ACIAR's Contribution to Lowland Rice Technologies in Laos

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Abstract

The lowland rice industry in Laos experiences dry conditions regularly. Rice producers also face rising labour costs as the Lao economy grows. Much of the crop is consumed by the farm households who grew it. Between 1997 and 2012 ACIAR co-funded a set of three projects with the main outcomes being the development of rice varieties more tolerant of dry conditions and direct seeding technologies to replace traditional hand transplanting. Human capacity and scientific knowledge were other significant outcomes from the projects. Direct seeding allowed the release of family labour for other on- and off- farm and household activities.

Assessing ACIAR's contribution to the economic and social impacts from this set of projects was difficult because of the length of time since the projects began, because of the lack of data about the adoption of the technologies and because the University team funded by ACIAR were not the only research team working on these technologies.

We focussed on estimating the economic impact of the two technologies applying welfare analysis in a farm level market model of the Lao rice industry and on describing gains in scientific capacity and knowledge. Potential social impacts from the releasing labour from transplanting were also described. Given the uncertainties created by inadequate data, care was taken to develop plausible causal pathways between project research activities and economic and social outcomes.

The present value in 2017 of the investment in the three projects by ACIAR and partners was estimated to be $A14.1m (all monetary values in 2017 $AUD and applying ACIAR's 5% discount rate). The present values in 2017 of the streams of measurable benefits from the adoption of more drought tolerant varieties and direct seeding technology were $A18.5m and $A44.1m respectively, for a total of $A62.6m. The net present value of these streams of benefits and costs in 2017 was $A48.5m. The benefit cost ratio was 4.44:1 and the internal rate of return was 16.0%. The modified internal rate of return, MIRR was 11.5% assuming that the net benefit stream can be reinvested through the life of the investment at a rate of 5%.

By these three measures the set of three projects, whose impact has been assessed here, are likely to have been a good investment from ACIAR's perspective. This conclusion is quite robust to the uncertainty surrounding our assumption about the rates of adoption of the technologies and the share of benefits from the two technologies attributable to the ACIAR projects. If both these parameters are halved (approximately) for both technologies, an unlikely scenario in our view, the investment in the projects still earns the required rate of return.

Keywords

Impact assessment, lowland rice in Laos, drought tolerant rice, direct seeding of rice

Introduction

Rice, a staple crop for the people of Laos, is grown on a semi subsistence basis by over 700,000 families (World Bank 2012). The great majority of rice production in Laos occurs in rainfed lowlands in the wet season (Schiller et al 2006). Production during the wet season in lowland systems accounts for around 80% (630,000 ha) of total paddy production. Irrigated dry season production has increased to almost 15% (100,000 ha) and upland production consequently has declined to about 8% to total paddy production. In the dry season non-irrigated land is used for low intensity livestock production. Most rice is glutinous. Two persistent problems faced by lowland rice growers in recent decades have been regular dry periods early in the growing season and rising labour costs as the Lao economy has grown.

Droughts and floods are a characteristic of lowland farming systems in Laos. Shiller *et al.* (2006) noted that ‘in the 37-year period from 1966 to 2002, for every year, at least part of the country was affected by either drought or flood, or a combination of both’. Such climatic variability influences many crop management choices by farmers. It motivated the direction of the ACIAR research program towards developing and promoting varieties of rice that were more resistant to drought than the varieties that were available.

Rice has traditionally been transplanted by hand from nurseries to paddies. It is very labour intensive. Labour costs have been rising quickly in recent decades as the Lao economy has grown. While labour saving is a dominant attraction of direct seeding, this technology also gives farmers some flexibility in sowing decisions at a time when rainfall is uncertain.

ACIAR has co-funded a series of research projects led by Professor Shu Fukai, University of Queensland and colleagues in Laos with the aim of developing technologies that ameliorate these problems. The research teams bred rice varieties with shorter growing seasons more tolerant of dry conditions and adapted labour-saving direct seeding technologies to rice production in Laos.

Each year ACIAR commissions impact assessments of a number of past research programs. We were commissioned to assess the impact of a set of three projects led by Professor Fukai between 1996 and 2012 (Mullen et al., 2019). In addition to drought tolerant varieties and direct seeding technology the projects made significant contributions to scientific knowledge and human scientific capacity.

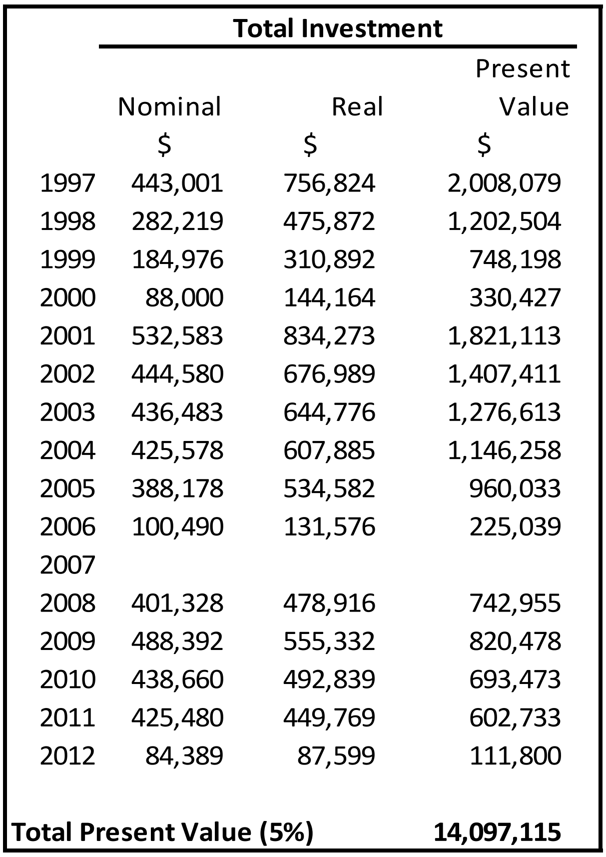
Investment by ACIAR and Partners

The most important source of data on investment by ACIAR and partners in the set of projects being assessed is the budget data maintained by ACIAR. In principle these data allow the total investment by all partners to be estimated and also the investment by ACIAR itself and can be used in estimating returns to investment.

The quality of the data in practice is sometimes deficient. The basis of estimating in-kind contributions from Australian collaborators and overseas partner institutions is usually quite subjective. ACIAR impact assessments typically do not have the resources to address this issue. In earlier projects ACIAR did not collect information on the contributions from Australian and partner country institutions. Again, this issue is difficult to resolve.

Historical investment data expressed in nominal Australian dollars were converted to real terms using the Australian GDP deflator based on 2017, and then compounded forward to 2017 at a 5% discount rate[1].

Using these methods, we estimated that the total investment in the three projects (1995/100, 1999/48 and 2006/41) to be $A14.1m in 2017 (Table 1). No estimates were available for the contributions from Australian, Lao, Thai and Cambodian institutions for project 1995/100.



	Total Investment		
	Nominal $	Real $	Present Value $
1997	443,001	756,824	2,008,079
1998	282,219	475,872	1,202,504
1999	184,976	310,892	748,198
2000	88,000	144,164	330,427
2001	532,583	834,273	1,821,113
2002	444,580	676,989	1,407,411
2003	436,483	644,776	1,276,613
2004	425,578	607,885	1,146,258
2005	388,178	534,582	960,033
2006	100,490	131,576	225,039
2007			
2008	401,328	478,916	742,955
2009	488,392	555,332	820,478
2010	438,660	492,839	693,473
2011	425,480	449,769	602,733
2012	84,389	87,599	111,800
Total Present Value (5%)			**14,097,115**

Table 1: Present Value (5% compound) in 2017 of Investment by ACIAR and Partners

The Welfare Analysis Framework

ACIAR generally requires that impact assessments are based on traditional principles of welfare analysis as described in Davis et al. (2008). The main principles can be distilled from a market model (Figure 1).

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[1] Net economic gains from the technologies prior to 2017were similarly expressed in real terms and compounded forward and projected future gains (and investments to secure these gains) were discounted back to 2017.

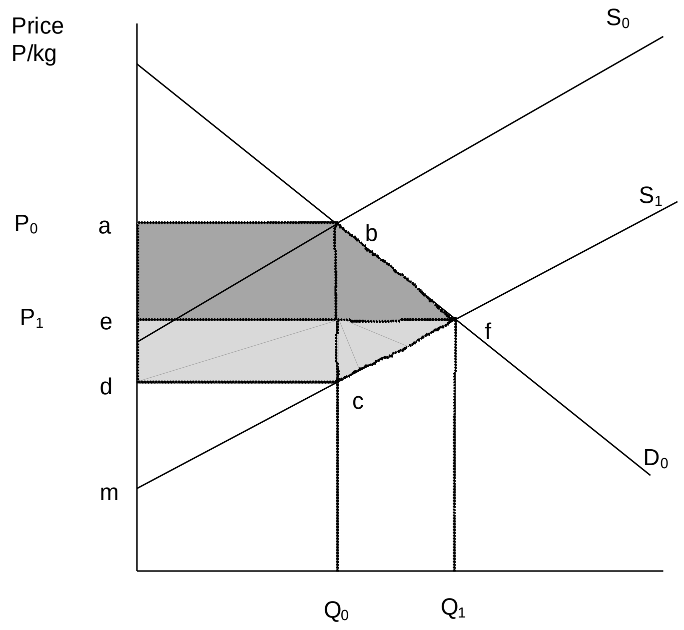

Figure 1: Approximating the impact of new technology

The change in economic welfare (or economic surplus) from a technology that lowers the unit cost of production by *bc* in Figure 1, the K – shift, is given by the sum of the two grey shaded areas where the darker area is the gains to consumers, CS, and the lighter area is the gain to producers, PS. The change in total economic surplus, TS, can be estimated as:

1. Δ TS = Δ CS + Δ PS

$$= Po*Qo*k(1 + 0.5*Z*n) \text{ where } Z = ke/(e+n)$$

and where P_0 and Q_0 are industry price and quantity at the farm gate before the introduction of the technology, e and n are the elasticities of demand and supply, and $k = K/P_0$. The new technology shifts the supply curve to the right from S_0 to S_1 and the new industry equilibrium position is a price of P_1 and output of Q_1. The elasticities of demand and supply have little impact on the size of total welfare gains but are critical to how these gains are shared. When supply is less elastic than demand, often the case in the short term, then producers capture a larger share of the total benefits.

Note that in this simple model the impact of research in terms of a supply shift is both contemporaneous and the technology is fully adopted across the industry (or that part of the industry to which the technology pertains). To estimate benefits through time, the lag between research activities and the availability to farmers of the new technology, and the rate and extent of adoption of the technology must be projected to allow welfare changes over the life of the technology to be estimated, and the usual techniques of financial analysis applied.[2]

The assumption that the technology causes a parallel shift in supply is a crucial one. A parallel shift means that the cost savings are *bc* per kg for all levels of production. It means

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[2] Up to when the impact assessment was undertaken actual adoption data can be used.

that producers can never be worse off from adopting this technology. Even if the supply curve is flat (or the demand curve perfectly inelastic) producers can't be worse off. If there is a group of producers who don't adopt the technology, then they could be worse off because of the lower price.

The market in which the technology is modelled determines who is classed as a consumer and who is a producer. In this example, the market is for rice at the farm gate and the technology is a farm level technology. Here producer surplus accrues to the rice grower and any input supplier he uses. Here consumer surplus accrues to all downstream of the farm gate including rice wholesalers and processors and the ultimate consumers of rice products.

There is now extensive literature describing how these welfare gains from research induced new technologies can be estimated. Detailed general expositions can be found in Alston (1991) and Alston, Norton and Pardey (1998).

A key step in any impact assessment is to develop plausible scenarios about how the industry would have developed 'with ACIAR projects' and 'without ACIAR projects'. It is easy to overestimate the benefits from a research project if the baseline 'without' project scenario is that the industry does not change. Yields and adoption evolve whether the project is undertaken or not.

Impact assessments have ex ante and ex post components. We have chosen to conduct the analysis from a 2017 perspective and so the ex post component extends back to 1997 and the ex ante component projects a stream of net benefits forward to 2026 (when we judged the benefits from the technologies to have ceased). This is different from much investment analysis which only has an ex ante perspective. In this analysis, monetary values are expressed in 2017 terms. Revenue and costs accruing before 2017 are compounded forward and those after 2017 are discounted back at a rate of 5% (the rate used in ACIAR impact assessments) allowing estimation of project performance criteria such as net present value, benefit cost ratio, IRR and MIRR in 2017 terms. Here 1997 was the year when investment began. Criteria in 2017 terms can be expressed in 1997 terms by applying the discount factor for year 20[3].

For the ex post component, the 'with project' scenario is represented by the historical experience of the rice industry in Laos. The challenge is to develop a plausible scenario about how the industry would likely have developed were the ACIAR projects not undertaken. Looking forward, the impact of the technology in 2017 is the starting point for projections of the 'with project' scenario but a plausible 'without scenario' must be developed.

How outcomes will be measured

The information required to make assessments of possible impacts on farm household welfare came from consulting with rice cropping experts in Laos and the farmers with whom they work. As well, there was information from the scientists who have conducted the research. There were no published data on the areas of rice sown to different varieties for lowland Laos nor was there any comprehensive published data on the adoption of direct seeding. We have been transparent in our method, but our analysis is based on many judgments rather than empirical evidence.

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[3] Only the NPV changes with these different year perspectives

Elasticities of demand and supply are integral to estimating the welfare triangle *bcf* in Figure 1 and in determining how welfare gains are shared between producers and consumers. There are numerous estimates of these elasticities in the literature but little consensus about their values. Many estimates of supply elasticity are less than 0.5 which to us represents a very short run scenario where producers and the industry have limited capacity to increase production in response to new technology. We have assumed a supply elasticity of 1.5 representing a medium to long run adjustment period. Rice is still a staple food for the people of Laos especially for its semi-subsistence rice growers and so we have assumed a demand elasticity of 0.5. Under these demand and supply elasticities the largest share of the benefits from the new technologies flow through to consumers.

We have modelled the impact of the two technologies independently. The methods we used to estimate the K-shifts are described below

For both technologies we judged that the ACIAR projects advanced the time by which they became available to farmers. This assumption and those about adoption rates meant that the flow of benefits attributable to the ACIAR projects ceased by 2026.

To arrive at a flow of net benefits an adoption profile was developed for each technology and a judgement made about the share of benefits attributable to the ACIAR projects. When data on such key parameters are missing it is even more imperative to develop plausible though still subjective causal pathways between research activities and changes in production methods by farmers. It is important to gain insights into the contribution of the research team both to the development of the technology and to its adoption by farmers. It is also important to gather as much information about the adoption of the technologies as possible. Our judgements were based on our discussions with the Australian and Lao scientists involved in the projects and with farmer groups near research sites.

Drought Tolerant Varieties

Why the ACIAR Projects are likely to have been influential

From FAO data Mullen et al. (2019) estimated that rice yields in Laos have been growing at an annual compound rate of about 2.5%. The challenge in assessing the impact of the ACIAR projects was first to assess what share of this growth could be attributed to the adoption by farmers of more drought tolerant varieties and second to assess what share of the growth from these varieties could be attributed to the ACIAR projects under review.

Some components of the design of the ACIAR supported projects make it plausible that they have identified both more drought tolerant varieties and advanced the rate at which these better varieties have been adopted by Lao farmers. The Lao scientists were emphatic that it was not possible to take varieties bred in other countries and expect Lao farmers to be able to grow them successfully. Genetic material suitable to Laos had to be identified and bred in Laos to suit the varying conditions throughout Laos. Perhaps most significantly, as pointed out by the Director of the Laos Rice Research Centre, Fukai brought skills in agronomy and plant physiology that neatly complemented the plant breeding skills at the Rice Research Centre. A component of all the ACIAR projects was training and assistance to scientists in the breeding program at the Rice Research Centre in how to assess and identify better varieties using quantitative methods.

After discussions with project scientists and staff at the Rice Research Centre, Mullen et al. (2019) attributed 30% of the benefits from the newer varieties to the efforts of Professor Fukai and the ACIAR projects.

A closely allied component was an expansive set of farmer participatory variety selection (PVS) trials (described more fully in Mullen et al. (2019)). Over the course of the projects nearly 800 farmers in Vientiane, Savannakhet and Champasak provinces were involved in trialling rice varieties and identifying those which performed best in their environment. Farmers were given seed and a recommended rate of fertilizer was also supplied. The project team produced an extension bulletin of recommended varieties for the rice provinces in Laos for wet and dry seasons and for three positions in the toposequence.

Fukai et al. (2016, p 41) reported that 15 rice varieties suitable for lowland rice systems were identified by the project and were being used by Lao farmers. Some were better adapted to upper fields in the toposequence likely to be more drought prone. Three varieties – TDK13, VTE450-2 and TDK36 – were released officially. One of the most popular varieties, TDK11, was not developed by the project team but was one of the varieties tested and promoted in the PVS trials.

It seems highly likely that this PVS approach advanced the pace at which better varieties were made known to farmers and adopted by them. The spread of these better varieties was aided by the common practice among Lao farmers of swapping varieties with their neighbours (Fukai et al. 2016, p42).

Increment in yields and the consequent k-shift

Assessing rice yields in Laos is a most uncertain enterprise. The FAO data has the yield of rice across all of Laos exceeding 3 tonnes/ha since 2000 and exceeding 4 tonnes/ha since 2014. According to data from Provincial Agriculture and Forestry Office (PAFO) for 2016 the yield of lowland rainfed rice was 4.45 tonnes per ha and for dry season irrigated rice it was 5.11 tonnes per ha. These yields far exceed those reported by Fukai and his team from their trials which were often less than 3 tonnes per ha.

Some of the scientists we spoke with suggested yields closer to those reported in the official data although in one district a yield of 2 – 2.5 tonnes per ha was suggested. A farmer group in Vientiane Province with access to irrigation reported stable yields of 4.3 tonnes per ha in the wet season and 4.5 tonnes/ha in the dry season[4]. One farmer group near Savannakhet reported a yield of 2 t/ha and another, 4.3 t/ha in the wet season.

Mullen et al. (2019) assumed an average yield for lowland rainfed rice (wet season, WS) of 3 tonnes per hectare and a yield of 4 tonnes per hectare for irrigated dry season rice. One approach to assessing the impact of the improved varieties would have been to assess each variety separately based on the areas sown and yield gains across lowland Laos. Data to implement this approach were unavailable.

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[4] It is hard for farmers to report yields in tonnes/ha because of the small fields and surrounding bunds. The amount of rice is often measured as the number of sacks which vary in weight.

Recognising that the influence of the work by Fukai and his team on the breeding program in Laos extended beyond the four varieties he particularly identified, Mullen et al. (2019) applied a small yield gain to all lowland rice in assessing the impact of more drought tolerant varieties. Fukai et al. (2016, p.43) reported that the recommended trial varieties yielded 3-7% more than the standard varieties being used in low fertility fields higher in the toposequence. The new varieties had a shorter growing season (7 – 10 days) making them more drought tolerant. The gains in yield can be attributed to improved water use efficiency for these newer varieties.

Mullen et al. (2019) applied a relative yield gain from better varieties of 5% (the average of the range estimated by Fukai) to the official yield figures. The official yield series represents the ‘with better varieties’ scenario and the ‘without better varieties’ scenario was the official yield series discounted by 5%.

Mullen et al. (2019) converted this 5% yield gain into a k shift of 0.0333 (3.33%, the relative change in price) by dividing the yield gain by the elasticity of supply (1.5)[5]. It is very sensitive to the value of the supply elasticity.

Adoption of Better Varieties

There are two dimensions to adoption – the time profile of when adoption starts and finishes, and the level of adoption achieved. Mullen et al. (2019) chose 2008 as the year significant adoption began, soon after large scale PVS trials began.

The last of the three projects assessed by Mullen et al (2019) finished in 2011. Later projects undertaken by Fukai have focused on mechanization. No doubt he still interacts with the breeders at the Rice Research Centre but Mullen et al. (2019) assumed that the contribution to Laos yield gains by varieties to which Fukai contributed started to decline from 2016 and was exhausted by 2020, such that yields ‘with’ and ‘without’ the ACIAR projects were both 4.38 tonnes per ha. Heuristically, the contribution of Fukai and the ACIAR projects from the newer more drought tolerant rice varieties is the area between the solid (‘with’ scenario) and dashed (‘without’ scenario) graphs of yield in Figure 2.

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[5] The more usual approach of estimating the k shift as the change in variable costs relative to price is discussed in Mullen et al. (2019)

Figure 2: Rice Yield Under 'With' and 'Without New Varieties' Scenarios

The Level of Adoption

There are no published data on the plantings of rice in Laos by variety at a district or province level. Fukai et al. (2016, p.42) conducted limited surveys of adoption by farmers participating in their trials in Vientiane and Champasak provinces. Mullen et al (2019) have been unable to assess the adoption of the four 'ACIAR' varieties - TDK36, TDK13, VTE405-2 and TDK11 - in any consistent manner across the lowland rice areas of Laos. The best they could do was ask the scientists and farmers in Vientiane and Savannakhet provinces about the varieties that were being grown in their districts. On most but not all occasions, at least one of the 'project' varieties was identified as being grown in the area. TDK11 was mentioned most often and is likely grown in many districts in lowland Laos. It seems a highly versatile variety grown in wet and dry seasons throughout many areas. Other varieties were popular in a small number of districts either because of particular agro-climatic conditions or because their qualities made them attractive in particular markets.

Some PAFO staff responded to an informal survey about the proportion of crop sown to the 'ACIAR' varieties in their provinces in 2017 (Table 3). Little can be said from such a small sample of sources, but it is consistent with the perception about the ongoing popularity of TDK11. A significant proportion of the other three varieties was sown in at least one of the provinces which responded.

In the absence of data on production by variety Mullen et al. (2019) made a further judgment that after 2008, 10% of production in lowland Laos came from the 'ACIAR' varieties.

Province	**Area sown to 'ACIAR' Varieties (% of total area)**			
	TDK11	TDK36	VTE450-2	TDK13
		Pakcheng 1	Vientiane 2	
Vientiane	30	20	10	20
Borikhamxai	15	0	15	0
Champasak	2	0	1.5	0
Khammouan	15	0	0	0
Saravan	30	22	0	5

Table 2: Proportion of 'ACIAR' varieties, selected provinces, 2017

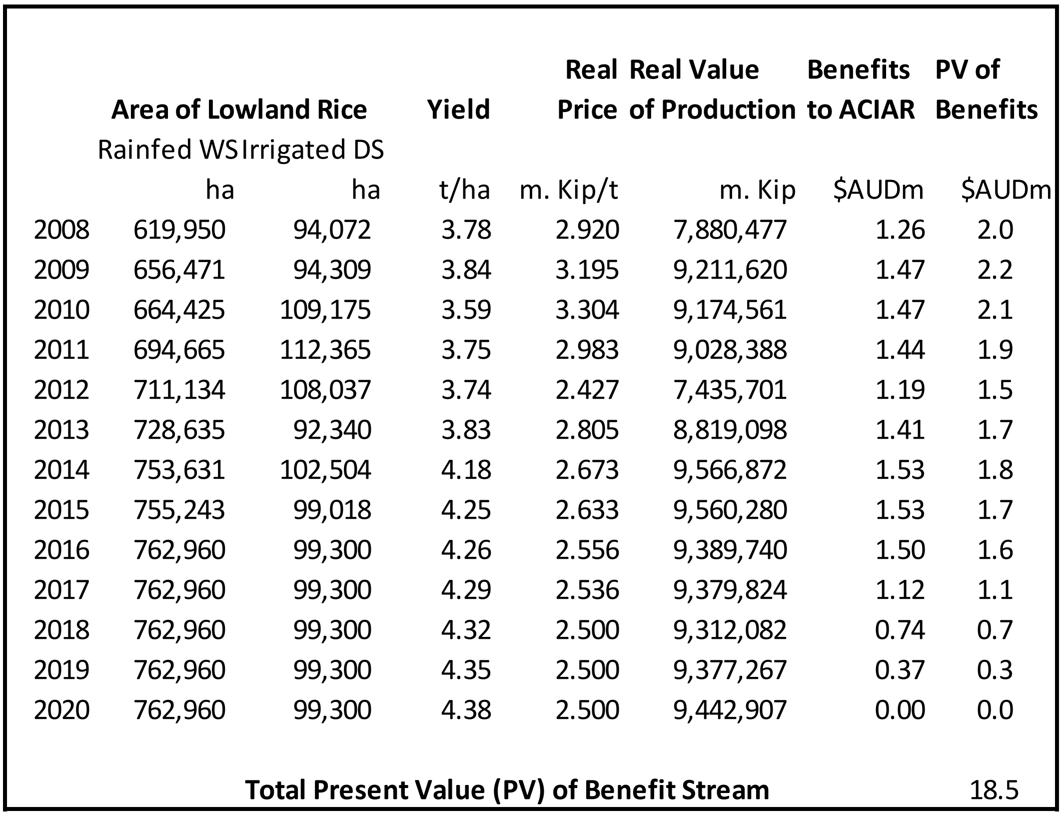
The Stream of Benefits from the drought tolerant varieties

Using these parameters, Mullen et al. (2019) first estimated the gross potential stream of benefits from the drought tolerant varieties if adopted by all farmers in the lowland areas (Table 4). This was done by applying the k shift factor (k(1 + 0.5*Z*n) from equation 1) to the real value of rice production in the lowland areas where the price of rice was expressed in 2017 terms after applying the GDP deflator for the Lao PDR and production was estimated as the area of rainfed and irrigated rice times the average yield for Laos from FAO data. Mullen et al. (2019) assumed that from 2016 the area sown to rice would not change but that wet season rice yield was assumed to grow at 0.7% per year as per the World Bank report reaching 4.38 t/ha (rainfed) in 2020.

To arrive at a stream of benefits attributable to the ACIAR projects, an adoption rate of ten percent was applied, and a 30% share of gross benefits was attributed to the ACIAR Projects. The stream of potential benefits is expressed in $AUD after applying the current exchange rate of 6,300 kip/$AU to the stream of potential benefits in 2017 kip values.

Applying ACIAR's recommended discount rate of 5%, the present value in 2017 of the stream of benefits from the adoption of more drought tolerant varieties in lowland Laos is $A18.5m. (Table 4).

We are uncertain about the level of adoption of the more drought tolerant varieties developed by Fukai and colleagues. It is also unclear how long these varieties will benefit Lao farmers were they used in breeding new varieties which were later widely adopted. We have applied a flat rate of adoption of 10% and set yield benefits to cut out in year 2020. Were the rate of adoption to reach 20% across lowland Laos, as has been the case in some provinces (Table 10) then the present value of the stream of benefits increases to $37.1m and the benefit cost ratio for the projects increases to 5.8 (from 4.4).



	Area of Lowland Rice		Yield	Real Price	Real Value of Production	Benefits to ACIAR	PV of Benefits
	Rainfed WS	Irrigated DS					
	ha	ha	t/ha	m. Kip/t	m. Kip	$AUDm	$AUDm
2008	619,950	94,072	3.78	2.920	7,880,477	1.26	2.0
2009	656,471	94,309	3.84	3.195	9,211,620	1.47	2.2
2010	664,425	109,175	3.59	3.304	9,174,561	1.47	2.1
2011	694,665	112,365	3.75	2.983	9,028,388	1.44	1.9
2012	711,134	108,037	3.74	2.427	7,435,701	1.19	1.5
2013	728,635	92,340	3.83	2.805	8,819,098	1.41	1.7
2014	753,631	102,504	4.18	2.673	9,566,872	1.53	1.8
2015	755,243	99,018	4.25	2.633	9,560,280	1.53	1.7
2016	762,960	99,300	4.26	2.556	9,389,740	1.50	1.6
2017	762,960	99,300	4.29	2.536	9,379,824	1.12	1.1
2018	762,960	99,300	4.32	2.500	9,312,082	0.74	0.7
2019	762,960	99,300	4.35	2.500	9,377,267	0.37	0.3
2020	762,960	99,300	4.38	2.500	9,442,907	0.00	0.0
	Total Present Value (PV) of Benefit Stream						18.5

Table 3: Benefit Stream from drought tolerant varieties attributable to ACIAR projects

The Impact of Direct Seeding of Rice

Direct seeding of rice has emerged throughout East and South-east Asia in response to the shortages of farm labour resulting from economic growth. Fitting direct seeding methods into rice farm systems is not straight-forward; solutions are specific to farmers and their systems. The major limiting factor to more rapid and wider adoption of direct seeding methods has been the yield-reducing and labour-increasing effects of the proliferation of weeds in rice crops that are seeded directly. The control of weeds by flooding and vigorous early growth of rice plants that are achievable with transplanted rice are not available with the direct seeded methods.

The reasons for the focus of researchers on direct seeding is obvious: the direct seeding methods requires 1-2 days/ha to sow a bund of rice, replacing the 30 days/ha labour it takes for the nursery to transplanting stages. Offsetting these savings in labour are an extra 8 days/ha to control the weed burden associated with direct seeding, and more commonly, lower yields than transplanted rice.

Less obvious, direct seeding adds flexibility and options to the annual rice planting decisions. If the rains are late in coming and delay the start of nursery operations and/or the time of transplanting, direct seeding offers the option of ‘planting dry’ in anticipation of the rains. The option of direct seeding a portion of the crop and transplanting another portion, commensurate with the supply of planting labour or with the needs to guarantee household rice supply for the coming year, spreads risk and deals with production constraints of labour and early season water supply.

While some of the benefits and costs of direct seeding are easy to value, harder to value are the system-wide effects and associated changes to farm and household risk. This means the decisions to adopt the direct seeding innovations will proceed slowly, farmer by farmer, system by system, village by village, region by region. Facing less and more costly labour supply over the medium-term, rice farmers are keen to find a way to make the mechanized options work.

Why the ACIAR Projects have likely been influential in developing and promoting the adoption of direct seeding in Laos

Each of the three ACIAR projects being reviewed had, among other aims, explicit objectives to find new information about direct seeding of rice and to inform farmers and fellow scientists about such findings.

Fukai et al (2013) reported that yields from broadcast crops, properly managed, were similar to those from transplanted crops. A survey of 76 farms found a mean reduction in direct seeding yield of 4%, or 140kg/ha. Fukai et al (2013) estimated it was likely in 2016 that more than 6% of rice area in Laos (50,000 ha) was planted using direct seeding. They considered that the total area combined for both dry and wet seasons might reach 50,000 ha in 5 years. It was noted that in 2009, there was 94,316 ha of dry season rice planted in Laos; around 45% was established in the project target provinces. Fukai et al. (2016) reported that

“Adoption of direct seeding has taken place gradually in Laos. In Champasak Province, the direct seeded area is about 10% in the wet season and 60-70% in the dry season. The direct-seeded area was almost zero in 2007 when the project commenced; the increase in the direct-seeded area has been more than 10,000 ha in the past 8 years in the dry season alone (p.42). “

Fukai et al (2013) noted that other projects, including their previous ACIAR projects and projects by Vorlasan et al (2016) and Clarke et al. (2016), contributed to the adoption of direct seeding, ‘making it difficult to single out the contribution of any particular project’ (p.4). However, a strong case can be made that the R, D&E work conducted by Fukai et al on direct seeding from 1995 to 2011 laid a foundation for the emergence of the direct seeding technology and incorporation of this technology by farmers into their systems. This work, the first to do direct seeding trials in the Laos lowlands, identified the questions that had to be asked and solved, and then began to solve some of the system-related questions, such as varieties that suited direct seeding and the critical issues of weed and fertilizer management to achieve comparable yields and GMs to transplanting crops.

The Impact of Direct Seeding on the Rice Enterprise and the Consequent K- shift

Mullen et al. (2019) used a partial budgeting approach using gross margins (GM) budgets to estimate the changes in costs and returns associated with direct seeding. The suite of budgets used can be found in Mullen et al. (2019). Here we present the gross margin budget for rainfed direct seeded rice (Table 5) and a summary of the gross margins for rice under direct seeding and hand transplanting for the rainfed and irrigated enterprises (Table 6).

Gross Income			RICE kip/ha	RICE AU$/ha
Rice	2,700 kg/ha	2,500 kip/kg (on farm)	6,750,000	1071
	Less threshing	5% of revenue	337,500	54
Total Income			6,412,500	1018
Variable costs	Quantity	Price		
Rice seed	40 kg/ha	4,500 kip/kg	180,000	29
46-00-00	10 kg/ha	4,000 kip/kg	40,000	6
16-20-00	50 kg/ha	4,,600 kip/kg	230,000	37
46-00-00	50 kg/ha	4,000 kip/kg	200,000	32
Fuel	30 litre/ha	10,000 kip/litre	300,000	48
Labour Costs	51 days	60,000 kip/day	3,060,000	486
Total Variable Costs			4,010,000	637
Gross Margin	TI - TVC		2,402,500	381
Unit Cost	TVC/Yield	Kip/kg rice	1,485	0.24

Table 5: **Direct Seeded Gross Margin budget: Lowland Wet Season Rice**

Method	**Wet Season**		**Dry Season**	
	Kip/ha	AU$/ha	Kip/ha	AU$/ha
Transplanting	1,585,000	252	2,920,000	463
Direct Seeding	2,402,500	381	3,500,000	556

Table 6: **Gross Margins for Lowland Rice by establishment method and season**

In preparing these budgets, the method of direct seeding was not specified. It could be broadcasting by hand (most commonly), drill seeding, drum seeding, or, as happens often, a combination of methods. The assumption was that the farmer owns a two-wheeled tractor and its operating costs for cultivation were included in the GM estimate. The further assumption was that the same amount of fertilizer was used with the two methods of establishing rice plants.

The differences in the costs of establishing rice using the two methods derived from (i) direct seeding has less labour for plant establishment, 1-2 days/ha regardless of method of direct seeding, compared with up to 30 days/ha for nursery and transplanting, at 60,000 Kip/day for labour; (ii) reduced seeding rate per hectare for direct seeding (40kg/ha) than transplanting (60 kg/ha) with a seed cost of 4500 kip/kg; and (iii) more weeding labour per hectare than transplanting, 16 days for direct seeding versus 11 days for transplanting .

Note that no costs associated with owning or contracting direct seeding machinery are in the budgets below. These costs are likely to be small and, on any farm, a variety of methods may be employed. Information about these costs can be found in an Appendix in Mullen et al. (2019).

Differences in GMs between the two methods also derived from yield differences. The yield of direct sown crops was reduced by 10% from transplanted crops to reflect losses from weed competition especially while farmers learn to apply this technology to their circumstances.

Lao farmers commented that weed problems meant that it was not possible to direct seed the same area every year. They reverted to transplanting after some years of direct seeding. In wet years many farmers still prefer transplanting. In Mullen et al. (2019), a rotation hectare consisted of a sequence of 3 years direct seeding followed by 2 years of transplanting to better represent the change in the wet season system, particularly in early years until alternative weed control systems are well developed. The annual GM for wet season directed seeded rice is a weighted average (3:2) of the GMs for direct seeded and transplanted crops. The weighted average yield is 2.82 tonnes/ha. The rotation constraint for weed control that applies to wet season direct seeded rice is assumed not apply to dry season irrigated direct seeded rice. This is because irrigation offers better weed control options, negating the need for occasional transplanting.

The unit cost of production (total variable costs per yield unit) was derived for each system. The k shifts (Table 7) for the rainfed and irrigates systems were estimated as the changes in unit cost relative to the price of rice per kg (that is 2,500 kip/kg). In the economic model used to estimate the welfare effects of the adoption of direct seeding, the k factor was 8.31% for wet season crops and 9.69% for dry season crops.

Method	**Wet Season**			**Dry Season**		
	Kip/ha	AU$/ha	%	Kip/ha	AU$/ha	%
Transplant	1,847	0.29		1,645	0.26	
Direct Seed	1,485	0.24		1,403	0.22	
Direct Seed Rotation*	1,639	0.26				
Change in Unit Costs**	208			242		
K shift			8.31			9.69

* 3 years Direct Seeding followed by 2 years Transplanting

** Unit Cost (Transplant) – Unit Cost (Direct Seed Rotation)

Table 7: **Unit Costs and k Shift for Lowland Rice by establishment method and season**

Adoption of direct seeding

To aggregate the economic benefits of direct seeding, the extent of direct seeding methods used each year to grow rice in in the lowland areas of Laos was estimated as well as the time profile over which adoption has and will continue to occur.

Fukai et al. (2013) judged in 2016 that possibly 6% by area was sown using direct seeding, an area of 50,000 hectares. It seems likely that there was little direct seeding prior to 2014 (Fukai, pers. comm.). Linearly extrapolating back from the 50,000 ha in 2016 to zero in 2013 gives assumed areas direct seeded of 17,000 and 34,000 ha in 2014 and 2105. These numbers refer to the wet season and Mullen et al. (2019) added a further 10% of that area for the dry season irrigated crop. The area of direct seeded lowland rice was projected to increase from the 50,000 hectares in 2016 to a level of 60% of annual rice crop area (almost 500,000 ha) by 2026.

The growing scarcity of labour for rice transplanting and the rising cost of labour in the Laos economy will see an increased use of direct seeding, especially if more direct seeding machinery becomes available as expected. Crop management constraints identified above mean that in any year a significant proportion of the crop will not be direct seeded.

Economic analysis required conjectures about the rate and level of adoption with and without, the ACIAR projects. Mullen et al. (2019) argued that because of the strong incentives for farmers to adopt labour saving technologies such as direct seeding, the path-breaking work of Professor Fukai and his colleagues would now been needed had it not been already done. They judged that the ACIAR projects had brought forward the use of direct seeding into rice production systems by at least 5 years. Their ‘without’ scenario was that it would have been not until 2018 that 17,000 ha were direct seeded. From there the rate of adoption in response to labour costs was projected to be even more rapid than in the ‘with projects’ scenario, such that in 2026 under both scenarios, an area of about 500,000 ha would be direct sown (Figure 3).

A related question is: how much can the earlier commencement of direct seeding be attributed to the investment in the three ACIAR projects? Others have also helped in demonstrating direct seeding technologies (developed in the ACIAR projects) and encouraged their adoption. Mullen et al. (2019) have assumed that 60% of the benefit from the growth of direct seeding to 2026 could be attributed to Professor Fukai and the ACIAR projects.

The stream of benefits from the adoption of direct seeding

Applying the k-shifts for rainfed and irrigated direct seeding to the areas direct seeded under the ‘with’ and ‘without’ projects adoption scenarios gave a stream of benefits which was further discounted by the 60% share of benefits attributable to the projects. Mullen et al. (2019) estimated that the present value (5% discount rate) of the stream of benefits attributable to ACIAR from the adoption of direct seeding was $A44.1m (Table 8).

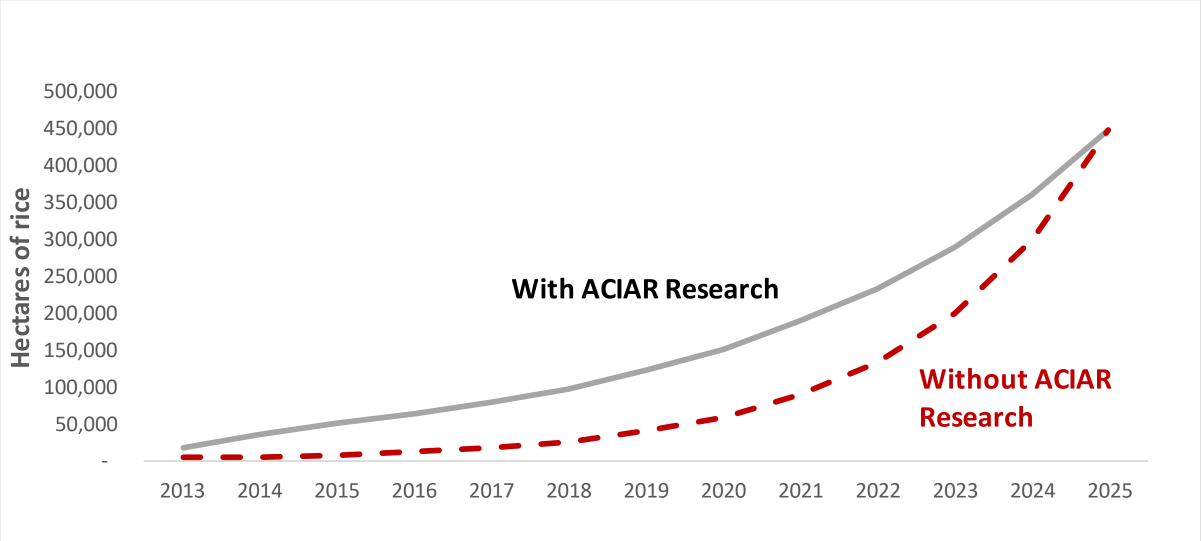


Figure 3: The Adoption of Direct Seeding 'With' and 'Without' the ACIAR projects

	Projected Area Direct Seeded		Gross Potential Benefits	Attributed to ACIAR	Present Value (5%)
	With ACIAR	W/O ACIAR			
	ha	ha	kip	kip	$A
2014	18,700	3,740	9,295,661,769	5,577,397,061	1,024,847
2015	37,400	5,618	19,748,492,476	11,849,095,485	2,073,592
2016	56,100	8,438	29,615,545,670	17,769,327,402	2,961,555
2017	69,723	12,675	35,448,304,097	21,268,982,458	3,376,029
2018	86,655	19,038	42,015,132,727	25,209,079,636	3,810,896
2019	107,699	28,596	49,151,704,776	29,491,022,865	4,245,909
2020	133,852	42,953	56,481,787,251	33,889,072,350	4,646,771
2021	166,357	64,518	63,279,426,441	37,967,655,865	4,958,109
2022	206,756	96,911	68,254,310,922	40,952,586,553	5,093,242
2023	256,965	145,566	69,219,889,348	41,531,933,609	4,919,328
2024	319,367	218,648	62,583,075,607	37,549,845,364	4,235,869
2025	396,922	328,423	42,563,104,845	25,537,862,907	2,743,656
2026	493,311	493,312			
	Total Present Value (5%)				**44,089,801**

Table 8: Stream of Benefits from Direct Seeding in Lowland Rice Systems

Economic Analysis

The 2017 present value of the investment in the three projects by ACIAR and partners was $A14.1m (Table 9). The 2017 present value of the stream of benefits from the adoption of more drought tolerant varieties and direct seeding attributable to the ACIAR projects was $A18.5m and $A44.1m, for a total of $A62.6m. Hence the 2017 net present value (5%) of these streams of benefits and costs was $A48.5m. The benefit cost ratio was 4.44:1 and the internal rate of return was 16.0%. The internal rate of return assumes that as benefits are received they can be reinvested at the rate of 16.0%. The modified internal rate of return, assuming that net benefits are re-invested through the life of the investment at 5%, was 11.5%.

The stream of net benefits (net of farm costs) from either the more drought tolerant varieties or from the direct seeding technology cover ACIAR's costs and opportunity costs. For drought tolerant varieties alone the NPV of the net benefit stream was $4.4m and for direct seeding it was $30m.

Suppose the size of the key parameters were halved, such that for the more drought tolerant varieties the level of adoption was 5% rather than 10% and the share of benefits attributed to the ACIAR projects was 15% rather than 30%. Suppose further that for the direct seeding technology the level of adoptions was 13% rather than 60% and the share of benefits attributed to the ACIAR projects was 30% rather than 60%. In this scenario the project investment criteria are just met; the benefit cost ratio becomes 1 and the internal rate of return becomes 5%. This 'just breakeven' scenario would have a low probability of occurring.

Despite uncertainty about key parameters such as the rate and level of adoption of the technologies and the contribution this set of three projects has made to the development and adoption of the technologies, Mullen et al. (2019) found that the returns to ACIAR's investment was robust to significant changes in these parameters and was a sound use of its funds.

Note that in addition to these economic gains, there are likely to have been significant gains in scientific capacity and social gains as household labour is released from the drudgery of transplanting rice.

Social Impact

Direct seeding technology releases some of the farm household, mostly the women and children and those employed off-farm, from the drudgery of transplanting. Some rice transplanting is done by hired labour. Some family labour too has a market opportunity cost, working for other farmers or working away from the farm but returning for the times of peak labour demand, harvest and transplanting. It is likely not practical for all the released labour, especially that of the women in the household, to earn off-farm income but that does not mean that this labour has no opportunity cost. It is likely to be put to use tending animals and other crops such as household vegetables. The family may also value increased leisure time. It is hard to value these non-market uses of released labour. In a semi-subsistence setting where the success of the rice crop is critical to the family's food security, family labour is difficult to value. Mullen et al. (2019) valued all labour released at the market rate of 60,000 kip/day.

	Project Costs	**Benefits**		**Net Flow**
		Improved Varieties	**Direct seeding**	
	$s (2017)	$s (2017)	$s (2017)	
1997	2,008,079			- 2,008,079
1998	1,202,504			- 1,202,504
1999	748,198			- 748,198
2000	330,427			- 330,427
2001	1,821,113			- 1,821,113
2002	1,407,411			- 1,407,411
2003	1,276,613			- 1,276,613
2004	1,146,258			- 1,146,258
2005	960,033			- 960,033
2006	225,039			- 225,039
2007	-			-
2008	742,955	1,952,637		1,209,682
2009	820,478	2,173,781		1,353,302
2010	693,473	2,061,939		1,368,465
2011	602,733	1,932,464		1,329,731
2012	111,800	1,515,772		1,403,971
2013		1,712,169		1,712,169
2014		1,768,900	1,024,847	2,793,746
2015		1,683,506	2,073,592	3,757,097
2016		1,574,738	2,961,555	4,536,292
2017		1,121,880	3,376,029	4,497,909
2018		706,061	3,810,896	4,516,957
2019		338,046	4,245,909	4,583,955
2020		-	4,646,771	4,646,771
2021			4,958,109	4,958,109
2022			5,093,242	5,093,242
2023			4,919,328	4,919,328
2024			4,235,869	4,235,869
2025			2,743,656	2,743,656
Total	**14,097,115**	**18,541,890**	**44,089,801**	
		Net Present Value (5%)		**48,534,577**
		Benefit Cost Ratio		**4.44**
		Internal Rate of Return		**16.0%**
		Modified IRR		**11.5%**

Table 9: Present Value Flows of Benefits and Costs and Rate of Return Criteria from the ACIAR Rice Projects in Laos

Capacities Built

Bilateral projects sponsored by ACIAR typically fund activities across a spectrum, including human capacity building and the development of farm ready technologies, in pursuit of economic, social and environmental benefits. Capacity building is likely to contribute to the successful outcomes of the project in which it was developed, but it can also add to the stocks of human and scientific capital that potentially yield a flow of services many years into the future in the form of new technologies used by farmers. Capacity building was a significant component of this set of projects but it was not possible to review it in the formal manner followed by Mullen et al. (2016).

Capacity was developed in four main areas:

- Additions to scientific knowledge in the form of scientific publications;
- Informal training of project scientists through mentoring, learning by doing and short courses;
- Formal post graduate training opportunities for scientists working on the projects.
- Building the capacity of farmers to grow rice and manage their farms through their participation in the rice variety trials;

Scientific Publications

The three projects gave rise to an impressive set of publications leading to additions to the stock of scientific knowledge which has a non-use value but also has the potential to lead to the development in later research projects of new technologies adopted by farmers. Most publications were authored jointly by scientists from Australia, Laos and Thailand. No doubt this experience added to human scientific capacity by enhancing generic skills such as scientific writing and presentation skills

Mullen et al.(2019) reported 144 scientific papers including conference papers from the three ACIAR projects. Some of Professor Fukai's papers have been cited more than 100 and up to 600 times.

Informal training

An important component of bilateral research projects is capacity building through mentoring, 'learning by doing' and workshops and short courses. During each project, workshops and short courses were held which provided collaborating scientists opportunities to analyse, discuss and present results and prepare publications, all adding to capacity. The generic skills likely to have been developed include:

- trial management, particularly on-farm participatory variety selection methods;
- experimental design;
- data analysis;
- scientific writing;
- English language and presentation skills;

- Joining scientific networks.

The pathway to changes in farm practice is more indirect for such capacities. Nevertheless, these skills likely increased the access of scientists to the international scientific community and made new knowledge accessible sooner. The opportunity to maintain and incrementally increase capacity was an important benefit of a succession of ACIAR-funded projects. At the Rice Research Centre, one of the John Allwright Fellows commented that in particular, working on the projects led to a significant development in her project design and management skills.

Some skills acquired during capacity building were technical in nature and closely related to the projects' research processes and the technology being developed. It is highly likely that many of these skills will prove valuable in developing new technologies in later projects.

Capacity building through training

Some scientists also had opportunity for post-graduate study, sometimes funded within the projects but usually funded either by ACIAR through its John Allwright and John Dillon Fellowships or by another international or Laotian funding body.

Typically, during a project a young scientist is identified and proposed for an ACIAR John Allwright Fellowship for post graduate study at an Australian university. Professor Fukai supervised some of the graduate students. Nearly all the graduate students undertook projects with some relevance to projects although this is not a requirement and often their training did not conclude until well after the project ended. Topics of study included drought tolerance, climate modelling, non-rice crops, direct seeding and cold tolerance. This set of projects extended from 1997 to 2012 and it is likely that capacities built in earlier projects were of benefit to later projects and contributed to their outcomes

From project reports there were 18 people who went on to undertake post graduate degrees after first working on these projects. ACIAR funded 5 PhD students and 1 Master student. The projects funded 1 other Master student directly. Other external sources funded 5 PhD students and 4 Master students.

Farmer Capacity Building

In all three projects many of the trials were conducted in farmers' fields. In the last project nearly 800 farmers took part in the PVS trials. Farmers had a role in selecting varieties that they thought would do best in their environment. Farmers have had to develop skills in comparing the performance of varieties. Direct seeding trials were conducted on farms. Direct seeding requires a new set of skills particularly in weed management and water and fertilizer management and preparing soil conditions necessary for rice to establish successfully. Moreover, skills were required in managing the trials and these skills in crop management are likely of lasting benefit to the farmers. In the last project economic as well as physical data were collected during the trials and reported back to the farmers. It is likely that they developed some skills in assessing the economic consequences of their decisions.

Executive Summary

An assessment of the impact of three ACIAR supported projects dealing with lowland rice production in the Laos PDR was undertaken by Mullen et al. (2019). This set of three projects led by Professor Shu Fukai from the University of Queensland and Dr Monthathip Chanphengsay from NAFRI in Laos, contributed to the development and adoption by farmers of rice varieties more tolerant of episodic dry seasons common to lowland rice areas in Laos and to the adaptation and adoption of direct seeding technologies. These projects were undertaken from 1997 to 2012 with impacts continuing beyond that time.

The greatest difficulty Mullen et al. faced was the lack of data – published or otherwise – on the area of rice plantings by variety and the area of rice direct seeded. Moreover, there is great diversity in rice production methods across the target population for these two technologies, reflecting not only variations in soil type and climatic conditions, but also in the economic and social incentives facing farm families, most of whom operate at a semi-subsistence level. Discussions with Australian and Laotian scientists and with farmer groups in Laos were invaluable in forming the judgements made in assessing the impact of these technologies.

Lindner, McLeod and Mullen (2013) classified each of a series of ACIAR impact assessments as being either ‘conceivable, ‘plausible’ or ‘convincing’, as the level of transparency and objective support for key assumptions increased. In view of their reliance on the judgment of scientists, anecdotal evidence and their own observations, and the lack of objective data on adoption of the technologies, Mullen et al. (2019) described their impact assessment as being ‘plausible’ rather than ‘convincing’.

Despite the uncertainties around key parameters such as adoption, it is likely that this set of projects has been a good use of ACIAR funds, generating net benefits and earning returns commensurate with other investments in agricultural R, D & E. A proportion of Lao rice growers in lowland areas have already benefitted from the two technologies – more drought tolerant rice varieties and the direct seeding technology – and the flow of benefits is likely to increase as adoption spreads. Moreover, other benefits, though difficult to measure and value, have resulted from these projects. For example, significant scientific capacity was built in terms of new knowledge, as evidenced by a strong publications record. As well human scientific capacity has been built through informal means such as mentoring and ‘learning by doing’, which often led to Lao scientists engaged on the project pursuing higher degrees, some as John Allwright Fellows. The direct seeding technology allows farm families to reduce their time on the onerous task of transplanting rice, providing opportunities for a range of off-farm and on-farm activities including employment, growing vegetables, tending livestock, managing the household and more leisure.

Using a market model for Lao rice, Mullen et al. estimated the on-farm impacts of the two technologies and then their potential gross benefits. A time stream of benefits (in real terms) was derived by applying projections about the adoption of the technologies and the share of benefits attributable to the ACIAR projects which was then offset against the investment stream.

They estimated that the present value in 2017 of the investment in the three projects by ACIAR and partners, using a 5% discount rate, was $A14.1m (all monetary values in 2017 $AUD). The present values in 2017 of the streams of measurable benefits from the adoption of more drought tolerant varieties and direct seeding technology were $A18.5m and $A44.1m respectively, for a total of $A62.6m (at a 5% discount rate). The net present value of these streams of benefits and costs in 2017 was $A48.5m. The benefit cost ratio was 4.44:1 and the internal rate of return was 16.0%. The internal rate of return assumes that interim benefits are reinvested at the rate of 16.0%. The modified internal rate of return, MIRR, allows for a market rate of reinvestment to be applied. If the net benefit stream can be reinvested through the life of the investment at a rate of 5%, the MIRR is 11.5%.

By these three measures the set of three projects, whose impact has been assessed here, are likely to have been a good investment from ACIAR's perspective. This conclusion is quite robust to the uncertainty surrounding assumptions about the rates of adoption of the technologies and the share of benefits from the two technologies attributable to the ACIAR projects. If both these parameters are halved for both technologies, an unlikely scenario, the investment in the projects still earns the required rate of return.

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