per cent of production, and the “market entry curve” shows the combinations for sales of 20 per cent of production, reflecting an incipient market orientation. There were few households above the “market-oriented curve”, especially in Savannakhet. As indicated in Figure 3, a large proportion of households selling rice in 2010 were from Champasak, reflecting the higher average yields in 2010 in that province. Again, the scatterplot shows that the opportunity for a household to meet these market criteria varies considerably with paddy area. Households with 3 ha or more could achieve a 50 per cent surplus with 2 t/ha or less, while the few market-oriented households with less than 2 ha were achieving yields of 3-4 t/ha.

In general, the data suggest that currently the majority of households remain largely subsistence-oriented and are willing to trade-off yields with paddy area to meet household requirements, limiting the incentive for intensification.

Technology Adoption

While there are many physical and biological constraints that continue to limit rice productivity in the rainfed lowlands, the farming system has by no means remained static over the past two decade. The traditional production system that relied on draught animal power for land preparation, traditional varieties, and organic fertiliser has almost completely disappeared from the landscape. Indeed, only 11 households from the 347 households surveyed that were growing paddy rice had not adopted any of the three main technologies - mechanised land preparation, improved varieties, or inorganic fertiliser. The current status of adoption of these technologies is summarised below.

Mechanisation

Economic growth in both Laos and neighbouring countries has created considerable employment opportunities away from the farm. Migrating to Thailand is a well-established livelihood strategy for young people from lowland households; 43 per cent of households surveyed in Champasak had a least one member working in Thailand (Manivong et al. 2012). In Outomphone, Savannakhet, 42 per cent of households had at least one family member working in Thailand, with the incidence falling away as distance from the border increased. At the same time, employment opportunities within Laos, both in urban areas (including the construction and service sectors) and rural areas (such as working in rubber plantations) is also drawing labour away from traditional, semi-subsistence agriculture. This is not only impacting on the availability of household labour, but also increasing the cost of hiring labour, especially during peak periods such as transplanting and harvesting. Wage rates varied from 25,000 kip/day to 50,000 kip/day depending on location, season, and activity. However, even in remote Phin District, the wage rate for transplanting was reported to have reached 50,000 kip/day (AUD 6.25).[3]

Mechanisation of rice production in Laos remains in its infancy, but with labour becoming increasingly scarce, changes are rapidly occurring as technology spills across the borders (Table 2). Around 75 per cent of survey households utilised two-wheel tractors for land preparation rather than relying on draught animal power (mainly buffaloes). The ownership of two-wheel tractors had expanded to over 60 per cent of households, while only 21 per cent of households continued to use draught animal power exclusively. As Table 2 shows, the area of paddy land owned did not have a major impact on adoption. Moreover, adoption had extended into some more remote areas where rice productivity remained low and almost no surplus rice was produced. While the technology is not divisible like seed or fertiliser, the extent of adoption is not surprising given the versatility of the tractors and the extent of labour saved in both production and non-production activities, e.g., transport to regional centres. However, in one village in Phonethong District (None Phajao) ownership of two-wheel tractors remained low compared to all other villages.

Other forms of mechanisation were less common, with the first transplanters, drill seeders, and harvesters only beginning to be utilised in the past few years and only in small areas. It

[3] The exchange rate is about LAK 8,000 = AUD 1.00 = USD 0.95

is expected that their use will continue to expand as labour becomes increasingly expensive. Currently, in order to minimise cash outlays, households tend to extend the period of transplanting and utilise the declining household labour resource rather than hire labour or transplanters (with obvious tradeoffs in terms of yield).

Table 2 – Mode of land preparation by paddy area and district

	Land preparation method (% of households in each category)			
	Buffalo	Own tractor	Hire tractor	Buffalo and hire tractor
Land preparation by paddy area				
Small (n=113)	21	57	16	4
Medium (n=121)	19	69	7	4
Large (n=113)	23	67	6	4
All (n=347)	21	64	10	4
Land preparation by district				
Outomphone (n=60)	18	78	2	0
Phalanxai (n=59)	19	56	20	3
Phin (n=53)	9	85	6	0
Phonethong (n=87)	47	43	3	5
Soukhuma (n=88)	6	69	16	8
All (n=347)	21	64	10	4

Improved varieties

According to a recent report on rice policy in Laos, the adoption of improved varieties has been the single most important factor in achieving significant productivity increases since the 1990s (Eliste and Santos 2012). The first improved varieties were released in Laos in the 1970s, and over the past two decades there has been widespread adoption. Indeed, the majority of households now grow at least one improved variety that has come out of breeding programs in Laos or neighbouring countries,[4] with the area of traditional cultivars contracting. The adoption of improved varieties has occurred at similar rates among different farm size classes (Figure 5). While the survey data suggest that adoption has been more widespread in Champasak than in Savannakhet (Figure 6), it is suspected that many respondents were calling the early released varieties, such as TDK1, by local names and now considered them to be "traditional" varieties. The impact of various projects can be seen in years (such as 2000) where significant jumps in adoption occurred.

Fertiliser use

Soil fertility has long been recognised as one of the major constraint to rice production in Laos. The soils throughout the main lowland rice-growing areas in the central and southern

[4] Thai varieties such as RD6 were common in lowland areas of Savannakhet

plains have been described as generally infertile, highly weathered, old alluvial deposits that comprise a series of low-level terraces with an elevation of about 200 m above sea level (Lathvilayvong et al. 1996). Previous studies have identified nitrogen as the most limiting nutrient in all regions of the country. In much of the central and southern regions phosphorus deficiency is also acute. Potassium is the least limiting of the three tested nutrients in the central region, yet the need for potassium inputs is expected to increase as production is increased through double cropping or as rice yields increase through changes in management (Schiller *et al.* 2001).

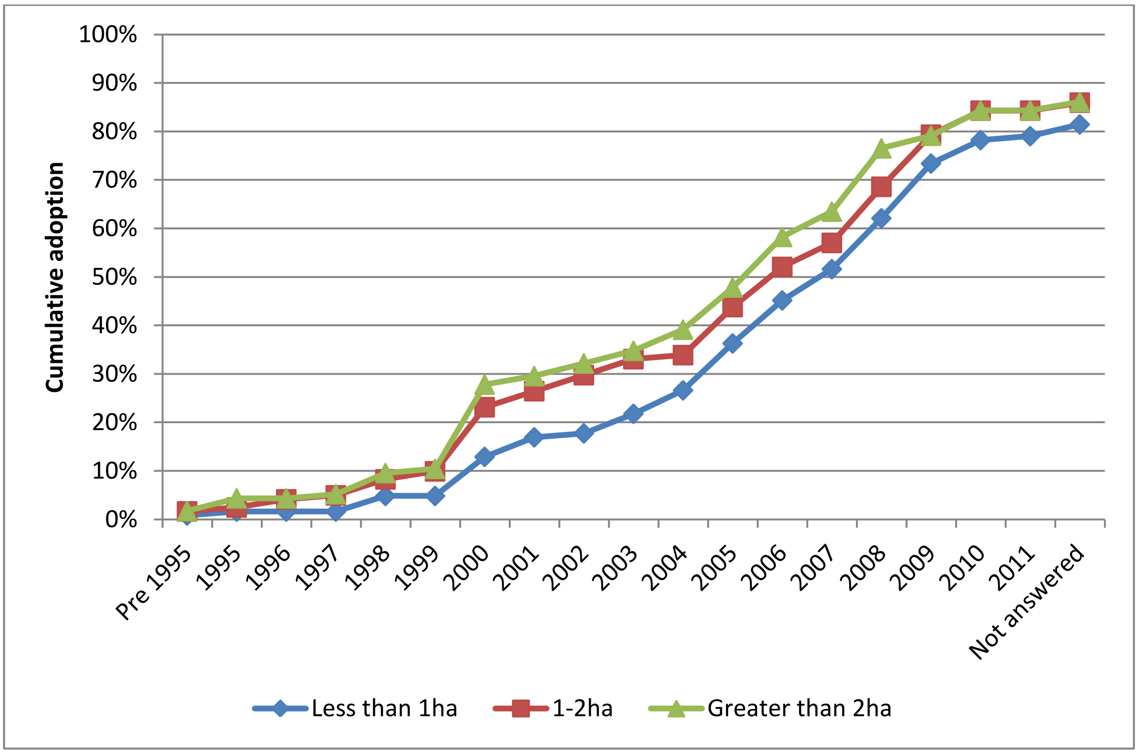

Figure 5 – Cumulative adoption of improved varieties by paddy area

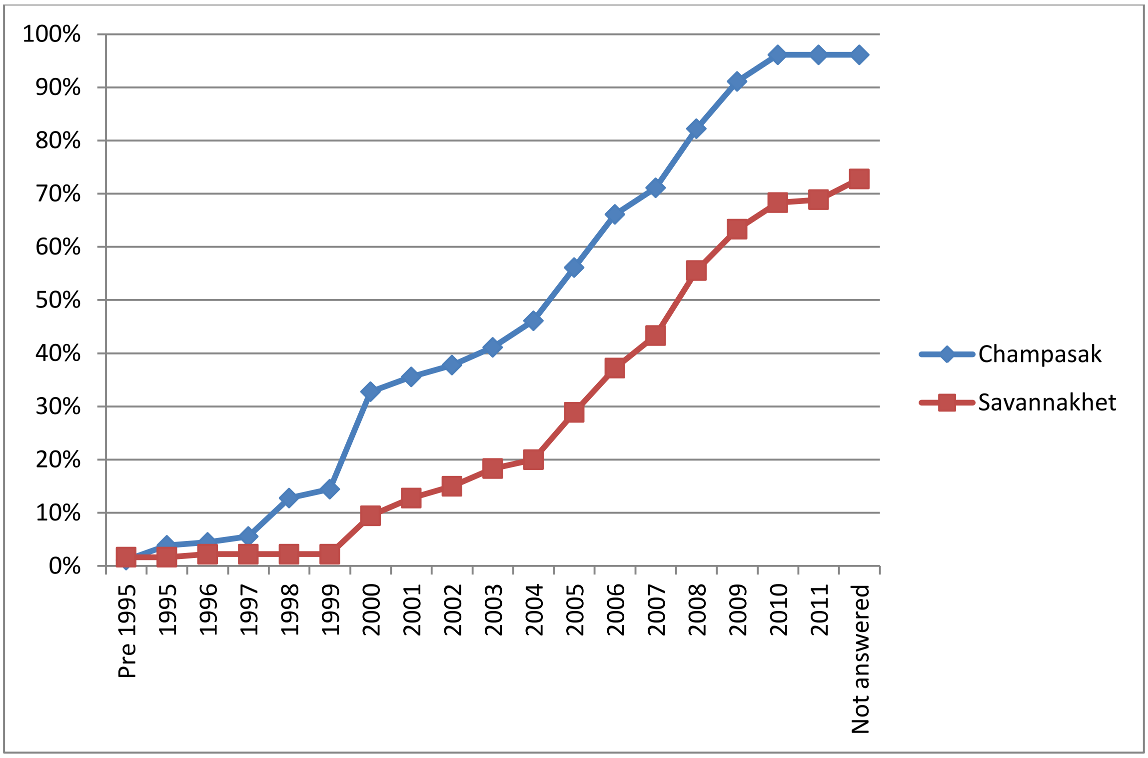

Figure 6 – Cumulative adoption of improved varieties by province

The use of both organic and inorganic fertilisers has been promoted in Laos for many years. Linquist and Sengxua (2001) developed broad fertiliser recommendations based on fertility management research throughout the country. Their recommendations recognised that the rainfed lowlands constitute a risky environment for crop production, hence obtaining maximum yields was not the objective of these recommendations. Rather, recommendations were formulated that required relatively low investment and used nutrients with maximum efficiency. Their recommendations were based on the three fertilisers that are more widely and readily available.

For the first year of application, the recommendation is to apply 60-X-25 kg/ha NPK, with the P rate varying according to soil texture. The rate of N recommended is lower than that required for maximum yields and reflects farmer risk in the rainfed environment. Higher rates of 90-120 kg/ha of N usually result in higher yields but only under good growing conditions. The recommended rate of P is 8.5 kg/ha in sandy soils, 13 kg/ha in sandy loam soils, and 19-26 kg/ha in loams and clay loams. In the second and subsequent years, the recommendation is modified to account for P that was not removed by the crop. These recommendations have been used in the scenario analysis presented in the following section.

The use of inorganic fertiliser by farmers in the lowland rainfed environment has historically been low. Surveys by Villano and Pandey (1998) for the 1996 wet-season crop in Champasak and Saravan Provinces found that 66 per cent of households were using some chemical fertiliser and 48 per cent of the area was fertilised. Of those applying fertiliser, about 54 per cent did so to both the seedbed and the main field, 16 per cent only to the main field, and 30 per cent only to the seedbed.

The use of small amounts inorganic fertiliser had expanded to around 80 per cent of surveyed households in 2010. A range of fertility management strategies was used, including only applying fertiliser to seedlings and various combinations of basal applications and topdressing (Figure 7). Only around 18 per cent of households were applying fertiliser to seedlings plus a basal application to the main field, followed by a topdressing. Most households not using inorganic fertiliser were from the two villages in Phin District, Savannakhet. However, the reasons for not using fertiliser were very different between the two villages. The average wet-season yields in Khamsa-e were the highest across the Savannakhet survey, with households growing longer-duration varieties due to favourable conditions. Farmers reported that they did not use fertiliser because the land was still fertile, hence additional (purchased) nutrients were not required. Some households reported that they had experimented with fertiliser in the past but had problems with lodging. On the other hand, Geangxai had the lowest average yields of the survey, with almost no household producing a surplus crop in 2010. Farmers in this village had frequent problems with drought as well as lower cash incomes compared to Khamsa-e. In Champasak the lowest rate of adoption was in the relatively remote village of None Phajao. Similar to Geangxai, this village had some of the lowest rice yields in the survey.

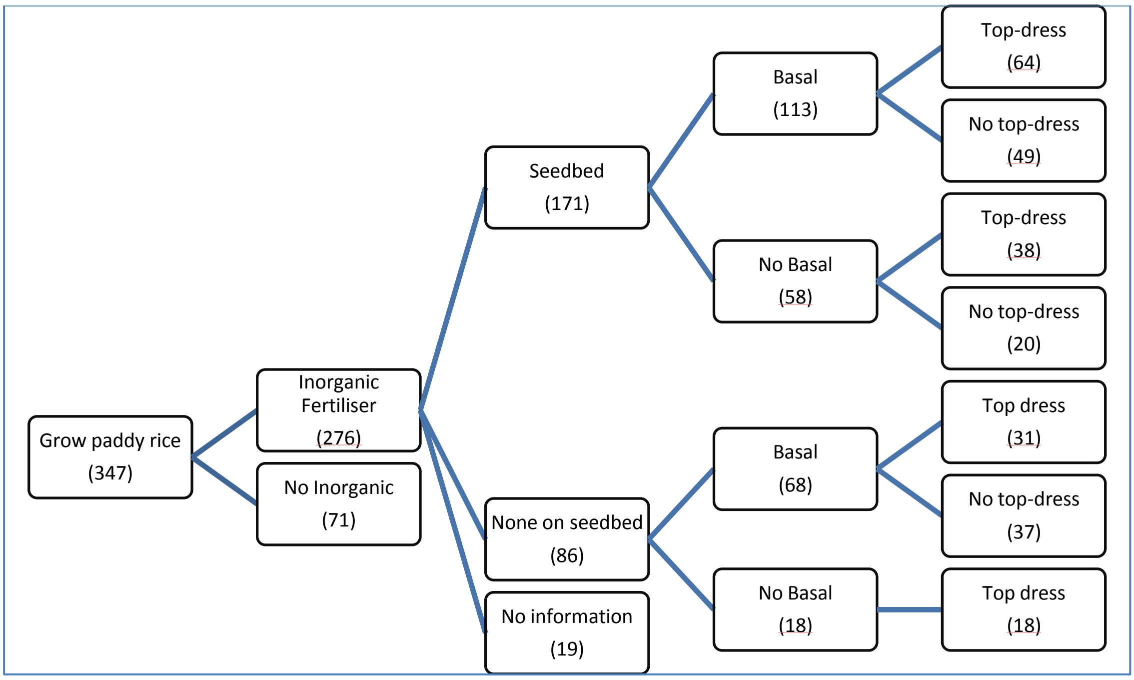

Figure 7 – Use of inorganic fertiliser by survey households growing paddy rice in Savannakhet and Champasak, 2010 (n=347)

While the percentage of households using inorganic fertiliser has increased significantly, the level of use remains well below recommended rates. The limited use of fertiliser reflects both the high cost of purchasing inputs, the limited access to credit, the high level of production risk, and market uncertainty should a surplus be produced. Physical access, counterfeit products, and limited knowledge about appropriate rates and timing contribute to the problems. Table 3 presents the average N-P_2O_5-K_2O rates for each village. The overall average of 15-12-2 kg/ha of N-P_2O_5-K_2O converts to 15-5-1.5 kg/ha of NPK – well below the conservative recommendation developed by Linquist and Sengxua (2001) of 60-[8/26]-25 kg/ha NPK, with the P rate varying according to soil texture.

The distribution of N rates varied with size of paddy (Figure 8). While households with less than 1 ha were less likely to be using inorganic fertiliser, if they did use it they were likely to apply more kilograms of N per hectare than those with larger areas. It should be noted that these average amounts assume that farmers spread the fertiliser equally across their paddy fields. In practice, farmers tend to vary their application rates based on previous crop performance and perceived risk. Figure 8 suggests that households with larger areas required less fertiliser to meet self-sufficiency and lacked the economic incentive to lift production further, and/or that households had a limited budget for fertiliser purchases.

Table 3 – Average nutrient application rate by village (kg/ha)

District/Village	Average applied N (kg/ha)	Average applied P_2O_5 (kg/ha)	Average applied K_2O (kg/ha)
Outomphone	**10.2**	**8.9**	**1.8**
Nagasor	13.1	10.6	2.2
Phonegnanang	7.5	7.2	1.4
Phalanxai	**14.4**	**13.0**	**1.1**
Phanomxai	18.2	17.4	2.1
Phontan	10.9	8.9	0.2
Phin	**9.5**	**6.9**	**0.0**
GeangXai	10.0	6.4	0.0
Khamsa-e	7.3	9.2	0.0
Phonethong	**21.1**	**10.5**	**3.2**
None Phajao	5.8	5.5	1.7
Oupalath	27.4	13.6	3.1
Phaling	20.8	9.5	3.8
Soukhuma	**15.9**	**15.3**	**1.7**
Boungkeo	21.8	22.5	2.5
Hieng	7.1	8.1	0.1
Khoke Nongbua	17.0	13.3	2.3
Average	**15.3**	**11.8**	**1.9**

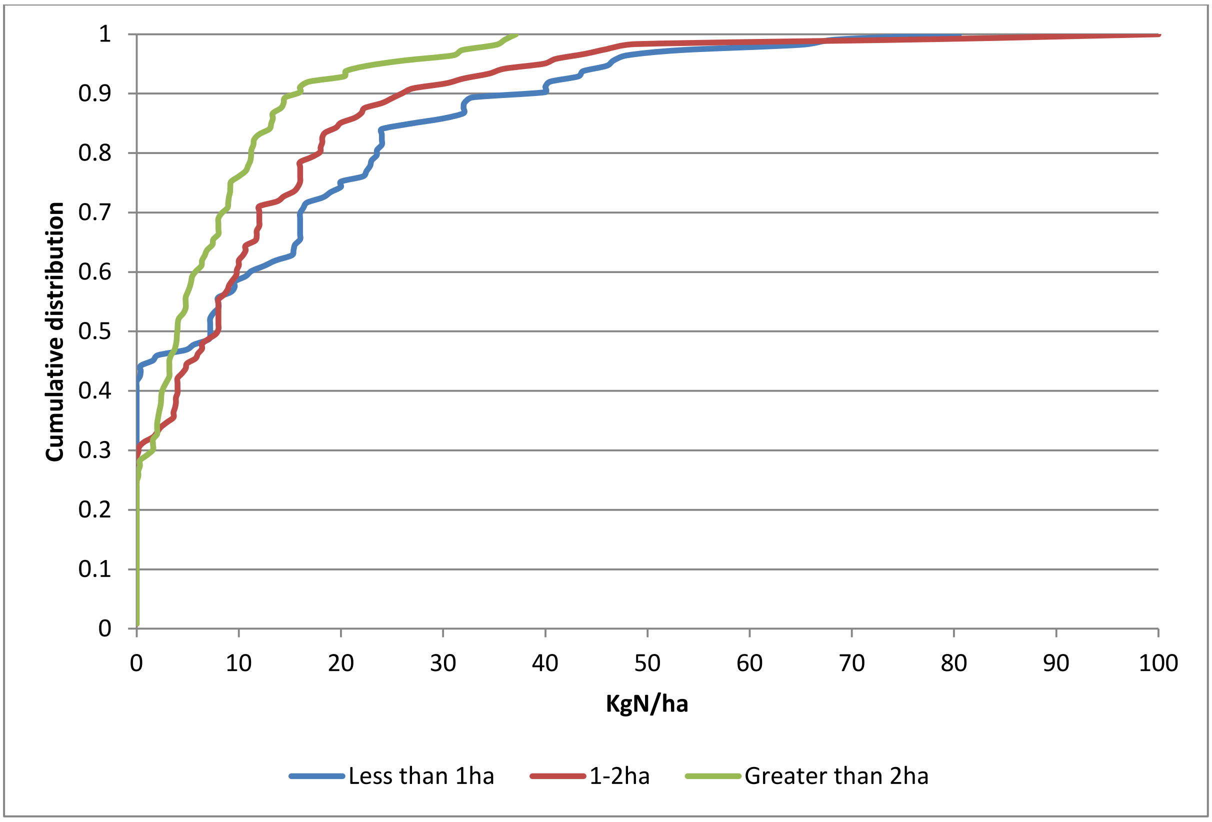

Figure 8 – Cumulative distribution of N application rate by paddy area

The Economics of Fertiliser Use for Rainfed Rice

To help understand the adoption patterns of fertiliser, some enterprise budgeting scenarios were developed based on household survey data and field experimental results. These representative budgets are first developed using average values for prices and yields, then sensitivity and risk analyses are applied. A range of indicators are used in an attempt to capture the criteria for farm-household decision-making with regard to input use, including net returns to land (NR), with imputed costs for household labour deducted; net returns to household resources (NRHR), with no costing of household labour or land; and net returns to household resources per day of household labour (NRHL). Marginal net returns to incremental changes in fertiliser use are also examined against different thresholds. The four scenarios are outlined below.

The fertiliser-yield scenarios

Scenario 1 (No-Input) – Yield estimates are based largely on experimental results in which no inorganic fertiliser is added to the transplant crop. The household survey suggests that this represents around 30 per cent of households. Both survey and experimental results show wide variation in the yields obtained where no inorganic fertiliser is used due to factors such as the indigenous soil fertility, soil-water balance properties, and other management practices. An average yield of 1.5 t/ha has been assumed for current purposes.

Scenario 2 (Low-Input) – This is based on the current low-input system that many households adopt. It assumes again that households use inorganic fertiliser to establish seedlings but then apply 1 bag (50 kg) of 16-20-0 as a basal application, followed by a topdressing of 1 bag of urea. This results in a rate of 31-10-0 kg/ha of N-P_2O_2-K_2O. An average paddy yield of 2 t/ha has been estimated.

Scenario 3 (**Medium-Input**) – This has been developed using the current broad recommendation of 60-30-30 kg/ha of N-P_2O_2-K_2O (or 60-13-25 kg/ha of NPK). This is applied through a basal application of 15-15-15 (200 kg/ha) with the remaining N coming via topdressing with urea. The yield assumption is based on adjusted experimental results (allowing for the well-known yield loss when moving from small to large plots). Again, experimental results have shown a range of responses to applied nutrients according to location. An average yield of 3t/ha has been assumed.

Scenario 4 (High-Input) – This is based on ongoing experimental work in the two provinces where a high rate is used in an attempt to achieve the Government target yield of 4 t/ha. The current trials have site-specific application rates with no replications and therefore it has been necessary to develop an average treatment with a rate of NPK of 120-60-60 kg/ha, resulting in a yield of 3.5 t/ha, based on experimental results from the 2011 wet season. This yield estimate will be revised once 2012 data become available.

Other key assumptions are presented in Table 4, including the values used for sensitivity analysis. Rather than conduct sensitivity analysis on the farm-gate price of paddy, threshold analysis has been conducted. The labour required for each scenario is only varied for harvesting, which is related to crop yield. The variation in labour for fertiliser application is minor.

Table 4 – Assumptions for scenario budgets

Parameter	Base assumption	Sensitivity analysis
Farm gate price	2,000 kip/kg	*Threshold analysis*
Fertiliser price		
- 16-20-0	230,000 kip/bag	250,000 kip/sack
- 46-0-0	220,000 kip/bag	220,000 kip/sack
- 15-15-15	250,000 kip/bag	300,000 kip/sack
Wage rate	30,000 kip/day	50,000 kip/day

1 AUD = 8,000 LAK

Results of enterprise budgeting

All four scenarios confirm the marginal nature of rice farming in the rainfed lowlands of Laos, and the challenge facing farmers and government alike (Table 5). The total cost includes all physical inputs and labour (but not land), with shadow values used for non-cash costs. Net returns (NR) result when total cost is subtracted from gross returns (GR), with all labour (household and hired) valued at the assumed shadow value of 30,000 kip/day. For the No-Input and Low-Input scenarios, this results in a negative NR. The same result can be seen with the net returns to household resources (NRHR), which does not deduct household labour costs. When calculated as a ratio to household labour, the net returns to household labour (NRHL) are below the shadow wage rate of 30,000 kip/day. That is, while there are positive returns to household-owned resources (land, labour, durable capital), these are not sufficient to provide a return greater than the opportunity cost of household labour. Nevertheless, there is a positive marginal benefit to moving from the No-Input to the Low-Input scenario, with a marginal rate of return (MRR) of 50% on incremental investment (including household labour). The Medium-Input scenario provides a positive NR per hectare and a NRHL marginally above the shadow value. Moving from the Low- to the Medium-Input scenario provides a MRR of 84%. However, a further movement to the High-Input scenario sees the NR to land and labour both fall, although the NRHL remains just above 30,000 kip/day.

Table 5 – Economic analysis of performance of fertiliser-input scenarios

	No Input	Low Input	Medium Input	High Input
Fertiliser applied (kg/ha of N-P_2O_2-K_2O)	0-0-0	31-10-0	60-30-30	120-60-60
Average yield (t/ha)	1.5	2	3.0	3.75
Gross returns (AUD/ha)	375	500	750	938
Total cost (AUD/ha)	454	538	673	874
Net returns (AUD/ha)	-79	-38	77	63
Net returns to household resources (AUD/ha)	294	356	512	529
Net returns per day of household labour (LAK/day)	23,618	27,143	35,293	34,068
Marginal net benefits (AUD/ha)		42	114	-14
Marginal rate of return (%)		50%	84%	-7%
Threshold P_r for positive NR (LAK/kg)	2,476	2,166	1,785	1,858
Threshold P_r for positive MNB (LAK/kg)		1,172	1,121	2,152
Threshold P_r for MRR>100% (LAK/kg)		2,733	2,159	4,543

Labour cost 30,000 kip/day; paddy price (P_r) of 2,000 LAK/kg; 1 AUD = LAK 8,000

Threshold analysis was conducted on the farm-gate price of paddy rice (P_r) to determine at what price (a) the NR would become positive, (b) there would be a positive MRR from moving to the next scenario, and (c) the MRR would be greater than 100%. The results, shown in the last three lines of Table 5, indicate that, unless the paddy price increases to above 2,166 kip/kg, the NR for a Low-Input system will remain negative, but as long as the price is above 1,172 kip/kg there is still some gain relative to applying no fertiliser at all. The threshold prices for realising positive returns to the Medium- and High-Input scenarios were in the achievable range, but the price would have to be very high indeed (>4,500 kip/kg) for the move from Medium-Input to High-Input to offer an acceptable rate of return.

The price of fertiliser varied between locations, particularly for composite fertiliser such as 16-20-0 and 15-15-15 in more remote areas. The impact of higher assumed prices (9 and 20 per cent, respectively) on the economic indicators can be seen in Table 6. The increase in prices reduces the NR, although the Medium- and High-Input cases remain slightly positive. Increased fertiliser costs also reduce the NRHL so that the Medium- and High-Input scenarios are barely above the shadow wage.

Similarly, wage rates varied across the study sites and had reached 50,000 kip/day in many areas. Rising wage rates do not impact on the NRHR if only household labour is utilised, but NRHL may fall below the higher shadow value, which is the case here (Table 6). Hence all scenarios experience a negative NR per ha. This further highlights the marginal nature of rainfed lowland rice production and the difficulties in maintaining a viable commercialisation pathway for households, given the economic environment.

Table 6 - Sensitivity analysis of fertiliser costs and wage rates

	No Input	Low Input	Medium Input	High Input
Increased composite fertiliser price (see Table 4)				
Net returns (AUD/ha)	-79	-40	52	13
Net returns to household resources (AUD/ha)	294	354	487	479
Net returns per day of household labour (LAK/day)	23,618	26,952	33,569	30,849
Marginal rate of return (%)		46%	58%	-17%
Increase in labour cost to 50,000 kip				
Net returns (AUD/ha)	-328	-300	-213	-247

Given these results, what strategy would a farm-household be advised to take? A move from the No-Input to Low-Input scenario improves the net return to land and labour, despite net returns remaining negative. However, the MRR of the change is only 50 per cent. Previous studies (CIMMYT 1988) have suggested a MRR of at least 100 per cent is required before adoption is likely, although 50 per cent may be sufficient for relatively small system changes. Assuming household self-sufficiency is an important objective, the small amount of fertiliser may push some households with smaller areas of paddy above the subsistence requirement, with returns to labour and capital considered secondary objectives. For example, an average No-Input household with 1.2 ha could move from being 75 per cent self-sufficient, with an output of 1,800 kg, to 100 per cent self-sufficient, with an output of 2,400 kg, by adopting the Low-Input package (Figure 9).

A move from the Low-Input scenario to the Medium-Input scenario provides a positive NR per hectare and a NRHL above the shadow wage. Even allowing for an increased price of fertiliser, this outcome held. The move provides a MRR of 84 per cent (or a 71 per cent return if the Low-Input strategy is considered dominated and removed). The threshold analysis on paddy price suggest that this scenario is likely to provide positive NR and MNB for most price scenarios, and a small increase in the price would deliver a MRR greater than the CIMMYT rule-of-thumb.

It is very unlikely that a household would adopt the High-Input scenario, given that returns to both land and labour decline compared to the Medium-Input case. Nevertheless, a land-scarce household may be forced to adopt this strategy if achieving household self-sufficiency remains the dominant objective, given that the returns to labour remain above the shadow wage. For example, consider a Medium-Input household with less than 0.8 ha in

Figure 9. However, it is unlikely that such a household would have the capital to make the necessary investment.

Given that labour use does not greatly increase with increased fertiliser application, rising wage rates are not predicted to impact on the wet-season decision greatly. On the other hand, for households with access to irrigation water that enables cultivation of a dry-season crop, the question becomes of greater importance, given that self-sufficiency may be achieved in the wet season, allowing labour to move off-farm and earn relatively higher returns in the dry season. Several case-study farmers were making this decision and not growing a second crop; rather they made their irrigable land available to households with smaller paddy areas who had not yet achieved self-sufficiency in the wet season.

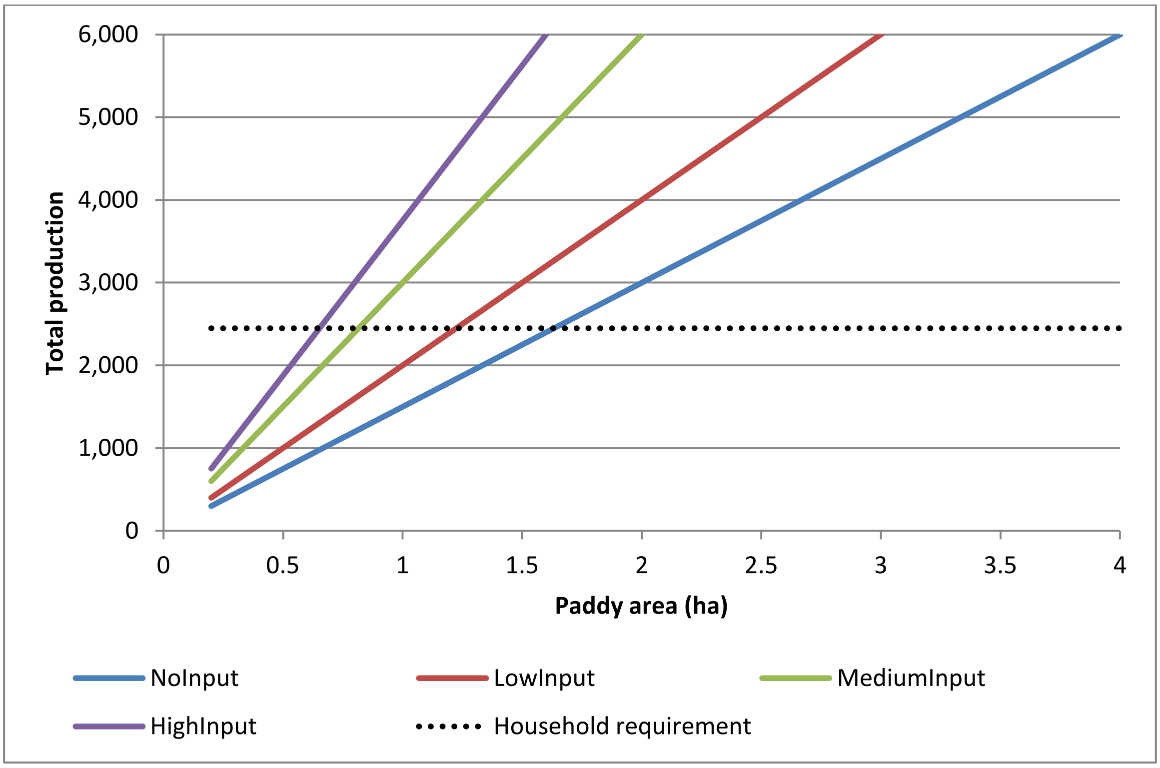

Figure 9 – Total production for each input scenario by paddy area

Risk analysis of fertiliser-yield scenarios

The results of the enterprise budgeting and sensitivity analysis suggest that households would be willing to adopt the Medium-Input scenario, provided they are satisfied with a return on additional working capital between 50 and 100 per cent. However, this analysis is based on averages that ignore both production and market risk, both of which are vital considerations in the rainfed lowlands. Risk analysis was conducted to assess the stability of the results to fluctuating paddy prices and uncertain grain yields.

The paddy price in recent years has fluctuated widely in response to supply shocks brought about by floods and droughts, and by demand shocks, transmitted from elsewhere in the Mekong region. Both these shocks have been exacerbated by policies aimed at securing national or regional food supplies through various ad hoc trade restrictions. The monthly price of paddy for the past five years is presented in Figure 10. This includes the nominal prices recorded in Savannakhet and Champasak and real prices computed in December 2012 values, averaged between the provinces and over the five-year period. Both the peak in 2010 and the low points in 2011-12 can be attributed to local and regional production failures and various government responses.

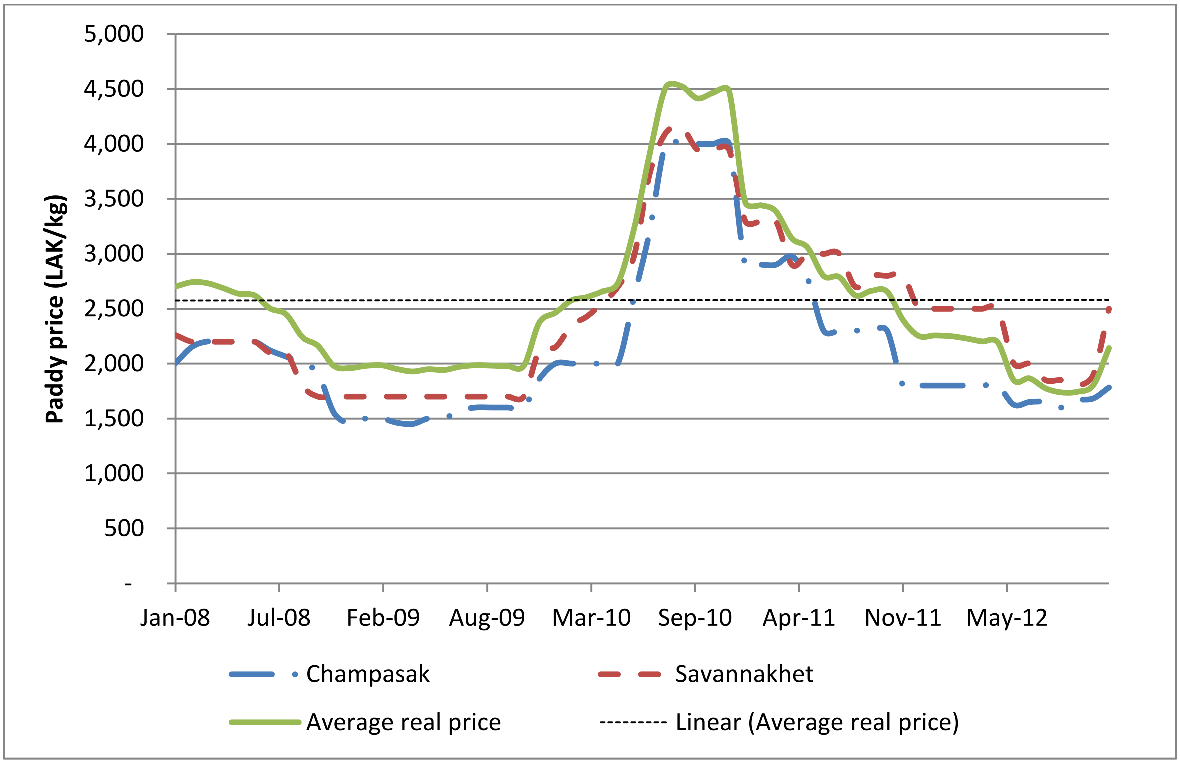

Figure 10 – Nominal and real paddy prices (at mill) in Savannakhet and Champasak, 2008-2012

For the risk analysis, triangular distributions were created for both the grain yields from each scenario and the paddy price, requiring estimates of minimum, most likely, and maximum values (Table 7). Two sets of maximum values were used for yield, following advice from a locally-based IRRI agronomist who felt the first estimates were too high. The cumulative distributions for grain yields are presented in Appendix 1. It should be noted that the prices used in Table 7 have been deflated from the mill prices in Figure 10 to reflect the farm-gate price. With regard to fertiliser prices, low-price and high-price assumptions were tested. The model budgets including the stochastic variables for price and yield were run using @Risk to determine the probability of important criteria being satisfied.

The results of the first version of the risk analysis, assuming higher maximum yield values and lower fertiliser prices, are presented in Table 8. On average, the Low-Input scenario gave the highest NR per ha, followed closely by the Medium-Input scenario. The Medium-Input scenario gave the highest NRHR. The probability of important criteria being met was assessed, including the probability that:

- NRHR is positive
- NR per ha is positive
- NRHL is greater than 30,000 kip/day (shadow value)
- NRHL is greater than 50,000 kip/day (current maximum)

- MNB is positive
- MRR is greater than 100%
- MRR is greater than 50%

Table 7 – Values for triangular distributions

	Rice yield (kg/ha)				Paddy price
	No Input (0-0-0)	Low Input (31-10-0)	Medium Input (60-30-30)*	High Input (120-60-60)	(LAK/kg)
Minimum value	200	200	200	200	1,500
Most likely value	1,400	2,000	2,500	3,500	1,800
Maximum value (1)	4,000	4,500	5,000	5,500	3,500
Maximum value (2)	3,000	4,000	4,500	5,000	-

* Current recommendation

Table 8 – Risk assessment of fertiliser-yield scenarios (Version 1)*

	No Input (0-0-0)	Low Input (31-10-0)	Medium Input (60-30-30)	High Input (120-0-0)
Mean net returns (AUD/ha)	48	76	73	27
Mean NRHR (AUD/ha)	436	479	490	464
	Probability of occurrence (%)			
NRHR>0	≈100	99	97	91
NR>0 (%) NRHL>30,000	53	59	56	51
NRHL>50,000	13	17	19	17
MNB >0 (%)		54	48	45
MRR > 100%		29	23	8
MRR >50%		35	29	14

* Version 1 uses the higher maximum yields in Table 7 and the lower estimate of fertiliser prices.

Across the scenarios, the probability that NRHR was positive was between 90 and 100 per cent, with yields high enough to at least pay for cash costs (fertiliser, fuel, and seed). However, the probability that the NRHL was above 30,000 kip/day (equivalent to a positive NR, given that labour is valued at the same rate) ranged between 51 and 59 per cent. That is, discounting self-sufficiency objectives, growing rice in all scenarios was only better than wage-earning in around 60 per cent of the iterations. If the higher wage rate (50,000 kip/day) is considered, this falls to less than 20 per cent. In only 54 per cent of the iterations was there a positive marginal benefit (MNB>0) in moving from the No-Input to the Low-Input scenario. Similarly, it was beneficial to move further to the Medium-Input scenario less than half the time. This suggests that, if households can achieve self-sufficiency, they may be willing to accept lower average returns to avoid the risk of losing out on investing in higher input levels. However, as remarked above, some households with less paddy land may have little choice but to apply fertiliser up to the point that they can achieve self-sufficiency, provided the returns to labour do not fall too far below the shadow wage.

The cumulative distributions of the returns to household labour for each scenario are presented in Figure 11. This shows that the Low- and Medium-Input scenarios display first-degree stochastic dominance over the High-Input scenario, while the No-Input scenario displays second-order stochastic dominance (that is, assuming risk aversion) over the High-Input scenario (Anderson et al. 1977). In other words, the High-Input scenario does not stand up in the risky environment of the rainfed lowlands.

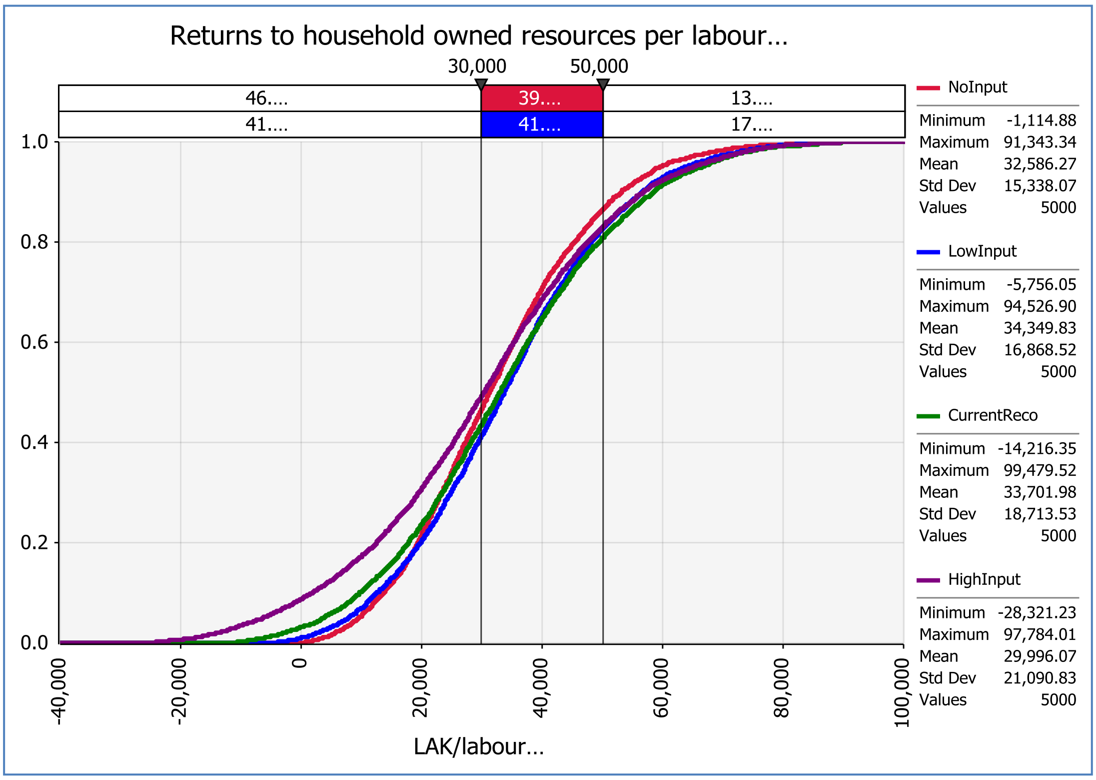

Figure 11 – Cumulative distribution of NRHL for fertiliser-yield scenarios (Version 1)

The risk analysis was repeated (Version 2) using (2a) the higher price assumption for compound fertiliser, (2b) the lower maximum values for yield, and (2c) a combination of higher fertiliser prices and lower maximum yield (Table 9). The results confirm that higher prices for compound fertiliser further limit the incentive to go beyond a Low-Input system. A lower maximum yield reduces the average yield of each scenario but does not change their ranking, the Low-Input system providing higher average net returns and a higher probability of meeting the key criteria. When both these changes are combined (Version 2c), the risk of failing to meet the key criteria is increased in all cases, except that the probability of achieving a positive marginal return from moving from the No-Input to the Low-Input scenario increases slightly from 54 to 61 per cent. In all cases the High-Input system provides no attraction to farmers, giving a negative average net return and a lower probability of achieving the key criteria. The impact of both higher fertiliser prices and a lower maximum yield on NRHL is shown in Figure 12. This figure again shows that the Low- and Medium-Input scenarios display clear first-degree stochastic dominance over the High-

Input scenario, and the No-Input scenario displays second-degree stochastic dominance over the High-Input scenario.

Table 9 – Risk assessment of fertiliser-yield scenarios (Version 2)

	No Input (0-0-0)	Low Input (31-10-0)	Medium Input (60-30-30)	High Input (120-60-60)
(2a) Higher price for compound fertiliser				
Average net returns (USD/ha)	49	74	48	-24
	Probability of occurrence (%)			
NR>0 (%)	53	57	53	44
NRHL>30,000				
NRHL>50,000	13	17	17	14
MNB >0 (%)		53	46	41
(2b) Lower maximum yield in triangle distribution				
Average net returns (USD/ha)	-28	38	35	-11
	Probability of occurrence (%)			
NR>0 (%)	38	52	52	45
NRHL>30,000				
NRHL>50,000	4	13	15	13
MNB >0 (%)		61	49	44
(2c) Higher price of fertiliser and lower maximum yield				
Average net returns (USD/ha)	-27	36	10	-61
	Probability of occurrence (%)			
NR>0 (%)	38	52	47	38
NRHL>30,000				
NRHL>50,000	5	13	12	11
MNB >0 (%)		61	46	42

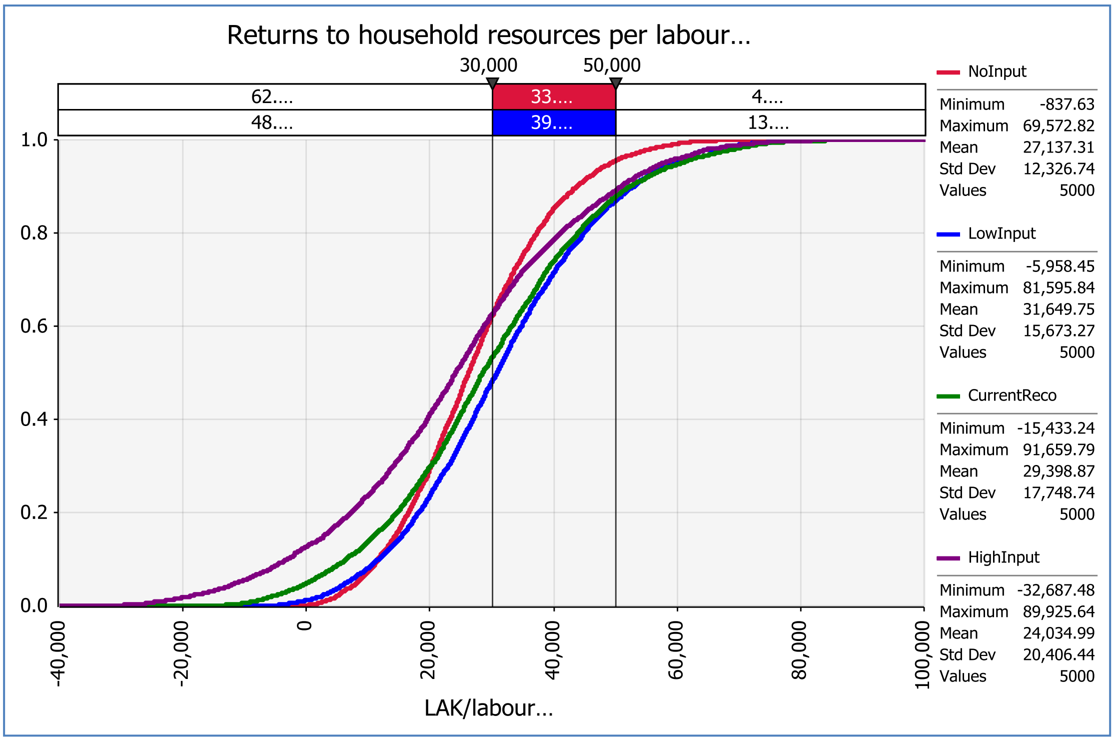

Figure 12 – Cumulative distribution of NRHL for fertiliser-yield scenarios (Version 2)

Conclusion

The survey evidence from central and southern Laos shows that households in the rainfed lowlands continue to manage rice production systems that are largely subsistence-oriented. The adoption of new technologies has been important in helping households meet self-sufficiency objectives and has enabled some to produce a small surplus. Despite this, rice production remains an economically marginal activity that is under increasing pressure from rising costs, particularly for labour. Rural livelihoods in the study area have become increasingly diversified, with households allocating labour to a range of alternative farm and non-farm activities. However, paddy rice production continues to be the platform on which these other livelihood activities are based. The development and adoption of technologies that enable households to achieve self-sufficiency in a labour-efficient manner are important to improving household welfare in this context.

The budget models show that, given their resource endowments and the high degree of production and market risk they encounter, households in the rainfed lowlands have been rational in adopting a low-input system rather than intensifying rice production to achieve government yield and production targets. As the costs of labour continue to increase, technologies that improve labour productivity and enable labour to move off-farm are likely to be adopted more readily than technologies that seek to intensify production. In the same way, the development and adoption of improved varieties that are well adapted to abiotic and biotic stresses and reduce risk in specific environments can potentially improve the profitability and stability of the lowland farming system. Moreover, it has long been argued that improving the efficiency of fertiliser application through site-specific recommendations is more important than increasing absolute fertiliser rates. While the improvements in profitability that these technologies bring may induce some intensification, we argue that the strategy of diversifying livelihoods while maintaining a largely subsistence-oriented rice production system is likely to persist, given the current economic trends. While this may not help lift rice production to reach national targets, it is likely to improve the livelihood outcomes of the numerous households living in this marginal environment.

Acknowledgements

This project was funded by the Australian Centre for International Agricultural Research (ACIAR). The household surveys were conducted by staff and students from the National University of Laos, staff from the National Agriculture and Forestry Research Institute, and staff from the Provincial Agricultural and Forestry Offices of Savannakhet and Champasak. We are grateful for the comments of Ben Samson (IRRI) on the fertiliser scenarios.

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Appendix 1 – Cumulative distribution of grain yields