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A policy dialogue on rice futures: rice-based farming systems research in the Mekong region

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A policy dialogue on rice futures: rice-based farming systems research in the Mekong region

Proceedings of a dialogue held in Phnom Penh, Cambodia, 7–9 May 2014

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Policy actors convene with researchers to deliberate on rice futures in the Mekong region (Photo: Lisa Robins)

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Foreword

The impetus for convening a policy dialogue on rice futures in the Mekong region was the conclusion of the 5-year research-for-development initiative, 'Rice-based Systems Research (RSR) program: food security in Lao PDR, Cambodia and Bangladesh'. The RSR program was one of four developed by the Australian Centre for International Agricultural Research (ACIAR) under the Australian Government's 'Food Security through Rural Development' initiative.

The RSR program invested $14.8 million from 2009 to 2014 to explore opportunities for alleviating poverty through improving the productivity and profitability of rice-based farming systems. These systems involve both rainfed and irrigated agriculture in Laos, Cambodia and Bangladesh, and are often associated with livestock production. The program comprised five large-scale farm-productivity projects and a suite of smaller policy-focused projects. Collectively, the projects spanned crop and livestock development; improved rice germplasm; technological advances in establishment, productivity and irrigation; new cropping niches; targeted marketing and extension; and alternative evidence-based policy options.

The meeting brought together researchers to present and discuss their work with senior policymakers in the Mekong region. The emphasis was on communicating the policy implications of ACIAR-funded research—especially, but not exclusively, from the RSR program's work in Laos and Cambodia—and some key complementary non-ACIAR research in the region. In turn, the policymakers responded with their considered assessment of the work presented, in the light of current and likely future policy settings.

The policy dialogue comprised five half-day forums, each consisting of 4–5 presentations followed by a panel discussion. The first set the scene by focusing broadly on 'rice futures' in the Mekong region. The four that followed examined intensification and mechanisation, diversification, climate change and natural resource management, and policy and knowledge. The lively dialogue around these policy-oriented papers, along with networking among delegates, stimulated fresh thinking about how to optimise outcomes from this important research.

These ACIAR proceedings comprise the papers presented at the policy dialogue, preceded by rapporteur synopses that capture the breadth of deliberations and panel discussions in each forum. These emphasised that technical solutions alone are insufficient for improving the productivity and profitability of rice-based farming systems: unless there are supportive policy settings, improvements in these systems will not occur. At ACIAR, we continue to work closely with policymakers in our partner countries to maximise the impact of our research-for-development investments.

Nick Austin
Chief Executive Officer
ACIAR

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Acknowledgments

The policy dialogue was overseen by the ACIAR Rice-based Systems Research (RSR) program Steering Committee, which comprised Research Program Managers Caroline Lemerle, Mike Nunn, Eric Huttner, John Dixon and Evan Christen, and Publications Manager Georgina Hickey. Secretariat support to the committee was provided by Rebecca McBride (Research Program Officer) and Janet Williams (Program Support Officer). Khun Chiraporn Sunpakit and Souphalack Inphonephong (ACIAR Country Office Vientiane) provided in-country support and logistical assistance.

Lisa Robins (Robins Consulting) worked with the RSR program Steering Committee to develop the program and coordinate event delivery, with support from Jason Condon (Charles Sturt University) and Bruce Munday (consultant) in terms of identification of panellists, facilitation, communication activities, logistics and event delivery.

ACIAR would like to thank all delegates for participating and sharing their experiences. We extend special thanks to our moderators and rapporteurs, namely Bounthong Bouahom and Len Wade (rice futures), Mike Nunn and Suzie Newman (intensification and mechanisation), Seng Mom and Robyn Johnston (diversification), Evan Christen and Christian Roth (climate change and natural resource management), and Ouk Makara and Rob Cramb (policy and knowledge).

A critical success factor was the open and active participation of our panellists, whom we gratefully acknowledge. We also thank our guest speakers: Yang Sang Koma (Cambodian Center for Study and Development in Agriculture), Peter Roggekamp (Cambodian Agricultural Value Chain Program), Itaru Minami (Mekong River Commission Secretariat), Bas Rozemuller (International Finance Corporation, Cambodia) and Uch Chanthol (Cambodia HARVEST).

We would also like to thank the numerous partners involved with ACIAR's rice-based farming systems research projects in the Mekong region. The papers in these proceedings were based on the following ACIAR-funded projects (the first six of which were funded under the RSR program):

- ASEM/2009/023, *Developing agricultural policies for rice-based farming systems in Lao PDR and Cambodia*
- ASEM/2009/039, *Agricultural policies affecting rice-based farming systems in Bangladesh, Cambodia and Lao PDR*
- CSE/2009/004, *Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*
- CSE/2009/005, *Improved rice germplasm for Cambodia and Australia*
- CSE/2009/037, *Improved rice establishment and productivity in Cambodia and Australia*
- LWR/2009/046, *Improved irrigation water management to increase rice productivity in Cambodia*
- AH/2010/046, *Domestic and international market development for high-value cattle and beef in south-east Cambodia*
- ASEM/2010/049, *Market-focused integrated crop and livestock enterprises for north-western Cambodia*
- ASEM/2012/081, *Improving market engagement, postharvest management and productivity of Cambodian and Lao PDR vegetable industries*
- CSE/2006/040, *Diversification and intensification of rainfed lowland cropping systems in Cambodia*
- CSE/2006/041, *Increased productivity and profitability of rice-based lowland cropping systems in Lao PDR*
- CSE/2012/077, *Mechanisation and value adding for diversification of lowland cropping systems in Lao PDR and Cambodia*
- HORT/2006/107, *Strengthening the Cambodian and Australian vegetable industries through adoption of improved production and postharvest practices*
- LWR/2008/019, *Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India*
- LWR/2012/013, *Investing in water management to improve productivity of rice-based farming systems in Cambodia*

Abbreviations

ACCA	Adaptation to Climate Change in Asia (project)
ACIAR	Australian Centre for International Agricultural Research
ASEAN	Association of Southeast Asian Nations
ASEM	Agricultural Systems Management (an ACIAR research program)
BDP2	(MRC) Basin Development Plan Programme Phase 2
CARDI	Cambodian Agricultural Research and Development Institute
CAVAC	Cambodian Agricultural Value Chain (program)
CLEAR	Cambodian Land and Environment Agricultural Resource
CSE	Cropping Systems and Economics (an ACIAR research program)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DAFO	District Agriculture and Forestry Office (Lao PDR)
DS	dry season
DSR	dry-season rice
EWR	early wet-season rice
FFS	farmer field school
FWUC	Farmer Water User Community
GDP	gross domestic product
GM	gross margin
ha	hectare
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IRRI	International Rice Research Institute (a CGIAR centre)
K	potassium
LSD	least significant difference
LWR	Land and Water Resources (an ACIAR research program)
MAF	Ministry of Agriculture and Forestry (Lao PDR)
MAFF	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
MSEA	mainland South-East Asia
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
MRC	Mekong River Commission
Mt	million tonnes
MWR	main wet-season rice
N	nitrogen
NPK	nitrogen–phosphorus–potassium (fertiliser)
NI	net income

NSW	New South Wales (Australia)
OAA	other aquatic animals
OFR	on-farm research
P	phosphorus
P	probability
PAFO	Provincial Agriculture and Forestry Office (Lao PDR)
PDR	(Lao) People's Democratic Republic
R^2	coefficient of determination
RSR	Rice-based Systems Research (an ACIAR program)
RUA	Royal University of Agriculture (Cambodia)
WS	wet season

Forum A: Rice futures

Rapporteur's synopsis

Len Wade[1]

Forum A panellists

The five forum panellists were:

- HE Mr Mey Kalyan (Senior Advisor, Supreme National Economic Council, Cambodia)
- Dr Xaypladeth Choulamany (Director General, Department of Planning and Cooperation, Lao PDR)
- Dr Nguyen Van Bo (President, Vietnamese Academy of Agricultural Sciences, Vietnam)
- Prof. Silinthone Sacklokham (Vice Dean, Faculty of Agriculture, National University of Laos, Lao PDR)
- HE Mr Pich Veasna (Director, Technical Service Centre for Irrigation and Meteorology, Ministry of Water Resources and Meteorology, Cambodia).

Summary

The statements from senior policy actors in the rice futures forum were challenging and left no doubt of the urgency to respond to impending change, the likely effect on farmers, and the need for appropriate policy settings to assist farmers to adapt. The statements stimulated wide-ranging discussion.

Context by country

Cambodia

Discussions commenced by reviewing progress with rice policy in Cambodia. Before 2010, Cambodian rice was sent to Vietnam for dehulling and polishing, but to some extent this value-adding can now be done in-country, retaining associated profits in Cambodia. This was accomplished via policy change to encourage ownership of processing capacity by government and private businesses.

Economic development in Cambodia, including the industry, services and tourism sectors, is now moving fast. Rice and agriculture generally are still important, but need to adjust, and the challenge is more complex than technical issues, such as irrigation and fertiliser. For example, during the past 10 years, the availability of farm labour has declined, with 700,000 people moving to the garment industry alone.

People will continue to move to the cities because of the likelihood of higher income there, at about US$100/month. To achieve a similar income on-farm would require each person to tend 3 hectares (ha) of rice alone, which would not be easy.

The World Bank recently asked if rice was the answer to poverty reduction. Sufficient rice to meet Cambodian demand is still needed, but by growing rice alone, farmers will remain poor.

There is an urgent need to manage infrastructure, value-add, diversify and integrate the farming system to increase farmers' incomes. As the profitability of rice remains low for farmers, the future of rice growing alone seems pessimistic.

Lao PDR

A panellist noted that rice production had doubled in Laos since the 1950s and that Laos had been self-sufficient in rice since 2000. Laos has one of the highest levels of rice consumption in the world, especially of sticky rice, with associated dietary challenges of too much carbohydrate and too little of other nutritional components. Even producing a surplus of rice did not really benefit farmers, due to the low price, high cost of production and inefficient milling.

The Lao Government target is 4.2 million tonnes (Mt) of rice by 2015. But Lao farmers need to diversify to ensure sufficient income, so rice is expected

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to decline in importance. To assist this adjustment, appropriate policies need to be considered, including directing public funding, targeting specific geographical areas, marketing in an Association of Southeast Asian Nations (ASEAN) framework, and investing in alternatives such as industrial tree crops, including rubber.

Vietnam

More than 90% of Vietnamese farmers tend less than 1 ha of land. The current socioeconomic priority is to allow diversification out of rice, against a background of how to make the rice sector favourable in terms of production and income, despite production increasing by 1 Mt a year over 30 years.

In growing rice, farmers remain poor, but processors and traders get rich. Appropriate policies are needed to assist farmers to make money from rice. There is also a need to retrain farmers in postharvest technology, value-added products and associated industry skills.

Vietnam had a policy limiting the number of children in cities, but not in rural areas, where additional farm labour was required. This now provides a challenge for population equality, with a need to improve education and quality of life in rural areas.

Increasingly, there are challenges in maintaining irrigation infrastructure and capacity, with older irrigation facilities being unprofitable. Rice is still important, with at least 6.5 Mt exported annually, so the policymaker needs to protect the subsistence farmer. But the way forward may be to partner rather than to compete. For example, to improve communication, should China be invited to be a member of the Mekong River Commission?

Challenges for rice policy development

Policy actors have highlighted the need for change. At issue is an underlying need to understand farmers' decision-making, which responds to internal and external factors. Farmers look at their land, labour and cash availability. Then they consider price, policies, available services and their level of training in making their decisions.

A farmer may decide not to invest in small on-farm irrigation because the US$3,000 set-up costs may be too high, or because there are issues of land availability, or lack of access to credit to purchase fertiliser. Before defining policy, governments need to understand the farmers' situation and decision-making, for different types of farmers.

In Laos, 'rice is life'. If asked, 'Have you had a meal?', the question is really 'Have you eaten rice?' Yet despite rice's cultural significance, it is not competitive for Laos to export rice. The quality is low, the infrastructure is poor, and the majority of production is sticky rice, which has limited international demand. Hence, rice production should primarily be for home consumption and the domestic market only.

On a world scale, the demand for rice is changing, with the increased demand for healthy food. Of concern is the global rise in people's weight and in the prevalence of diabetes. White rice and sticky rice are seen as undesirable, due to their high carbohydrate levels and high glycaemic index. In future, rice must target niche markets for healthier products, including brown rice, low glycaemic index rice, chicken rice, purple rice and rice cakes.

There is also the need to educate the poor rice farmers and consumers in Laos and elsewhere on the benefits from a switch to brown rice. Finally, there is a research gap in understanding farmers' drivers of choice—between remaining on the farm or migrating to the city, between buying more extensive land or investing in equipment or hiring labour to intensify, and seeking out-of-season off-farm work only. What type of farmer will continue to invest in the farm?

It was noted that policymakers can consider the research findings, which can contribute to the goals of government, but some evidence provides cause for concern. Changes such as the movement of migrant labour from rural areas to the cities and across borders, the rapidity of adoption of tractors and other machinery, and the loss of draught animals present serious challenges for policymakers.

Where are the young farmers? They are the ones who are moving. What about the costs involved in generating the higher incomes through intensification of labour and equipment? This comes with a need for greater access to credit, and its associated risks from higher indebtedness. These are unfortunate consequences of the current farming revolution. As a result, new policies are needed to mobilise resources to fit, accommodate or counter demand, as is appropriate. In particular, how do we retain young farmers? How do we cope with the higher risk of investment in farming for higher returns? How do we keep farmers from migrating? How do we develop and retain the capacity to meet the water demand? If farmers do not want to move away, they will need to adapt to climate change, so will need access to more water. How can we supply more water in a way they can afford? There is an urgent need to modernise the irrigation system, but this can only be done at a huge cost.

Extension services need to be strengthened in this time of change, to assist farmers to adapt. To keep going, farmers must feel secure. The Australian Centre for International Agricultural Research (ACIAR) was urgently requested to continue this important policy dialogue with the key players, so they can continue to learn from each other.

Discussion focused on how to generate policy to assist farmers to cope with these changing demands. In the end, it is farmers who produce the rice, so policies need to address issues ultimately at the level of the farmer.

How do governments provide the incentive to farmers to produce the desired larger public good (e.g. food security for the nation)? Under some forms of government, decree is possible, but in a market economy, it is more difficult.

Governments will push rice as long as it is profitable. It will be essential to ensure that planning for investments in irrigation development and land conversion for other industries (e.g. factories for manufacturing) are more strategic than in the past. Rice will be pushed only to the limits of its profitability, then other enterprises will be selected instead. To do so will require the clear identification of, and engagement with, key stakeholders. How does the government find suitable players and investors? All players will be needed, including the commercial sector. Confident leadership is needed from government, with assistance from development partners.

Editor's note: Papers for three of the five presentations are not incorporated in these proceedings, namely 'Insights from the CEDAC network' (Dr Yang Sang Koma, Cambodian Center for Study and Development in Agriculture (CEDAC)), 'Exploring Mekong region futures project' (Dr John Ward, Department of Foreign Affairs and Trade—CSIRO Research for Development Alliance, Australia) and 'Understanding the *agricola economicus* in Cambodia' (Mr Peter Roggekamp, Cambodian Agricultural Value Chain Program).

Trajectories of rice-farming households in mainland South-East Asia

Rob Cramb[1]

Abstract

The five countries of mainland South-East Asia (MSEA) are undergoing the major agrarian and demographic transitions associated with rapid economic growth, with significant implications for the livelihood trajectories of rice-farming households in the lowlands. The experience of early-transforming countries, notably Thailand, provides clues to the possible trajectories of late-transforming countries such as Laos and Cambodia. The growth in incomes and reduction in poverty has led to a diversification of diets, with rice taking on less significance. The sharp drop in fertility has provided a 'demographic dividend' to rural households, reducing the dependency ratio, slowing the growth in the number of households, and slowing the reduction in farm size. Combined with the rise in rural–urban and cross-border wage migration, this demographic trend has created a shortage of farm labour and increased the incentive for adoption of labour-saving innovations, notably mechanisation. Improvements in infrastructure and the growth in demand for a wider range of agricultural products have increased the returns to non-rice crop and livestock activities relative to rice. Although the share of agriculture in the economy (and of the rice sector in particular) will continue to fall, the overwhelming trajectory is not one of agricultural decline but of farm and livelihood diversification—with rice cultivation still an important component—helping to lift many rice-farming households out of poverty.

Introduction

This paper is based on the ongoing Australian Centre for International Agricultural Research (ACIAR) Project C2012/229 (*Review of rice-based farming systems in mainland South-East Asia*) which aims to provide: (1) an analysis of recent trends and the current status of rice-based farming systems in both lowland and upland environments in mainland South-East Asia (MSEA); (2) an assessment of future trajectories in these systems over a 10–20-year planning horizon; and (3) a diagnosis of critical knowledge gaps and research priorities for these systems. MSEA comprises the five countries of Burma, Thailand, Cambodia, Laos and Vietnam. My focus here is on significant region-wide changes affecting the trajectories of farm households that manage rice-based farming systems, with particular attention to the lowlands.

In his recent book titled 'Unplanned development: tracking change in South-East Asia', Rigg (2012) questions whether we can predict future development pathways, given our inability to predict, or even explain ex post, some of the major changes that have occurred in past decades. These include the acceleration of South-East Asian economic growth, the unexpected onset of both the Asian (1997–98) and global (2007–08) financial crises, sudden political shifts (such as the 'doi moi' reforms in Vietnam), and lesser known farmer innovations and choices (such as the invention and rapid adoption of the motorised shrimp-tail water pump that universally replaced the pedal-powered water wheel in the Mekong Delta in the early 1960s).

It is certainly important to recognise that agricultural change is not easily extrapolated from past or current trends. Nevertheless, I argue it is possible to examine these trends, in conjunction with the

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influence of development interventions (policies, programs and projects) and possible biophysical and economic shocks (e.g. the collapse of rice price support in Thailand), to deduce what can be termed 'provisional or contingent trajectories', both in farm household systems (the basic unit of change) and in the village and wider agrarian systems in which farm households are embedded (Figure 1).

I am basing these provisional trajectories on the working hypothesis that there is a convergence in trends and responses in the rural economy in the MSEA region. In particular, recent trends in the lowlands of Thailand give us a clue to trajectories in the same agroecological zone in Burma, Cambodia and Laos, because of a broad similarity in the resource base, sociocultural features and rice-based farming systems, as well as direct links through investment, trade and diffusion of innovations.

Economic growth, structural change and rural poverty

Since the emergence of an industrial market economy in Britain in the decades around 1800, countries undergoing modern economic growth have all moved along a trajectory from being agriculture-based countries, in which subsistence-oriented agriculture accounts for the major share of employment and national income, to urban-based economies in which agriculture accounts for a small share of the economy relative to industry and services (Tomich et al. 1995). The World Bank (2007) refers to countries in the process of transition between 'agriculture-based' and 'urbanised' as 'transforming countries', in which 'agriculture contributes less to growth, but poverty remains overwhelmingly rural [and] growth in agriculture and the rural nonfarm economy is needed to reduce rural poverty and narrow the urban–rural divide' (World Bank 2007, p. 30).

The five countries of MSEA are all now experiencing the structural changes associated with modern economic growth and are classed as 'transforming countries', with first Thailand and more recently Vietnam moving firmly into this category, while Burma, Cambodia and Laos are on the margin between 'agriculture-based' and 'transforming'. The economic indicators in Table 1 help to highlight the relative positions of the five economies within this agrarian transition. All five countries were experiencing gross domestic product (GDP) growth rates of 5–8% in 2012, despite year-to-year fluctuations. Thailand had the highest income per capita, while

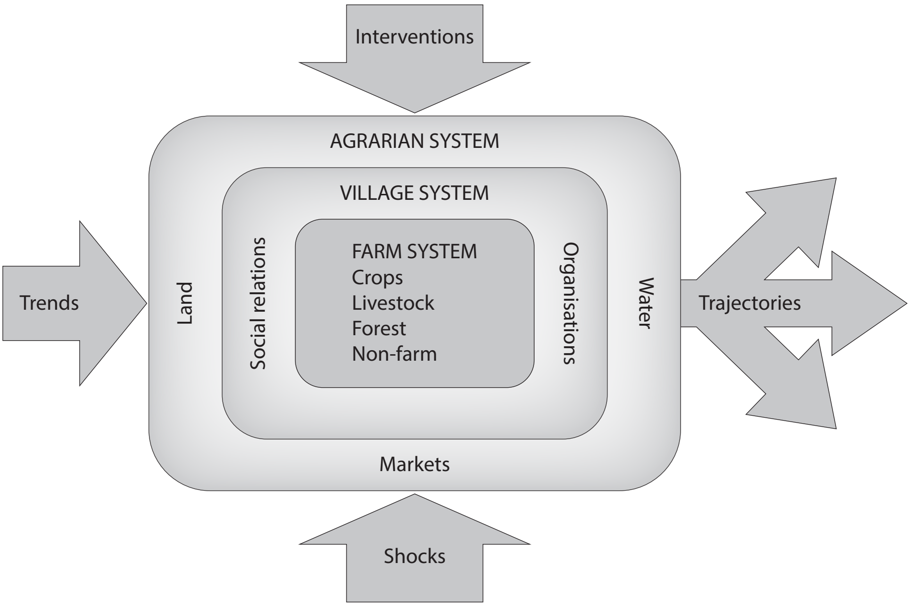

Figure 1. Influences on the trajectories of farm household systems

agriculture's share of the labour force had fallen to 39% and its share of GDP to only 11%. Vietnam ranked second in per capita income, and agriculture's share of the labour force (47%) and GDP (20%) were correspondingly higher. In the three poorest countries, agriculture's share of the labour force was still over 70%, and of GDP, closer to 30%. Nevertheless, time-series data show that all countries are following the general pattern associated with the agrarian transition, with agriculture growing significantly in absolute terms but declining in its share of employment and income.

Explaining the phenomenon of economic growth in MSEA is not straightforward. However, a number of factors have been at work, including: several decades of relative political stability; the abandonment of earlier collectivist economic strategies (which had been pursued at some stage in all countries except Thailand); a decline in dependency ratios associated with the demographic transition (see below); major investment in infrastructure in the Greater Mekong Subregion; and the growth of other Asian economies, leading to an increase in regional demand and foreign direct investment (Bird and Hill 2010; Glassman 2010; Rigg 2012). Although this economic growth has not necessarily been equitable or inclusive, there is strong evidence that it has been responsible for a rapid fall in the incidence of both urban and rural poverty from their historically high levels. In a paper prepared for the ACIAR Project C2012/229, Warr

Table 1. Economic indicators for countries of mainland South-East Asia, 2012

Indicator	Burma	Thailand	Cambodia	Laos	Vietnam
Population					
Total (millions)	61.0	64.4	14.8	6.5	88.8
Density (persons/km^2)	90	125	82	28	268
Annual change (%)	1.0	0.4	1.7	2.0	1.1
Urban share (%)	30.8	45.1	22.0	34.3	31.9
Agriculture's share of labour force (%)	70.0	38.9	71.1	73.1	47.4
Production and income					
GNI per capita (US$/year)	n.a.	5,210	880	1,270	1,550
Sectoral share of GDP (%)					
agriculture	30.5	11.4	35.6	27.6	19.7
industry	32.1	38.2	24.3	33.1	38.6
services	37.5	50.3	40.1	39.3	41.7
Growth of GDP (%)	7.6	6.5	7.3	7.9	5.2
agriculture	2.0	5.8[a]	4.3	3.3	2.7
industry	8.0	–4.8[a]	9.2	11.4	5.7
services	12.6	3.3[a]	8.1	9.2	5.9
Price change					
Consumer price index (%)	1.5	3.0	2.9	4.3	9.2
Food price index (%)	–1.5	4.9	3.2	5.9	n.a.
Trade					
Growth of exports (%)	n.a.	5.7	7.9	3.6	18.2
Main export destinations	Thailand India China	China Japan USA	USA UK Germany	Thailand China Vietnam	USA China Japan
Growth of imports (%)	n.a.	10.8	18.7	2.6	6.6
Main import sources	China Thailand Singapore	Japan China UAE	Thailand Vietnam China	Thailand China Vietnam	China Rep. of Korea Japan

[a] Sectoral growth rates are for 2011 when the overall GDP growth in Thailand was 0.3%.
Note: GDP = gross domestic product; GNI = gross national income; n.a. = not available; UAE = United Arab Emirates; UK = United Kingdom; USA = United States of America
Sources: ADB (2013); GNI per capita from World Bank, World Development Indicators; labour share for Burma and Laos from CIA (2014)

(2014) demonstrates that poverty reduction in MSEA has been driven by the growth of real GDP per person. In particular, econometric analysis indicates that the rate of agricultural growth—and to some extent services; for example, in Cambodia—and declines in the real price of food have been major factors in both urban and rural poverty reduction. These findings underscore the continuing importance of agricultural development during the process of economic transformation, notwithstanding agriculture's declining relative position in the economy.

Agricultural labour and wage migration

A key dimension of the agrarian transition is that the numbers employed in agriculture continue to increase but at a decreasing rate until the economy reaches a 'structural transformation turning point', after which not only the share but the absolute size of the agricultural workforce begins to decline (Tomich et al. 1995). Figure 2 shows that Thailand has already reached this turning point in the past decade. Projections for the other four countries depend on agriculture's (A) initial share of the total labour force (L), the rate of growth of the non-agricultural workforce (N^*), and the rate of growth of the total labour force (L^*). The lower the initial share (A/L) and the greater the coefficient of differential growth ($N^* - L^*$), the sooner the turning point will be reached (Tomich et al. 1995). For Laos, with around 73% of the labour force in agriculture, a growth of 2% in the total labour force, and a growth of say 4% in non-agricultural employment, the turning point is up to three or four decades away (though calculating the turning point for Laos is complicated by wage migration to Thailand, as discussed below). For Vietnam, however, with less than 50% of the labour force in agriculture, a lower rate of growth in the total labour force (just over 1%), and a higher rate of growth in non-agricultural employment (say 6%), the turning point could be reached within a decade. These differences have significant implications for the future demands on rice-based farming systems to absorb labour.

A particular feature of the movement of labour out of agriculture in the MSEA countries is the importance of cross-border wage migration, particularly from Burma, Cambodia and Laos into Thailand. An estimated 1.8 million legal and irregular migrants were living in Thailand in 2006, the latter comprising 75% of the total (Glassman 2010; Rigg 2012, p. 166). As Manivong et al. (2014) have shown for Laos, most of this migration is induced by greater employment opportunities and higher wages in Thailand, both of which are products of economic growth, structural change and industry policy in that country (Glassman 2010). Younger family members

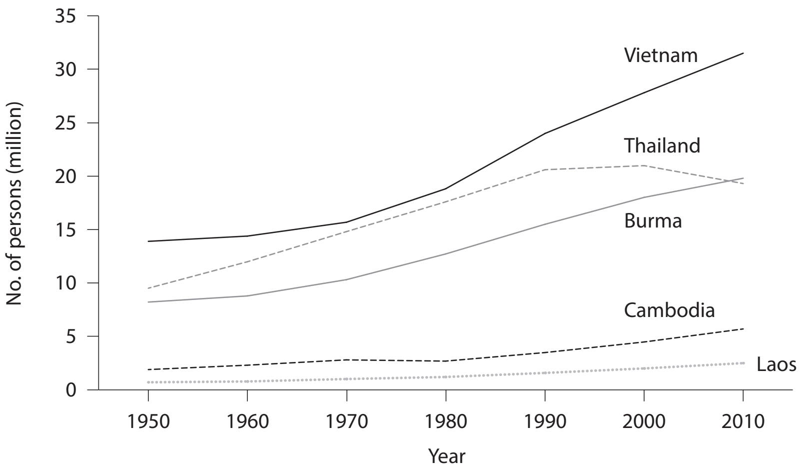

Figure 2. Number of persons economically active in agriculture in mainland South-East Asian countries, 1950–2010. Source: FAOSTAT in De Koninck and Rousseau (2012)

work in both rural and urban pursuits in Thailand for extended periods, filling gaps left by Thai workers, enduring considerable risk and hardship, and sending remittances to support their parental households in Laos. There are up to 300,000 migrant workers from Laos in Thailand—nearly 8% of the Lao labour force. A survey in 2011 of 180 rural households in six villages in varying economic circumstances in the lowlands of Champassak province in southern Laos found that 75% of households had family members engaged in non-farm employment away from the village (whether in Laos or Thailand), including 43% with one or more family members working in Thailand (Manivong et al. 2014).

Although the net effect of this cross-border movement is to contribute to a shortage of farm labour in the source countries, the dynamics of the phenomenon are such that most migrant workers eventually return to the villages from which they came, so the migration is in effect long-term 'circular' rather than permanent rural–urban migration. Rigg et al. (2012) identify a 'generational shift' from non-farm back to farm work among migrant workers within Thailand, especially among women in their 40s. Many migrants also return to their villages during economic downturns—an option they are highly motivated to maintain given the precariousness of their position in the urban economy (Rigg et al. 2014). There is evidence that the experience, skills and capital acquired by internal and cross-border migrant workers are more likely to be directed to diversified, commercial agriculture or non-farm business activities on their return home, as indeed when Thai migrant workers return to rural pursuits in their home village (Vandergeest 2012). This will continue to add to the impetus towards more diversified and market-oriented farm household systems in the region, though the extent of on-farm diversification in the lowlands depends to a significant extent on a household's access to natural resources, especially water for irrigation (Johnston et al. 2009; Fukai and Ouk 2012; Chea 2014; Manivong 2014; Manivong et al. 2014).

Consumption effects of economic change

An important feature of the agrarian transition is that, as incomes rise, not only does the proportion of income spent on food decline but the proportion of the food budget spent on the traditional staple also declines as diets become more diversified. In fact, there is evidence that in the rice-consuming countries of Asia, beyond a certain income level, rice becomes an 'inferior good'—that is, one for which consumption per capita declines in absolute terms with further growth in per capita income (Pingali 2004). This has already occurred in the high-income, urbanised countries of north-eastern Asia (Japan, South Korea and Taiwan) and, within MSEA, in Thailand, where rice consumption per capita had fallen to about 100 kg/person by 2007, compared with 150–165 kg/person in the other four countries (Figure 3). The income elasticity of demand for rice in Thailand is negative for both urban and rural households and, in the latter case, is comparable to the figure for South Korea (FAO 2014). In Vietnam, rice consumption per capita has also begun to fall and was reported to be 130 kg/person in 2013, down from over 160 kg/person in 2007 (Nguyen Van Bo, pers. comm. May 2014). Eliste and Santos (2012) found that even in Laos, which still has one of the highest per capita levels of rice consumption in the world, a significant portion of the population is already past the maximum consumption level and there has been a declining trend in per capita consumption since the mid 2000s.

Slower population growth and increasing incomes thus entail slower growth in the domestic demand for rice. This means that, other things being equal, it is easier for rice-producing households (and countries)

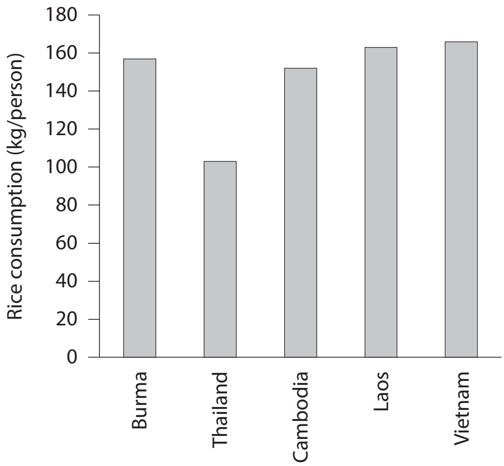

Figure 3. Rice consumption per capita in mainland South-East Asian countries, 2007. Source: International Rice Research Institute

to achieve self-sufficiency, even with modest levels of fertiliser use and yields. More generally, increased incomes in both urban and rural areas mean increased domestic demand for other sources of calories and protein to satisfy preferences for more diversified diets (Pingali 2004). These preferences, if translated into effective demand through adequate marketing infrastructure, induce more diversified farming systems, with greater emphasis on non-rice crops and livestock—although, of course, the demand may also be met through imports. This is not to downplay the need for further productivity gains in rice cultivation—in particular, through mechanisation and improvements in postharvest technologies, storage and marketing—given that increasing urbanisation and incomes mean that the demand for marketed rice, and higher quality rice, increases. However, it does underscore the observation that rice production will continue to become progressively less profitable than other farm and non-farm activities over time.

Demographic change and rural households

Interconnected with the agrarian transition in complex, recursive ways, the demographic transition is the period of change from the long-term historical state of high birth rates, high death rates and low (and fluctuating) rates of natural increase, to one of low birth rates, low death rates and low (or even negative) rates of natural increase (Bloom et al. 2003; Norton et al. 2010; Rigg 2012). During the transition between these two states, death rates fall first, largely due to improvements in public health, while the fall in birth rates lags behind by several decades, resulting in a period of accelerated population growth. This phenomenon has been observed in most countries over the past two centuries, with the MSEA countries experiencing rapid population growth since around 1950 (Figure 4), and entering the phase of declining fertility rates (and declining rates of natural increase) from around 1970 (Thailand), 1980 (Vietnam and Burma), and comparatively recently in Cambodia and Laos (Figure 5). Thailand already has a fertility rate below 2.0 children per woman, Vietnam and Burma are close to this figure and are projected to drop below it by 2025, while Cambodia and Laos are anticipated to drop below 3.0 children per woman but remain above the population replacement rate of 2.1 by 2025 (De Koninck and Rousseau 2012). Burma's early fertility decline, despite its late economic development, might reflect the 'reaction of a formerly well-educated population to hard times' (Jones 1999, p. 12).

The drop in fertility rates means households, rural communities and entire economies experience several decades of what has been termed a 'demographic

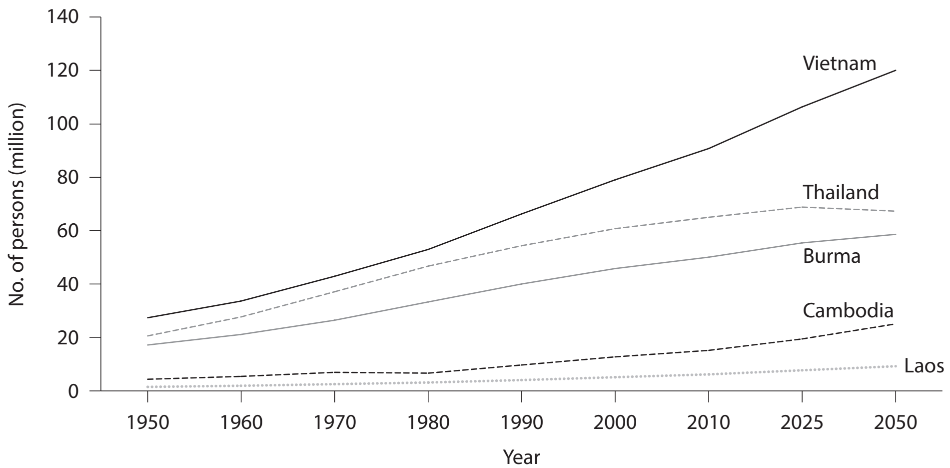

Figure 4. Population in mainland South-East Asian countries, 1950–2050. Source: UNPOP in De Koninck and Rousseau (2012)

dividend' (Bloom et al. 2003). During this transition to low fertility, the child dependency ratio declines while the elderly dependency ratio is still low; hence, although households are smaller, there is a high percentage of household members who are economically active. This has been confirmed in household surveys in the MSEA region in recent years (e.g. Newby et al. 2012; Chea 2014; Manivong 2014). The smaller number of children also means that, over time, there is less subdivision of land through inheritance, hence the rate of decline in average farm size is reduced. This trajectory can, of course, be adversely affected by large-scale land concessions and land reallocation policies.

Though dependency ratios are declining, the rural–urban migration associated with the agrarian transition means that the percentage of economically active household members who are farmers has also declined, especially among the young and educated. The movement of the working-age population out of farming has given rise to more complex rural households. In particular, split-generational households comprising grandparents and grandchildren have become more common, where the middle generation is absent, working in non-farm employment for extended periods and sending remittances to help support the parental household. Such households likely have less capacity to intensify or diversify their farming systems. As noted earlier, many of the migrant family members eventually return, but are more likely to invest their time and savings in market-oriented farming or non-farm activities rather than traditional rice farming.

More generally, the combined effects of declining fertility levels and increasing out-migration mean there is a widespread shortage of farm labour. Where landlessness is minimal, as in much of the lowlands, the supply of rural wage labour is limited, as most workers are needed to work on their own farms. Hence, farm wage rates have been increasing rapidly. Induced innovation theory tells us that if the price of labour is rising faster than the price of land, farmers will seek to substitute land for labour by developing and adopting labour-saving innovations (which increase the productivity of labour) in preference to land-saving innovations (which increase the productivity of land) (Hayami and Ruttan 1985). The relatively slow increase in levels of fertiliser use (a land-saving innovation) compared with the rapid rise in tractor use (a labour-saving innovation) reflect this innovation pathway. Vietnam, with abundant labour and scarce land, has reached by far the highest rate of fertiliser use in MSEA, though mechanisation is also proceeding; of course, mechanisation is not purely a labour-saving innovation but can facilitate more intensive and higher yielding cropping systems.

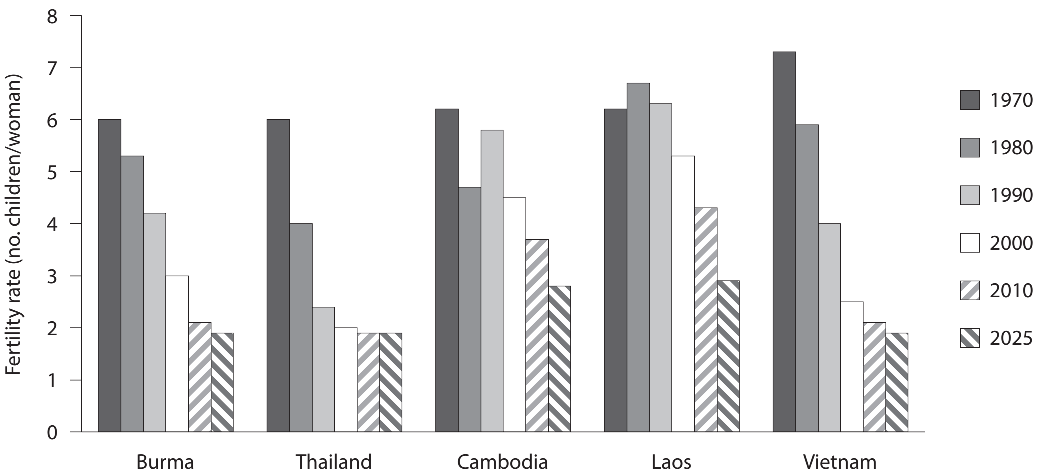

Figure 5. Fertility rates in mainland South-East Asian countries, 1970–2025. Sources: Rigg (2012); UNPOP in De Koninck and Rousseau (2012)

A case study from north-eastern Thailand

A long-term study of two rice-growing villages in north-eastern Thailand demonstrates the ways in which the foregoing trends are working out on the ground, as well as providing an indication of future trends in similar settings in neighbouring countries (Rigg and Salamanca 2011, 2012; Rigg 2012; Rigg et al. 2012). Situated firmly within the rainfed lowlands of MSEA, in the early 1980s these villages were centred—both socially and economically—on traditional, subsistence-oriented, wet-season rice cultivation, such as readily observed in the rainfed lowlands of neighbouring countries (Laos, Cambodia and Burma) until quite recently. A major element of the changes that have taken place in the subsequent quarter century relate to migration, and mobility more generally. 'The implications of this heightened level of mobility resonate through the villages: they help to explain, inter alia, the reshaping of families and households, the "geriatrification" of farming, the diversification of livelihoods, the fracturing of the village covenant, changes to agricultural production, and shifts in the production and reproduction of poverty and prosperity' (Rigg and Salamanca 2012, p. 90).

Table 2 highlights key trends in farming in the two villages. Notwithstanding the decline in fertility and the high incidence of out-migration, population growth had still led to a reduction in farm size, though not to the emergence of landlessness. However, farming had become less labour intensive due to the reduction in the availability of farm labour and the increased importance of non-farm occupations. This was translated into increased mechanisation (at the expense of draught animal power) and the adoption of labour-saving innovations such as seed broadcasting. Rice yields increased marginally due to improved varieties, better water control and increased use of inputs, but not enough to offset the 35% decline in farm size, leading to a fall in output per farm (Rigg et al. 2012).

The associated household trends are captured in Table 3. There had been a significant improvement in education, incomes, consumption (e.g. televisions) and household assets (e.g. motorbikes, pick-up trucks). The decline in fertility and the long-term out-migration of younger household members had led to a significant ageing of the farm and village population, an increase in female-headed households and an increase in cross-generational households (grandparents/grandchildren)—a phenomenon referred to locally as *liang laan* ('taking care of grandchildren') (Rigg and Salamanca 2011). Rigg (2012) shows how the shift to non-agricultural employment is correlated with age cohorts, with 80–90% of all cohorts in the village engaged in farming in 1982, whereas in 2008 farm employment ranged from only 15% of those aged 16–30 years to 85% of those aged 60 years and over. The pattern in 2008 was very similar for both genders.

Table 2. Farming trends in two villages in north-eastern Thailand, 1982–83 to 2008

Trend	Indicator	1982–83	2008
Increasing pressure on land	Mean landholding size (ha)	2.6	1.7
Farm labour in short supply	% of household workers engaged in farming	48	33
Increased farm mechanisation	% of households with one or more buffalo	86	1
	% of households with tractor	0	22
Changes in cropping practices	Households broadcasting rice	Very few	Most
	Households exchanging labour	Most	Very few
Increasing work outside	% of non-farm work	9	49
Outside work is increasingly non-farm	Ratio of farm to non-farm occupations	5:1	1:1

Source: Rigg and Salamanca (2012)

Table 3. Household trends in two villages in north-eastern Thailand, 1982–83 to 2008

Trend	Indicator	1982–83	2008
Rising importance of education	% of children with upper secondary or more	4	46
Ageing of farmers	Median age of household members in farming (years)	31	48
	% of household members aged 60+	4	22
Ageing of village population	Mean age of household head (years)	47	60
Increase in female-headed households	% of female household heads	14	43
More multi-sited, cross-generational households	% of households with grandchildren	22	57
Increasing consumption needs	% of households with television	25	96
Increase in vehicle ownership	% of households with motorbike	33	87

Source: Rigg and Salamanca (2012)

Conclusion

Notwithstanding significant inter-country differences, rapid economic growth is resulting in a widespread agrarian transition throughout MSEA that is drawing labour out of rice-based farming systems and altering the incentives for rice production relative to other farm and non-farm sources of livelihood. This is being accompanied by dramatic demographic changes that have slowed growth in both population and the number of farm households competing for available land, and reduced dependency ratios, conferring a 'demographic dividend' on rural households. This dividend may have been largely 'cashed in' in Thailand, where the rural population in particular is now ageing, but can underwrite several decades of agricultural and economic development for the other countries in the region, given supportive policies. Movement of labour out of agriculture and rural areas will continue but, apart from in Thailand, the agricultural labour force will continue to increase, perhaps for only a decade in Vietnam but for several decades in the later transforming countries of the region.

Given these socioeconomic trends, the overwhelming trajectory being pursued by rice-farming households in the lowlands is one of farm and livelihood diversification. Rice farming remains an important part of household livelihood strategies but, given the increasingly scarce and ageing farm workforce, the trend will be to greater use of labour-saving innovations and both self-provided and contracted mechanisation services. There will be less interest in maximising rice yields and output and more in stabilising yields to provide a resilient basis for the new, diversified livelihoods. Meanwhile, opportunities for commercial production of non-rice crops and livestock will become more attractive, particularly where water resources can be tapped in the dry season, and private-sector contract farming arrangements will become more prevalent, requiring a shift in the focus of research and extension activities and in government policies towards agriculture.

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The future of rice-farming systems—insights from the Mekong River Commission

Prasong Jantakad[1]* and Itaru Minami[1]

Abstract

Rice farming is the dominant basis of rural livelihoods in the Mekong region. As the world's biggest rice bowl, the Mekong region is self-sufficient in rice, with Thailand and Vietnam as the leading world exporters. Increasing rice exports are major policy priorities of the governments of the Lao People's Democratic Republic (PDR) and Cambodia. In contrast, the populations of rice-growing villages are ageing, with rice sales comprising about 20% of household incomes, and high dependence on remittances from the younger generation working in urban areas. In response to market forces, farming practices are shifting rapidly towards mechanisation and outsourcing, together with increasing chemical and fertiliser use. The use of groundwater to increase rice production is also expanding. The majority of rice farming remains rainfed and is therefore vulnerable to drought and climate change. Farmers are often exposed to significant risks in their efforts to increase profits. Within this context, wider disparities in wealth and wellbeing among rice farmers are emerging. The demand for better regulation, support services and safeguard measures is increasingly more pronounced. However, national rice-production policies are highly focused on self-sufficiency, and are unlikely to shift attention to equity and sustainability issues until country-level targets have been achieved; at which time, national agencies in the agriculture sector will have an even greater role to play. The Mekong River Commission perceives a development opportunity in the expansion of irrigation for food security and poverty reduction; however, the maintenance of existing irrigated land also requires significant ongoing effort. Fish raising in rice fields and canals, for example, is a key source of local food security, especially for the rural poor. Sustaining current rice production and food security in the region is dependent upon high-level technical and interdisciplinary capacity for integrated water resource management.

Overview of the rice sector

Rice farming is the dominant basis of rural livelihoods in the Mekong region. Rice cultivation occupies more than 10 million hectares (ha) of 18 million ha of the Mekong Basin's arable land. Although some of the countries in the region remain among the world's poorest, increased rice prices and production have contributed to reducing poverty. Rice yields in the region are relatively low as rice fields are largely rainfed and crop management is basic. About 40% of paddy fields are irrigated to some extent (MRC 2010a). The region as a whole is now self-sufficient in rice with current rice production at about 53 million tonnes (Mt). Thailand and Vietnam are leading rice exporters, and the governments of Laos and Cambodia are promoting rice exports as major policy initiatives.

The World Bank estimates that the long-term downward trend in the prices of agricultural commodities may be coming to an end. A real-term increase of 5.6% in agricultural prices was observed during 2005–07, offering a preview of a world with higher food prices (De Hoyos and Medvedev 2009)—and the Food and Agriculture Organization of the United Nations (FAO) estimates that cereal demand will grow at 1.5% per annum to 2030, though more slowly than in the previous two decades. Although

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rice is the staple food for the Lower Mekong River Basin population, per capita consumption has been declining in Thailand, as the wealthiest nation, where annual milled rice consumption is 100 kg per capita per year compared with 162 kg per capita per year in Laos (MRC 2010b).

Observations on rice farming

Income from rice cultivation varies significantly within the Mekong region. According to a recent study in four countries by the Mekong River Commission's (MRC's) Agriculture and Irrigation Programme (Shivakoti et al. 2014), net income from rainfed rice production ranged from US$25/ha to US$660/ha, and irrigated rice varied from US$210/ha to US$2,090/ha. Of seven samples of rainfed rice, the average gross margin (i.e. revenue minus expenses divided by revenue from rice production) was 38% compared with 50% in the case of 11 samples of irrigated rice.

Rice sales generally comprise a moderate share of household incomes. For a 15-km corridor of the Mekong River, per capita income from rice sales was only about US$16.50 per month on average, comprising about 18% of household income. Income from collecting 'other aquatic animals' (OAA) was about one-third of this value (Bouapao et al. 2013). Other studies report about the same or higher income from OAA collection. The lead author's interviews with three groups of farmers in Battambang, Siem Reap and Kampong Cham provinces in Cambodia revealed that remittances from the younger generation who work in urban areas were even more significant. Farmers reported that their sons and daughters each sent home US$30–40 per month.

The populations of rice-growing villages are ageing, and there are no longer many young people. As such, rice farming in lowland areas is rapidly becoming reliant on machinery and non-family labour and services. In the case of upland areas, industrial crops are replacing rainfed rice and other traditional farm household plantings. In terms of farming techniques, direct sowing has become dominant regardless of the rice variety or the season. Most interviewed groups reported applying significant amounts of fertiliser and chemicals. Interviewees also reported increasing inequality in wealth and wellbeing among rice farmers.

Opportunities and risks in irrigation

As rice production in the region is largely rainfed, the MRC perceives a development opportunity in the expansion of irrigation for food security and poverty reduction. Planned and ongoing hydropower development in the Mekong Basin will result in an increase in average dry-season flows by 19% at Kratie (Cambodia), with water levels rising by about 0.8 m in March (MRC 2011). MRC's Basin Development Plan Programme Phase 2 (BDP2) project, which examined various scenarios of current and planned developments, concluded that future flows throughout the basin will accommodate the expansions of irrigated area and water withdrawals planned by all countries. Given this, 'expansion of irrigation' is listed as one of the strategic priorities in the MRC's Basin Development Strategy.

Currently, the number of irrigation projects that plan to draw water from the Mekong mainstream is small compared with those planned along its tributaries. As the Mekong River flows through the lowest lying terrain, mainstream diversion necessitates extensive-scale works like the Khong–Loei–Chi–Mun water transfer project in Thailand. Such projects face considerable obstacles, including financing, environmental impacts, socioeconomic considerations, uncertain irrigation demand and labour availability, and have been taken into account in the aforementioned scenarios.

As more irrigation plans seek to extract water from tributaries, water imbalances may emerge within sub-basins. One study of current and future water availability found that irrigation demands were occasionally unmet in four subcatchments (Kirby et al. 2009).

Groundwater use for irrigation is not extensive in the region, and has not been incorporated in the river system modelling in the BDP2 scenarios. Groundwater use by crops is indirectly incorporated in the model—the hydrology of sub-basins is simulated by SWAT (Soil and Water Assessment Tool) models, which calculate evapotranspiration based on land cover. Individual irrigation tube wells are found in several locations as an increasing number of farmers irrigate rice through tapping groundwater. Aquifers in Prey Veng province in Cambodia, which are linked with Mekong River flow (Roberts 1998), are known to be extensively tapped for irrigation. Takeo province is also experiencing significant drawdown of groundwater levels.

The impact of irrigation on fish and OAA needs attention. Thousands of barrages, weirs, sluices, headworks and other river-crossing structures in irrigation schemes are prevalent in the region, obstructing the migratory movements of fish and OAA. They negatively affect fish guilds and potentially harm food security and the rural poor in the long run. Capture fishery and OAA provide the most important source of animal protein and are of higher nutritional value than rice. In addition, the capture fishery and OAA are common property resources and, for the poor, constitute their last safety net.

A significant number of existing irrigation schemes in Cambodia and Laos fall into the mainstream flood-risk area—beside 'creek' irrigation schemes in the Mekong Delta. Projects are also concentrated in the Dac Lac–Dac Nong area of the Vietnam highlands and in northern Laos, located in the high-risk areas for flash floods. Throughout the world, flood protection and irrigation schemes in lowlands are usually developed side by side, and often irreversibly alter ecosystems. The Vietnamese delta is moving in this direction. Cambodian irrigation schemes in flood-risk areas are characterised by fragmented development without being integrated in flood management areas. Current rice production relies on these unprotected fields and infrastructures.

Irrigation is assumed to reduce the risk of crop loss from droughts. Unless scientifically based management protocols for water diversion are established, however, the development of each additional irrigation scheme will only aggravate drought risk for other water users downstream. All MRC member countries need more capacity for basin management, and Cambodia and Laos lag seriously behind.

Efforts underway in MRC

Although extensive scenario assessments were conducted under the MRC's BDP2, many data and knowledge gaps remain in predicting the future of rice-based farming systems in the region. Here we outline some key MRC efforts in trying to fill these gaps:

- *Updating land cover and wetland mapping*. Land cover change affects run-off and evapotranspiration, which define available water for irrigation—specifically, the MRC is updating its 2003 land cover map.
- *Improving the decision-support framework*. The model applied for BDP2 contained 510 SWAT (Soil and Water Assessment Tool) sub-basins with an average size of 962 km^2. The MRC's latest model contains 910 sub-basins so that water balances can be assessed more precisely.
- *Social impact monitoring and vulnerability assessment*. In 2012, a livelihoods assessment, including household economy of rice farming, was conducted in the 15-km corridor from the Mekong mainstream.
- *Study on crop sector and rural poverty*. In 2013, the current condition of five crops (rainfed and irrigated rice, maize, soybean and cassava) and rural poverty was studied based on literature reviews, interviews and field visits.
- *Guidelines development for fish-friendly irrigation*. Irrigation weirs will be prioritised for improving fish migration, and guidelines suitable for the Lower Mekong River Basin will be proposed for design, construction, operations and evaluation of fish passage.
- *Pilot assessment of agricultural groundwater use*. Pilot studies on the state and potential of agricultural groundwater use are underway.
- *Study of food security under climate change*. Future food balance under climate change was assessed with existing data, and the AquaCrop model and Food Balances Sheets in 2013 for indicative food balance assessment. The study showed the likelihood of a food-insecure future in the region together with potential policy-response options.

Future of rice and irrigation

Rice production is the basis of rural livelihoods in the region. Its suitability as a dominant crop in land use will not change in the foreseeable future. However, market forces are leading rice farming into higher risk and less sustainable operations. Farmers are demanding proper regulation of input use, knowledge and market-access support services, and safeguard measures against natural disasters.

Irrigation systems will provide basic infrastructure for reliable rice production. System expansion can maintain achievements in food availability, reduce poverty and enable broad-based rural development—and assist with drought management. Where water constraints are severe, however, watershed management and storage developments become necessary supplements. Where systems are prone to flood damage, they need upgrading and protection from floods.

Cropping system diversification is an important rural development pathway and attention should be paid to non-rice crops as well as fish production. Significant capacity building is required in applying integrated water resource management (IWRM) principles based on solid science.

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Forum B. Intensification and mechanisation

Rapporteur’s synopsis

Suzie Newman[1]

Forum B panellists

The five forum panellists were:

- Dr Ouk Makara (Director, Cambodian Agricultural Research and Development Institute, Cambodia)
- Mr Vinoth Vansy (National Project Director, Sustainable Natural Resource Management and Productivity Enhancement, International Fund for Agricultural Development – Asian Development Bank (IFAD–ADB), Department of Planning, Ministry of Agriculture and Forestry, Laos)
- Dr Leigh Vial (Head, Experiment Station, International Rice Research Institute, Philippines)
- Dr Tran Duc Toan (Deputy Director General, Soils and Fertilizers Research Institute, Vietnam)
- Dr Yoichiro Kato (Scientist, International Rice Research Institute, Philippines).

Summary

This report discusses three key themes to emerge from the dialogue presentations and discussions, followed by a synopsis of deliberations on future directions and policy implications.

Key themes

Germplasm improvement

A partnership between the International Rice Research Institute (IRRI), the Cambodian Agricultural Research and Development Institute (CARDI) and Rice Research Australia Pty Ltd has seen 1,459 rice lines introduced (969 irrigated, 315 rainfed and 175 aerobic rice). The program has taken a two-pronged approach—testing introduced lines and supporting the local breeding program. It has focused on:

- agronomic performance—including yield (targeting 4.5 t/ha); short-duration lines for the dry season (90–105 days) and medium–long-duration lines for the wet season (120–130 days), and varieties that are tolerant to drought, flooding, and pests and diseases
- grain quality traits—including grain shape, aroma, chalkiness, colour and textural qualities.

In 2013, the program released a new variety ‘Damnoeb Sbai Mongkal’ and further releases are anticipated in the near future. Similarly, Australian research priorities have centred on revisiting the development of a northern Australian rice industry.

Discussion focused on the opportunities for high-end niche rice varieties with the consensus that market research is needed to determine if this option is viable. Variation in quality and determining its causes was seen as critical to delivering improved rice varieties to farmers.

Technology development and commercialisation

A shortage of farm labour is fuelling rising labour costs and the rapid increase in mechanisation. This has brought a new set of challenges to the rice industry in Cambodia and Laos. Australian Centre for International Agricultural Research (ACIAR) projects in these countries have examined appropriate management practices (e.g. irrigation regimes, land levelling and weed control) for optimising farmers’ investment in mechanisation, intensification and improved productivity. Improved technology and management practices can lead to yield gains of 24%. However, there is also a need to understand impediments to adoption if these gains are to be realised at the farm level. Similarly, sustainable intensification will require incorporation of non-rice crops into double- and triple-cropping scenarios.

Discussion centred on the engagement of the commercial sector early in the process to take machinery prototypes through to commercial adoption. This is

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likely to result in improved design, enhanced equipment reliability and cheaper unit costs. Questions also remain about viable models for machinery investment and whether farmer groups or contractors are better placed to invest in new technologies.

Capitalising on market opportunities

The Cambodian Government has set a rice export target of 1 million tonnes (t) per year by 2015. The International Finance Corporation (IFC) is working with rice exporters to reach this goal. Cambodian rice exports grew from less than 50,000 t in 2010 to 400,000 t in 2013. Cambodia's rice quality has been recognised with Cambodia winning the World Best Rice Award in 2012 and 2013.

Despite the growth in exports, a number of challenges remain, including:

- export procedures are costly and complex
- lack of proper infrastructure
- insufficient access to finance
- skilled labour gap
- high energy costs.

IFC has focused its efforts on improving paddy quality, enhancing milling efficiency and improving marketing of Cambodian rice.

Future directions and policy implications

Germplasm improvement

Rice production systems could be transformed by anaerobic germination combined with direct seeding. Varieties that can achieve this while still delivering good yield and quality offer exciting future opportunities. Varieties that are tolerant to different stresses (e.g. drought) are also likely to lead to significant improvements in these systems. Research needs to focus on how to make the best use of these varieties.

Mechanisation: public–private partnerships

Delegates discussed how to introduce the latest developments in mechanisation suited to smallholders. Many technologies (e.g. direct seeding) are more than 50 years old. However, developing machinery that works on small land parcels has been problematic, as has the capacity of smallholders to invest.

Major machinery manufacturers are now aware of the potential market in South-East Asia and have scope to develop technologies that meet smallholder needs. However, this depends on the capacity of governments to create operating environments conducive to business engagement and innovation. Import costs, taxes and the ease of doing business all affect the willingness of businesses to invest in different countries. Policy actors need to be cognisant of addressing any impediments to pro-poor investments by major businesses in South-East Asia.

Research institutions like IRRI have a role to play in the successful introduction of these technologies. Ultimately, 'hand-over' to the commercial sector is needed, so equipment should be low-cost, robust and reliable, and should deliver on its intended use. Failure to meet these criteria may put at risk the successful implementation of such technologies.

Technology transfer

Research teams across the program have developed some excellent innovations, but there is a significant gap between the information generated by scientists and what farmers need at their fingertips to produce the crop. More effort and investment is needed in developing farmer-friendly resources and training programs.

The issue of barriers to adoption was a recurring theme. Effectively integrating research outputs into farming systems necessitates much better understanding of such impediments.

Developing rice cultivars for Cambodia and Australia

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Abstract

Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/005 (*Improved rice germplasm for Cambodia and Australia*) identified the current and future rice germplasm needs in Cambodia through a survey of farmers, millers and traders, and used the results as benchmarks for developing new rice cultivars for Cambodia. The project evaluated 1,459 introductions from the International Rice Research Institute (IRRI) and Australia under aerobic or lowland conditions in-field for agronomic traits and in-laboratory for quality. The project has: (1) identified a number of lines that are suitable for direct-seeded aerobic systems; (2) identified 14 early lines suitable for irrigated lowland systems; (3) developed five promising backcross lines with improved grain quality and drought tolerance for rainfed systems; and (4) released a glutinous variety, Damnoeb Sbai Mongkul, in 2013. Additionally, the project has developed 246 F_5 photoperiod-insensitive lines for short maturity and good grain quality, and 99 F_3 photoperiod-sensitive lines for lodging resistance and quality. The project is still introgressing *Sub1* and AG1 genes into Phka Rumduol using molecular breeding, and identifying quantitative trait loci (QTLs; genes responsible for sensory quality traits) of Cambodia jasmine rice.

Northern Australia is a tropical region with significant potential for rice production. The Australian component of the project is to evaluate the direct-seeded aerobic system in northern Australia and to identify suitable rice germplasm through varietal trials at five locations across that region. The project evaluated 120 local cultivars and introductions from other countries under direct-seeded aerobic conditions. The results show that the yield of some adapted cultivars under direct-seeded aerobic conditions in northern Australia is as high as that in southern Australia, indicating that tropical northern Australia has potential as a new rice-producing region. The project has also identified a number of cultivars that can be grown in northern Australia.

Rice cultivars needed in Cambodia

A survey was conducted at the beginning of the Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/005 (*Improved rice germplasm for Cambodia and Australia*) in 2010 to identify the current and future rice germplasm needs of Cambodian farmers and traders to determine priorities and strategies for new germplasm development and dissemination. The survey included 12 focus-group discussions and 24 in-depth interviews in Kampong Thom, Kampot and Takeo provinces.

The survey showed that farmers prefer cultivars with the following agronomic traits: high yield,

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short growth duration for the dry season (DS) and medium–long duration for the wet season (WS), tolerances of abiotic (drought and flood) and biotic (pests and diseases) factors, and resistance to lodging. It also showed that all respondents prefer cultivars with the following grain-quality traits: big and slender grain, aroma, little chalkiness, high translucence, high head rice, and medium stickiness and texture after cooking. These results have been used for screening and developing new rice cultivars for Cambodia.

Screening for aerobic rice cultivars for Cambodia

In all, 175 aerobic rice lines/cultivars and 106 rainfed lines with drought tolerance—mainly introduced from the International Rice Research Institute (IRRI)—were continuously evaluated under direct-seeded aerobic soil conditions in the WS and DS during 2010–12 at the Cambodian Agricultural Research and Development Institute (CARDI), at the Bati station in Takeo province, and at the Prey Phdau station in Kampong Speu province. Selection was conducted based on agronomic and quality traits by the end of each season to gradually decrease the number of lines on which to focus. Trials were replicated three times with plots of six 4-m rows spaced 25 cm apart, and fertilised at a nitrogen–phosphorus–potassium (NPK) rate of 60:30:30 kg/ha, respectively.

The analysis showed that line IR 78936-B-9-B-B-B performed well consistently across seasons and out-yielded the reference variety Rumpe by 0.5 t/ha on average (Table 1). A few other lines like IR 80013-B-141-4-1, IR 66, and IR 07L122 showed promise. These lines mature in about 100–105 days and have a plant height of around 100 cm under direct-seeded aerobic conditions. Therefore, they have potential usage in Cambodia in the uplands in the WS and in the lowlands with limited irrigation in the DS.

In the 2013 WS, a subset of the aerobic rice lines was evaluated in replicated trials under both direct-seeded aerobic and transplanted lowland conditions at three sites to test their difference in adaptation to

Table 1. Mean values of aerobic rice lines across three sites—Cambodian Agricultural Research and Development Institute, Bati and Prey Phdau—in the wet and dry seasons during 2011–12

Line	Days to flowering 2012 WS (days)	Plant height 2012 WS (cm)	Yield 2012 WS (t/ha)	Yield 2012 DS (t/ha)	Yield 2011 WS (t/ha)	Yield overall mean (t/ha)
IR 78936-B-9-B-B-B	74	94	4.4	4.7	4.5	4.5
IR 80013-B-141-4-1	76	101	4.5	3.9	4.6	4.3
IR 66	71	90	4.1	4.3	4.6	4.3
IR 07L122	71	106	4.6	3.8	4.3	4.2
IR 06G113	76	93	3.8	4.5	4.2	4.1
IR 05A235	75	99	4.3	3.9	4.1	4.1
IR 78875-207-B-1-B	76	105	4.9	3.0	4.3	4.1
CT 6510-24-1-2	74	98	4.3	3.4	4.5	4.1
IR 06L136	72	93	3.9	4.0	4.2	4.0
IR 06L167	71	105	4.1	3.8	4.1	4.0
IR 06L141	78	91	4.1	3.9	4.1	4.0
Rumpe (CK)	71	86	4.2	3.5	4.4	4.0
IR 07L290	75	103	4.3	3.5	4.1	4.0
IR 05N412	81	97	4.3	3.5	4.2	4.0
IR 06L168	72	97	3.8	4.1	4.0	4.0
IR 69502-6-SRN-3-UBN-1-B	77	98	4.4	3.3	4.2	3.9
IR 06L164	72	100	3.9	3.4	4.4	3.9
IR 81040-B-78-U 2-1	72	104	4.0	3.2	4.4	3.9
$LSD_{0.05}$	1.1	3.9	0.4	0.33	0.47	–

Note: DS = dry season; WS = wet season; CK = check (control); LSD = least significant difference either environment. The counterpart trials had the same plot size (10 m^2) and were fertilised at the same rate (NPK = 60:30:30 kg/ha).

Among the six test lines, two lines (IR 06L136 and IR 81040-B-78-U 2-1) are better adapted to aerobic conditions, while another two lines (IR 06L167 and IR 69502-6-SRN-3-UBN-1-B) are better adapted to lowland conditions, and two lines (IR 06L164 and IR 06L141) are equally adapted to either environment (Table 2). The result indicates that there are differences in adaptation among these cultivars, although all are suitable for aerobic cultivation. It should be noted that all lines have a 7–10 day shorter growth duration under direct-seeded aerobic conditions than under transplanted lowland conditions (Table 2). The longer growth duration under the transplanting regime may simply result from 'transplanting shock'. However, no significant difference in plant height was observed for most lines between the two conditions.

Screening for early-maturing cultivars for dry-season cultivation in Cambodia

In the 2010 WS, 802 lowland and rainfed lines introduced from IRRI in 2010 were firstly evaluated under lowland conditions at CARDI. Subsequently, 114 selections were grouped into two sets (early and medium), and each set underwent field evaluations in replicated trials at three stations (CARDI, Bati and Prey Phdau) and further selection in the 2011 DS and WS. Thirteen promising lines were then identified and promoted to larger scale testing for three consecutive seasons. There were nine testing sites in three provinces (Phnom Penh, Takeo and Prey Veng) in the 2012 DS, 13 in five provinces (Phnom Penh, Takeo, Prey Veng, Kampot and Kampong Thom) in the 2012 WS, and 16 in the same five provinces in the 2013 DS. These varietal trials were either transplanted or direct seeded (broadcast), had three replications with 10 m^2 plots, and were fertilised at a NPK rate of 60:30:30 kg/ha, respectively. Only successful trials (9 in the 2012 DS, 8 in the 2012 WS, and 12 in the 2013 DS) were included in the data analysis.

Based on field performance in multi-season location testing (Table 3) and on grain quality, the six most promising lines (IR 03L148, IR 04N155, IR 06L164, IR 07L167, IR 77674-3B-8-2-2-8-2-4, and IR 83415-B-SDO3-3-AJY1) were selected for 'on-farm adaptive trials' in the 2014 DS; the last testing step before varietal release. Briefly, these lines are early maturing (about 100 days), short (about 100 cm in height) and high yielding (Table 3), and have acceptable grain quality (Table 4). It should be noted that line IR 06L164 performs well not only under lowland conditions but also under aerobic conditions (Tables 1 and 2), indicating its wide adaptation.

A new set of eight promising early lines was identified from another batch of 525 IRRI lowland and rainfed lines after equivalent continuous field valuation at a number of locations since 2011 WS. Table 5 shows their agronomic traits, and Table 6 shows their grain quality traits. These lines are currently under seed production, and will be promoted to on-farm adaptive trials in the 2014 WS for varietal release.

Improving drought tolerance and grain quality of Cambodian varieties

Backcross (BC) populations were developed at CARDI to improve the drought tolerance of Phka Rumduol, a famous Cambodian jasmine rice variety, and to improve the grain quality of CAR3, a local variety with drought tolerance. In all, 180 $BC_{3\text{-}4}F_4$ (Phka Rumduol/CAR3) and BC_3F_6 (CAR3/Phka Rumduol) populations were screened for drought tolerance in the 2011 DS, and subsequently 131 selections screened for yield in the 2011 WS. In the 2012 WS, 58 selected lines were evaluated under both lowland and drought conditions, and in the 2013 WS, 28 selected lines underwent field evaluation under lowland, drought, and aerobic conditions, and quality evaluation.

This effort identified five promising lines, listed in Table 7. Out of the five, three lines (CIR 827-2-4-B-5-1-1-27-1-2, CIR 827-21-23-B-5-7-47-1-13-3-1 and CIR 827-13-15-B-3-3-1-29-1-5) are similar in grain quality to their recurrent parent Phka Rumduol (Table 8), but out-yield Phka Rumduol under either lowland, drought or aerobic conditions (Table 7); two lines (CIR 792-19-3-3-105-1-B and CIR 792-6-2-5-57-16-B-2) are similar to the recurrent parent CAR3 in agronomic performance, but possess improved grain quality (Tables 7 and 8). These lines will be advanced to multi-location trials in the 2014 WS for further testing before possible release.

Table 2. Overall mean values of aerobic rice lines tested under both direct-seeded aerobic and transplanted lowland soil conditions across three sites—Cambodian Agricultural Research and Development Institute, Bati and Prey Phdau—in the wet season of 2013

Line	Aerobic conditions			Lowland conditions			Difference (aerobic—lowland)		
	Days to flowering (days)	Height (cm)	Yield (t/ha)	Days to flowering (days)	Height (cm)	Yield (t/ha)	Days to flowering (days)	Height (cm)	Yield (t/ha)
IR 06L136	73	94	4.5	80	100	4.0	–8	–6	0.4
IR 06L164	73	101	4.3	81	101	4.2	–9	1	0.1
IR 81040-B-78-U 2-1	71	109	4.3	81	108	3.6	–10	1	0.7
IR 06L141	77	99	4.1	85	97	4.1	–8	2	0.0
IR 06L167	71	106	4.0	79	107	4.8	–8	–1	–0.8
IR 69502-6-SRN-3-UBN-1-B	78	98	3.8	85	100	4.5	–7	–2	–0.7
Chul'sa (CK)	68	89	3.8	78	87	3.7	–9	2	0.0
Rumpe (CK)	72	85	3.6	80	90	3.3	–8	–6	0.3
$LSD_{0.05}$	2.3	4.0	0.8	1.3	3.5	0.8	–	–	–

Note: CK = check (control); LSD = least significant difference

Table 3. Overall mean values of early rice lines evaluated in three replicate trials under lowland conditions in three dry and wet seasons during 2012–13 in five Cambodian provinces (Phnom Penh, Takeo, Kampot, Kampong Thom and Prey Veng)

Line	2013 DS, across 12 sites					2012 WS, across 8 sites					2012 DS, across 9 sites[a]		
	DTF (days)	HT (cm)	Yield (t/ha)	>IR504 (%)	>Chul'sa (%)	DTF (days)	HT (cm)	Yield (t/ha)	>IR504 (%)	>Chul'sa (%)	DTF (days)	HT (cm)	Yield (t/ha)
IRRI 148	66	95	4.3	30	23	68	98	4.1	5	–7	67	93	3.9
IR 07L167	71	99	4.3	30	23	71	102	4.5	15	2	71	95	4.2
IR 03L148	69	99	4.3	30	23	72	102	4.7	21	7	NA	NA	NA
IR 77674-3B-8-2-2-8-2-4	69	92	4.2	27	20	69	95	4.2	8	–5	72	88	3.6
IR 06L158	69	98	4.1	24	17	69	102	4.3	10	–2	NA	NA	NA
IR 04N155	69	95	4.0	21	14	71	97	4.8	23	9	69	94	4.3
OM 5796	69	88	4.0	21	14	69	93	3.9	0	–11	NA	NA	NA
OM 2718	66	87	3.9	18	11	69	91	4.4	13	0	67	84	4.3
IR 06L164	70	94	3.8	15	9	69	94	4.5	15	2	NA	NA	NA
IR 83415-B-SDO3-3-AJY1	69	89	3.8	15	9	69	91	4.4	13	0	71	83	4.1
IR 73678-6-9-B	65	91	3.7	12	6	68	93	4.4	13	0	67	88	4
OM 3535	69	87	3.7	12	6	70	92	4.5	15	2	69	80	3.9
IR 06L132	67	92	3.5	6	0	68	93	4.4	13	0	67	92	4.4
Chul'sa (CK)	67	85	3.5	6	0	69	86	4.4	13	0	69	81	4.5
IR 504 (CK)	61	76	3.3	0	–6	64	87	3.9	0	–11	64	73	4.5
$LSD_{0.05}$	0.4	1.4	0.16	–	–	2.2	6.6	0.41	–	–	2.3	3.1	0.35

[a] In this season, the sites were across three provinces only—Phnom Penh, Takeo and Prey Veng

Note: DS = dry season; WS = wet season; DTF = days to flowering; HT = plant height; >IR504 = percentage of yield over IR504; >Chul'sa = percentage of yield over Chul'sa; NA = not available; CK = check (control); LSD = least significant difference

Table 4. Grain quality characteristics of the six most promising early rice lines for Cambodia

Line	Chalkiness (%)	Grain length (mm)	Grain shape (L/W)	Amylose content (%)	Head rice (%)	Gelatinisation temperature	Gel consistency (mm)
IR 03L148	3	6.8	3.5	27.1	65.0	I/L	100
IR 04N155	28	6.7	3.3	25.7	67.6	HI/I	98
IR 06L164	6	6.6	3.4	25.6	65.8	HI/I	90
IR 07L167	2	6.8	3.5	24.7	69.2	I	100
IR 77674-3B-8-2-2-8-2-4	5	6.7	3.9	26.3	62.6	I/L	75
IR 83415-B-SDO3-3-AJY1	8	6.5	3.4	30.5	68.3	I	100
Chul'sa (CK)	8	6.5	3.5	22.2	69.4	HI/I	90

Note: L/W = grain length/width; H = high; I = intermediate; L = low; CK = check (control)

Table 5. Overall mean values of a new set of eight promising rice lines evaluated at multiple locations in the dry and wet seasons of 2013 in Cambodia

Line	2013 WS									2013 DS					
	On-farm, 16 sites			Early set, 6 sites			Medium set, 6 sites			Early set, 4 sites			Medium set, 4 sites		
	DTF (days)	HT (cm)	Yield (t/ha)	DTF (days)	HT (cm)	Yield (t/ha)	DTF (days)	HT (cm)	Yield (t/ha)	DTF (days)	HT (cm)	Yield (t/ha)	DTF (days)	HT (cm)	Yield (t/ha)
IR 10L149	71	94	5.1	75	95	4.7	NA	NA	NA	72	92	3.7	NA	NA	NA
IR 04L186	73	98	5.0	77	97	4.6	NA	NA	NA	75	94	3.5	NA	NA	NA
IR 87753-5-2-1-3	73	98	4.9	NA	NA	NA	79	97	4.5	NA	NA	NA	79	86	4.1
IR 87808-21-2-2-2	72	97	4.9	NA	NA	NA	80	95	4.3	NA	NA	NA	79	95	3.8
IR 87759-7-1-2-2	73	97	4.8	NA	NA	NA	79	97	4.3	NA	NA	NA	80	93	4.0
IR 87760-17-2-1-1	72	98	4.7	NA	NA	NA	79	95	4.2	NA	NA	NA	80	97	3.7
IR 87753-5-1-6-4	72	97	4.6	77	99	4.8	NA	NA	NA	76	95	3.4	NA	NA	NA
IR 09L337	71	97	4.5	75	98	4.7	NA	NA	NA	72	93	3.5	NA	NA	NA
Chul'sa (CK)	69	89	4.4	73	89	3.9	NA	NA	NA	70	88	3.4	NA	NA	NA
$LSD_{0.05}$	0.4	1.1	0.19	1.8	3.8	0.50	1.9	3.6	0.42	1.9	3.9	0.51	2.0	4.7	0.53

Note: DS = dry season; WS = wet season; DTF = days to flowering; HT = plant height; NA = not available; CK = check (control); LSD = least significant difference

Table 6. Grain quality characteristics of a new set of eight promising rice lines for Cambodia

Line	Chalkiness (%)	Grain length (mm)	Grain shape (L/W)	Amylose content (%)	Head rice (%)	Gelatinisation temperature	Gel consistency (mm)
IR 04L186	14	6.8	3.5	26.7	46.7	L	95
IR 09L337	6	6.7	3.5	20.1	59.5	HI/I	100
IR 10L149	7	6.7	3.7	25.4	36.1	L	100
IR 87753-5-1-6-4	17	6.5	3.5	19.0	47.8	HI/I	97
IR 87753-5-2-1-3	7	6.6	3.6	19.1	43.9	I	75
IR 87759-7-1-2-2	4	6.7	3.6	20.2	46.0	I	90
IR 87760-17-2-1-1	6	6.7	3.7	20.3	49.7	I	95
IR 87808-21-2-2-2	4	6.7	3.7	20.4	36.9	HI	100

Note: L/W = grain length/width; H = high; I = intermediate; L = low

Table 7. Mean values of five promising backcross rice lines evaluated under lowland, lowland drought and aerobic conditions at Cambodian Agricultural Research and Development Institute in the 2013 wet season

Line	Lowland				Aerobic		Drought	
	Days to flowering (days)	Height (cm)	Yield (t/ha)	>PRD (%)	Yield (t/ha)	>PRD (%)	Yield (t/ha)	>PRD (%)
CIR 827-2-4-B-5-1-1-27-1-2	104	126	3.4	17	4.4	25	2.3	55
CIR 827-21-23-B-5-7-47-1-13-3-1	113	134	3.3	14	3.6	2	1.8	20
CIR 792-19-3-3-105-1-B	109	127	3.2	9	4.0	13	2.1	45
CIR 827-13-15-B-3-3-1-29-1-5	117	133	3.0	2	3.8	10	1.9	26
CIR 792-6-2-5-57-16-B-2	111	129	3.0	2	3.6	2	2.0	38
CAR3 (CK)	121	132	3.3	14	3.3	–7	2.1	43
Phka Rumduol (CK)	105	123	2.9	–	3.5	–	1.5	–
$LSD_{0.05}$	5	9	0.9	–	0.8	–	0.5	–

Note: >PRD = percentage in yield over Phka Rumduol; CK = check (control); LSD = least significant difference

Table 8. Grain quality characteristics of five promising backcross rice lines

Line	Chalkiness (%)	Grain shape (L/W)	Gelatinisation temperature	Gel consistency (mm)	Amylose content (%)	Aroma
CIR 827-2-4-B-5-1-1-27-1-2	2	3.3	I	76	15	Yes
CIR 827-21-23-B-5-7-47-1-13-3-1	0	3.5	I	86	14	Yes
CIR 792-19-3-3-105-1-B	5	2.7	H/I	93	14	Yes
CIR 827-13-15-B-3-3-1-29-1-5	0	3.5	I/L	86	19	Yes
CIR 792-6-2-5-57-16-B-2	5	2.7	H/I	95	13	Yes
CAR3 (CK)	20	2.7	I	55	23	No
Phka Rumduol (CK)	0	3.4	I	65	14	Yes

Note: L/W = grain length/width; H = high, I = intermediate and L = low; CK = check (control)

A glutinous cultivar for rainfed systems released in Cambodia

After testing in on-farm adaptive trials at a number of sites in three to four provinces, the project released one glutinous variety (Damnoeb Sbai Mongkul) in Cambodia in December 2013. The new cultivar typically yields 3.1 t/ha (Table 9) and is tall (150 cm), photoperiod sensitive (flowering in the middle of November) and moderately tolerant to both drought and flooding. It may, therefore, be widely grown in the WS in Cambodia. It has a big, slender grain (thousand grain weight, 34 g; grain length/width, 3.3), low gelatinisation temperature, low amylose content (1.6%) and has a soft texture after cooking.

Breeder seed has been produced and disseminated to 24 Provincial Department of Agriculture Offices for seed production in the 2014 WS.

Direct-seeded aerobic rice and lowland irrigation for northern Australia

Northern Australia has been subject to numerous attempts of agricultural development. The reliable summer rainfall and large volumes of stored water have stimulated interest in rice production over a long time. The project aimed to identify rice cultivars suitable for cultivation in northern Australia under direct-seeded conditions (where birds are less of a problem). The project has tested 120 introduced and local cultivars at five sites: Mackay in Queensland; Coastal Plains, Tortilla Flats and Katherine in Northern Territory; and the Frank Wise Institute at Kununurra in Western Australia. All trials were established using drill-seeding methods, and mostly managed as aerobic rice (some as lowland). They differed somewhat in plant density and nitrogen rates, but high potential yields were found at all sites.

Major findings are:

- under direct-seeded aerobic or lowland conditions, high yields can be achieved (Table 10), and are as high as those in the traditional rice region in southern Australia—therefore, direct-seeded rice is proven to be a successful rice system in northern Australia
- a number of cultivars that can produce a high yield consistently across dry and wet seasons have been identified (Tables 11 and 12)—considering the milling and cooking qualities (data not shown), Viet 4 seems to be the most promising cultivar for rice production in northern Australia
- blast (a fungal disease) and drought are two major constraints to rice production in the WS, and cold in the DS in northern Australia—these factors should be considered in a breeding program for northern Australia
- when grown in Mackay (Queensland), a Cambodian jasmine cultivar Phka Rumduol contains 2AP (jasmine aroma base) five times that of the same cultivar sourced from Cambodia, indicating that tropical northern Australia can be a potential region for aromatic rice production
- seedling vigour, an important trait that largely determines the weed competitiveness of a cultivar, is critical for weed control in the direct-seeded aerobic system.

Table 9. Yield of glutinous rice cultivar Damnoeb Sbai Mongkul evaluated in on-farm adaptive trials under rainfed conditions in the wet seasons of 2011–2013 in Cambodia

	2011 WS		2012 WS		2013 WS	
No. of trials	12		24		44	
Province	Kampong Thom Kampot Takeo		Battambang Prey Veng Takeo		Battambang Prey Veng Takeo Siem Reap	
Cultivar	Damnoeb Sbai Mongkul	Local cultivars	Damnoeb Sbai Mongkul	Local cultivars	Damnoeb Sbai Mongkul	Local cultivars
Yield (t/ha)	2.9±1.0	2.6±0.9	3.1±0.6	3.0±0.4	3.1±0.8	2.8±0.9
Range (t/ha)	1.3–3.9	1.2–3.9	2.0–4.2	2.0–3.9	1.7–4.4	0.8–4.0

Significant findings expected in the near future

A population of 365 F_6 recombinant inbred lines derived from the cross Phka Rumduol/Thmar Krem was created in the 2013 WS at CARDI, and delivered to IRRI and the University of Queensland for phenotyping and genotyping to identify quantitative trait loci (QTLs) or genes responsible for sensory quality traits of Cambodian varieties. This research is continuing and is expected to be completed in 2015. The identified QTLs/genes will be used in molecular breeding to improve grain quality.

Introgression of *Sub1* and AG1 genes into Phka Rumduol is taking place at IRRI. A new version of Phka Rumduol with submergence tolerance and anaerobic germination will be ready for use in 2 years.

In all, 246 F_5 lines derived from nine crosses aimed to develop photoperiod insensitive, early and high-yielding cultivars with good grain quality and with/without drought tolerance are being evaluated

Table 10. Yield range of rice cultivars evaluated under direct-seeded conditions in the dry and wet seasons during 2012–13 at five sites in northern Australia

Site	Year/season	No. of plots	No. of cultivars	Production system	Range in yield (t/ha)
CPS/ N-NT	2012/DS	77	29	Upland	4.5–1.2
JER/S-NSW	2012/DS	40	10	DPW	7.1–0.3
MKY/N-QLD	2012/WS	80	20	Aerobic	8.6–0.1
MKY/N-QLD	2012/DS	96	24	Aerobic	7.7–0.1
FWI/N-WA	2012/DS	80	20	Aerobic/Lowland	11.5–0.9
MKY/N-QLD	2012/WS	80	27	Aerobic	11.7–3.9
YDP/S-NSW	2013/DS	81	22	DPW	11.6–3.6
MKY/N-QLD	2013/DS	96	33	Aerobic	9.7–2.5

Note: DS = dry season; WS = wet season; CPS/N-NT = Coastal Plains, Northern Territory; JER/S-NSW = Rice Research Australia, Jerilderie, southern New South Wales; MKY/N-QLD = Mackay, northern Queensland; FWI/N-WA = Frank Wise Institute, Kununurra, Western Australia; YDP/S-NSW = Yanco Institute, southern New South Wales; DPW = delayed permanent water irrigation system

Table 11. Yield (t/ha) of promising cultivars evaluated under aerobic conditions at Mackay in Queensland in the dry and wet seasons of 2011 and 2012

Cultivar	2011 DS	2011 WS	2012 DS	2012 WS	Mean
ULP RI7	6.0	13.6	NA	NA	9.8
Viet 4	NA	13.5	6.1	NA	9.8
Doongara	6.7	14.8	5.3	10.7	9.4
IR 72	7.7	12.8	6.6	NA	9.0
Takanari	9.5	11.3	6.1	8.8	8.9
Lemont	7.7	12.0	5.3	10.2	8.8
IR 64	8.5	11.9	6.1	8.4	8.7
Langi	6.5	10.5	5.2	11.8	8.5
Kyeema	6.3	11.4	3.0	11.3	8.0
Bengal	8.8	NA	6.7	NA	7.8
Viet 1	NA	9.2	6.1	NA	7.7
YRL39	6.9	8.9	4.4	9.3	7.4
Tachiminori	5.8	10.8	4.1	8.9	7.4
Jefferson	7.8	NA	5.4	7.3	6.8
$LSD_{0.05}$	1.11	0.77	0.93	1.4	–

Note: DS = dry season: WS = wet season; NA = not available; LSD = least significant difference

Table 12. Yields and growth duration of rice cultivars evaluated under aerobic conditions in the dry and/or wet seasons during 2010–12 at Tortilla Flats and Katherine, Northern Territory, Australia

Cultivar	Tortilla Flats, 2010–11 WS			Cultivar	Tortilla Flats, 2012 DS			Cultivar	Katherine, 2011 DS		
	Grain yield (t/ha)	Stover yield (t/ha)	Growth duration (days)		Grain yield (t/ha)	Stover yield (t/ha)	Growth duration (days)		Grain yield (t/ha)	Stover yield (t/ha)	Growth duration (days)
Takanari	4.7	4.2	101	Viet 4	11.2	6.2	143	B6144FMR6	4.0	2.6	179
IR 24	4.6	6.6	107	Illabong	9.7	6.4	140	Yunlu29	3.9	3.9	162
PW10#	4.4	10.0	132	Quest	9.6	5.8	133	Tachiminori	3.5	3.3	168
Milyang23	4.3	5.7	102	Kyeema	8.9	6.8	140	Takanari	3.3	1.9	175
NTR426	4.1	5.8	111	IR 72	8.9	7.1	149	PSBRC9	3.2	2.3	181
Vandana	4.1	4.2	88	Viet 5	8.8	7.5	148	Lemont	3.2	2.0	182
Muncul	4.0	9.8	132	NTR587	8.4	6.4	153	IR 64	3.2	2.6	176
IR 64	3.9	5.4	106	Viet 1	8.3	8.6	150	Azucena	3.1	4.1	175
IR 72	3.6	6.2	106	NTR426	8.0	8.7	147	NTR426	2.9	2.3	194
PW7#	3.5	7.4	106	Fin	7.8	6.4	147	Vandana	1.7	2.5	160
IR 66	3.3	3.3	103	Lemont	7.6	5.5	138				
Tachiminori	3.1	3.4	95	Doongara	7.2	5.9	133				
Basmati370	2.8	–	111	PW7#	7.2	8.1	142				
Moroberekan	2.2	8.3	107	IR 64	6.9	5.9	146				
Azucena	2.2	4.7	102	Langi	6.7	4.8	141				
Yunlu29	2.2	4.0	103								
Amber33	1.8	–	110								
$LSD_{0.05}$	NS	5.6	9	–	4.4	3.4	3	–	1.4	1.1	3

Note: DS = dry season; WS = wet season; NS = not significant; LSD = least significant difference and advanced under both lowland and drought conditions in the 2014 DS at CARDI. Another set of 99 F_3 lines derived from four crosses aimed to develop photoperiod sensitive and high-yielding cultivars with good grain quality and lodging resistance have been produced. A new generation of improved cultivars developed in Cambodia can be expected in a few years time.

Quality and market evaluation of seven high-yielding, blast-tolerant and fragrant rice cultivars identified across northern Australia is ongoing. For some of these, commercial production in northern Australia may be expected soon.

The policy implications of project findings

Aerobic cultivars require less water than lowland ones, and grow well under direct-seeded aerobic soil conditions. Therefore, aerobic rice is useful in plains where irrigation is limited, and in uplands where there is no irrigation, but where rainfall can bring the soil to saturation frequently throughout the growing season. In Cambodia, the identified high-yielding aerobic cultivars are particularly useful in mountainous areas in the north-east and south-west, and in the drought-prone plains. Efforts are needed to introduce these new cultivars to farmers through national extension systems.

There are not many cultivars available for DS cultivation in Cambodia. IR 504 is still widely grown, though it is low in yield and poor in grain quality. IR 66 is relatively good in yield but poor in grain quality. In contrast, Sen Pidao is good in grain quality but poor in yield. The newly identified early cultivars are high yielding and have good grain quality, and may therefore provide a new generation of early varieties for DS cultivation in Cambodia.

Rainfed lowlands will continue to be the major rice system in Cambodia, where drought and flood are two major constraints to rice production. Breeding efforts by the project may bring new cultivars that cope better with these climatic stresses. Traditional cultivars that are widely grown in the WS in Cambodia are relatively low-yielding but have good grain quality. Future breeding efforts should focus more on improving yield potential while maintaining good grain quality.

In northern Australia, we have seen many differences between locations. The Ord River irrigation area lends itself to a DS water-seeded crop, but cold is still an issue during the early crop establishment and pollen microspore stages. Northern Territory is similar, with the option of WS crops in Katherine. Queensland has produced good yields from both WS and DS crops, but cultivars have been tested mainly as an aerobic or ‘alternate wetting and drying’ crop. All testing has had high nutritional inputs to gain highest potential yield data.

Northern Australia offers an opportunity to grow specialty rice types, such as the high-value jasmine (fragrant) types. It will take a good deal of technical and extension support to encourage commercial rice production in these regions if the crop is to compete with sugarcane, cotton and other traditional practices.

Resistance to blast and insect pests is another area that will require further breeding and enhancement to deliver successful high-yielding rice varieties for northern Australia.

Improved rice establishment and productivity in Cambodia and Australia

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Abstract

The aim of this 4-year project in Cambodia was to increase rice production through the development and adoption of: suitable direct-seeding technology for three main rice ecosystems; improvements to machinery; and development of weed management options appropriate to smallholder farmers. The target group of the project was small-scale lowland rice farmers in the provinces of Kampong Thom, Takeo and Kampot. The project has shown that there is significant potential for improvements to the livelihoods of rice farmers across the main farming ecosystems in Cambodia—from adoption of new crop establishment and weed management techniques, improvements in efficiency and increases in income, and extension of improved rice farming practices. The project demonstrated that productivity can be increased by up to 50% by a shift from double-cropping to triple-cropping irrigated rice, and average yield increases of 775 kg/ha have been achieved by the adoption of improved agronomy and crop management. The project has made a significant contribution to the scientific and technical capacity of scientists at the Cambodian Agricultural Research and Development Institute, the Provincial Department for Agriculture and the General Directorate of Agriculture, and the Royal University of Agriculture, which will support wider adoption of crop establishment and management technology in Cambodia. The final review of the project recommended a 6-month extension to September 2014 to develop technical information and technology adoption pathways to enable the full impact of the project to be realised. The new management approaches identified by the research should be further refined and translated into farmer extension programs.

Introduction

Rice accounts for over 80% of Cambodia's cropping area and 50% of the agriculture sector's output, the production from which is mostly consumed domestically. In all, 75% of Cambodian rice is produced in the main wet season under rainfed systems. The Cambodian Government has recently established a new rice policy for transforming Cambodia into a major rice-exporting country. This new rice policy emphasises developing a commercially oriented sector to improve national food security and reduce poverty, and is creating a momentum of development and extension activities across the country.

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The costs of labour required for transplanting rice have risen as a result of alternative employment opportunities. As a result, direct-seeded rice via manual seed broadcasting has dramatically replaced transplanted rice in the lowland systems. Although seed broadcasting is rapid, easy to implement, low in labour costs, and provides quick rice establishment, significant limitations are experienced, including high seed rate, high losses to predation and staggered crop emergence. Further issues are a high weed burden and uneven rice establishment due to poor land levelling and water management and non-uniform seedbed preparation.

Coinciding with the changes in crop establishment techniques is the growing use of farm machinery in rice production, replacing manual labour and animals for tillage and transportation. The number of two-wheel tractors (2WTs) in operation has increased markedly since the early 2000s, with a sharp rise observed over the past 3 years.

Methodology

This Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/037 (*Improved rice establishment and productivity in Cambodia and Australia*) is a component of the larger Mekong–South-East Asia Food Security Research program. The project was an outcome of a 2008 ACIAR/Australian Agency for International Development (AusAID) co-hosted workshop on 'research priorities for future improvement of the productivity and profitability of rice-based farming systems in Cambodia', where improving rice establishment methods coupled with better agricultural machinery was highlighted as a key priority. This project started in 2010 following further consultations and a series of field study visits during 2009 in collaboration with the new Cambodian Agricultural Value Chain (CAVAC) program, an AusAID-funded research-for-development initiative promoting modern farming practices. With a focus on three provinces in Cambodia—Kampong Thom (central), Takeo (south) and Kampot (south-west)—this 4-year project aimed to answer the following three questions:

- How can appropriate mechanisation help alleviate some of the constraints associated with manual seeding of rice crops?
- What management practices, including land preparation and pest, weed and nutrition management, would be appropriate to optimise farmers' investment in mechanisation and improve rice productivity?
- What constrains the successful adoption and integration of rice cropping technology options by farmers?

The project team made use of baseline and farmer focus-group surveys to benchmark practices and establish project directions to improve rice establishment methods, agricultural machinery use, farm practices and rice cropping productivity.

Baseline data combined with the development of the Cambodian Land and Environment Agricultural Resource (CLEAR) aimed to provide an accessible database to support agricultural development in Cambodia.

The project's agronomic program aimed to:

- provide data on the performance of different crop establishment and weed control options
- identify options to raise productivity of lowland rice cropping with a focus on dry season (DS) and early wet season (WS) opportunities
- build capacity through the development of training packages, publications and collaboration with, and mentoring of, Cambodian staff to lead adaptive research.

A series of benchmarking experiments validated crop establishment and agronomic options, which were then integrated in a systems trial conducted across a number of permanent sites in the three provinces over seven consecutive seasons. Additional experiments and demonstrations conducted in parallel included the optimisation of different crop establishment and management techniques, weed control options, and mechanised wet- and dry-seeding technologies with the potential to improve the productivity of Cambodian rice farming systems.

Extension activities and industry involvement were implemented in collaboration with CAVAC (initially) and project partners: the Cambodian Agricultural Research and Development Institute, the Provincial Department for Agriculture, the General Directorate of Agriculture—Departments of Rice Crops and of Agricultural Engineering—and the Royal University of Agriculture Faculty of Agronomy.

Results

A significant repository of baseline information has been collected and the CLEAR database is available to over 350 people trained in Cambodia. There remain some issues about the future accessibility of data and maintenance of CLEAR, which need to be addressed. Although access to extension services in Cambodia has been somewhat of a challenge, the project has demonstrated strong evidence from crop establishment trials and its extension activities, notably:

- the ability to reduce seeding rates from 200 to 400 kilograms per hectare (kg/ha) down to 80 kg/ha with mechanised row seeding, offering new opportunities to manage weeds in inter-rows
- significant productivity increases of 45–50% measured in the shift from double to triple cropping
- a strengthening shift to mechanisation primarily for seedbed preparation over the project period—in farmer focus discussion groups, 80% of farmers on average were found to use two-wheel tractors in the recession areas of Takeo province—with an early indication of significant farmer interest in mechanised drills for two-wheel tractors
- an average crop yield increase of 775 kg/ha compared with farmer practice, demonstrated across 44 'farmer field schools' (FFSs), due to adoption of improved agronomy and management—better quality seeds, improved land preparation, 15-day-old seedlings under WS line transplanting or DS drum seeding, fertiliser application based on soil tests, effective weed control and integrated pest management
- variation in weed infestations according to rice establishment method with a shift in some cases to problematic annual grass species under more intensive or direct-seeded systems
- effective weed control with combinations of hand weeding and herbicide application—subject to proper knowledge and equipment for timely, accurate and appropriate application.

The project observed the success of mechanised dry- and wet-sowing technologies in many parts of Cambodia and directly engaged with industry in testing and evaluating a range of seed drill machinery. A Cambodian-trialled seeder is a key output of the project, and a significant step towards supporting a locally manufactured rice drill for two-wheel tractors that meets the desired specifications of Cambodian farmers. Further economic analysis of mechanisation options will provide farmers and advisers with a clearer understanding of the potential returns on investment in machinery.

Finalising the project's results and recommendations

The project has been externally reviewed and a recommendation for a no-cost extension for a period of 6 months (until 30 September 2014) has been supported by ACIAR. The full scientific and community impacts of this project have not yet been realised. In the main, this is due to the highly exploratory nature of the research, conducted to increase knowledge of improved technology and management options for Cambodian rice agroecosystems from a comparatively low base.

The 6-month extension to the project—including a project team meeting to compare and synthesise findings, particularly the impacts of project findings on farmer incomes—will allow more detailed and better targeted recommendations to be generated from the experiments, data, observations and experiences of the project team during the past 4 years.

There is a strong need for extension and advisory networks to translate project findings into clear and appropriate recommendations for farmers that can be built into training packages. Local FFSs have demonstrated considerable success in reaching significant farmer numbers and significantly increasing farmer capacity. Efforts should focus on integrating key project messages into future FFS programs, which should continue to be supported as these provide a clear path to adoption of project-derived recommendations.

Future directions of rice farming in Cambodia

Although mechanisation in the farming sector continues to spread, results from this project highlight variable levels of machinery ownership and use across provinces and specific issues and opportunities for adoption of direct-seeder equipment. The rapid rate of adoption of mechanisation raises new opportunities, including gender-mainstreaming research in mechanised solutions, as the availability of labour changes in the developing economy of Cambodia.

Most farmers grow two crops a year in the irrigated rice-based farming systems. Triple cropping represents an opportunity for these farmers to significantly improve their income, where mechanisation input can become a significant catalyst. However, there remain issues in the transition to more intensive cropping, including:

- affordable credit for access to, or ownership of, machinery in villages
- labour and time constraints during the limited windows of opportunity for early wet-, wet- and dry-season (recession) rice crops
- access to high-quality seeds of new short-duration varieties suited to triple cropping
- informed extension advice regarding inputs and management.

Improvements to crop establishment techniques (weed control and rice-seeding technologies), crop nutrition and variety selection will help farmers improve yields and income under both double- and triple-cropping systems.

The project has played a significant role in introducing and demonstrating a range of crop establishment mechanised options for rice farming systems, including hydrotillers, drum seeders, sprayers and weeders, and seed drills. These activities have particularly focused on lifting the capacity of partners in using, evaluating and adapting these technologies. The Cambodian-trialled seeder developed within this project has generated strong interest following demonstration in Takeo, and is ready for targeted farmer evaluation.

The project has synthesised the observations and results of a series of baseline and replicated trials conducted by all partners into options for crop establishment by season, hydrology and topography for Cambodian lowland rice systems, and recommendations on the suitability of mechanised dry/wet direct-seeding options according to soil type, toposequence and season. Together with the development of weed management methods, these options should be further refined—for example, to identify the respective on-farm windows of opportunity that influence the economics of adoption—and translated into farmer-focused extension programs that could guide the development of more productive and profitable rice crop farming systems in the rapidly developing agricultural sector in Cambodia.

A key aspect of sustainable intensification lies in diverse crop rotations whereby profitable options for non-rice crops are also integrated into triple-cropping scenarios.

Agricultural intensification for food security in rainfed rice-based systems of southern Lao PDR

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Abstract

Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*) investigated pathways towards intensification of rice-based agricultural systems. Deployment of rice varieties well suited to defined environments and to meet known or expected constraints is a viable approach, but requires good knowledge of the yield-limiting and yield-reducing factors in the growing environments. Studies on nutrient – soil moisture regime interactions showed that farmers can manage these factors to enhance productivity. Soil properties can be modified to increase their moisture- and nutrient-holding capacities, which may lead to increased yields. Where water is available, dry-season cultivation of high-value crops extends production and raises household livelihoods. Increasingly scarce and expensive labour is stimulating the shift towards mechanisation and direct seeding to establish the rice crop. The realisation of expectations of high returns and the reduction of perceived risks are necessary for farmers to transition from subsistence to commercial production. This requires consistent policies that mutually reinforce agricultural, rural development and environmental goals. Intensification also requires comprehensive technical and extension support to ensure not only increased production but also increased benefits for farmers now and into the future.

Introduction

Intensification of agricultural production is producing more units of agricultural products per unit of all inputs. It includes novel combinations of these inputs and related innovations. Intensification occurs as a result of three elements: an increase in the gross output in fixed proportions due to the application of proportionately more inputs using existing technology; a shift towards more valuable outputs; and technical progress that raises land productivity. A related term is sustainable intensification, which entails optimising productivity and a range of desired environmental and other outcomes. This paper presents key results and conclusions of the research on crops and soils improvement undertaken as part of Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*), and provides pointers to the applications and policy implications of these findings for agricultural intensification in Lao PDR.

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Genetic variation and novel genes for intensification

Significant improvement in production and productivity may be gained through the use of appropriate rice cultivars that are resistant to environmental stresses, such as floods and droughts, or are resilient to these stresses. The project assessed the suitability of 13 modern improved Lao rice lines (TDK1, TDK6, TDK8, TDK11, VTE450-2, TSN2, TSN3, TSN7, TSN8, TSN9, PNG1, PNG3, PNG5) evaluated in on-farm trials in Savannakhet and Champassak provinces during the 2011 and 2012 wet seasons (WSs). Rice grain yield was higher in 2012 than in 2011, but there were consistent trends in both years. Rice lines differed significantly in their performance across all sites. Grain yield of TDK1 and TDK11 was stable across the 2 years of the trials. In contrast, TDK8, TSN8, PNG1 and VT450-2 showed plastic yield response, varying between the two growing seasons. Productivity of rice in Savannakhet was stable between the years of the trials; however, grain yield at the Champassak sites varied. Champassak's Soukhouma district produced the highest rice grain yield among the districts in 2012, and contributed significantly to the higher Champassak mean rice yield.

The rainfed environments may not be amenable to production of a single commercial cultivar and may be better served by a basket of lines suited for defined target environments. Further progress in developing high-yielding (beyond 4–6 t/ha), resilient, and pest- and disease-resistant rice cultivars may be realised through access to, and use of, non-Lao genetic resources for breeding of glutinous and non-glutinous rice in Laos. Institutional capacity for enhanced data analysis and interpretation, especially with respect to 'geography by environment' (G × E) to aid interpretation and guide selection and cultivar choice, is greatly needed. Rice growers need incentives (price support, market development initiatives, machinery development and enterprises) to raise crop productivity beyond subsistence levels. Prevailing market prices do not differentiate between 'premium' and 'ordinary' rice.

Intensifying productivity in upland rice-based systems is a major challenge. High-yielding traditional cultivars (Nok, Non, Laboun, Makhinsoung) from northern Laos and an aerobic rice line (B6144F-MR-6) were introduced and evaluated on upland farmers' fields in Xepon and Nong districts in Savannakhet. During the first year of the trials, these entries produced more than twice the grain yield of local check cultivars. However, average grain yields in 2012 were about half those in 2011. The introduced traditional lines from northern Laos consistently produced higher rice grain yield than local check cultivarss in both years. The work described here illustrates that creative, focused and effective use of internal/domestic resources and assets may deliver enhanced crop productivity. This argues for policies that support labour/resources for the characterisation, testing, 'mining' of desirable traits, and dissemination of Laos' heritage varieties. Basic underlying issues—such as the clarification and stabilisation of land-use rights/tenure in the uplands in order to engender responsible use and long-term planning for sustainability of resources and productivity—have to be resolved effectively and ethically.

Enabling farmers to harvest rice even when their rice fields have been inundated can be a means of intensifying production and assuring food security, and a means towards climate-proofing rice production systems. The International Rice Research Institute (IRRI) introgressed the *Sub1* gene, which stops growth for as long as 2 weeks and resumes growth when flood waters ebb, into TDK1 to give rise to TDK1-*Sub1*. TDK1-*Sub1* was field-tested successfully in flood-prone areas of Laos. Flooding occurred in all sites, but flood duration, turbidity and flow characteristics differed among sites. Field data showed that the productivity of the rice line is strongly influenced by the nature of the flood event; whether it took place during the growth of the crop, and the growing conditions after the flood. The variety must be officially released for use by Lao farmers in flood-prone areas. Variety release needs to be accompanied by financial support for dissemination and extension for its use and management by farmers. Issues concerning the uniformity and purity of TDK1-*Sub1* seed need to be assured through a national authority. In order to optimise access and give farmers in flood-prone areas more options, there is a need to prioritise the transfer the *Sub1* gene to other Lao rice varieties. Future breeding and selection activities for durable, flexible rice varieties for the rainfed lowlands may seek to combine submergence and drought tolerance with enhanced nutrient capture and use traits. Provision for labour, facilities and other support requirements are needed to realise these goals.

The rainfed lowlands of Laos and its neighbouring countries are undulating. Improvement of productivity, in the upper toposequence positions of rainfed lowlands, more prone to drought and, therefore, alternating anaerobic and aerobic soil states, was addressed with on-farm testing of three aerobic rice varieties (B6144-MR-6, IR 55423, TDK11), which can be grown in both upland and lowland conditions. These sites comprise the most drought-prone environments in the rainfed lowlands. Rice breeding, selection and testing for drought tolerance, and alternating aerobic and anaerobic conditions in these areas have positive spillover effects on similar efforts in other rice production systems. Recognition of the significance of these rainfed systems from government to its development partners may stimulate support research and development in these ecosystems.

Nutrient × water interactions

With soils of low fertility, low water-holding capacity and variable rainfall, Lao farmers are reluctant to apply fertiliser due to unreliable crop yield responses. We sought to explore opportunities to use combinations of nutrient doses, at rates likely to be economically viable, along with supplementary water application and choice of rice lines to vary the risk of crop loss. Two nutrient treatments (nil; NPK 60:30:30, i.e. nitrogen at 60 kg/ha, phosphorus at 30 kg/ha and potassium at 30 kg/ha), two water treatments (supplementary; nil) and three rice lines were tested on-farm in Savannakhet and Champassak in 2009 and 2010. Locations accounted for 62% and nutrient/water treatments and their interactions accounted for 38% of the variation in grain yield. Rice productivity responded to supplementary water only when nutrients were adequate. At the Savannakhet sites only, there was greater response to NPK and water with line TDK1 when soil fertility was low. These results indicate that farmers have a choice of management options (rice line, water, fertiliser) to raise rice productivity and their livelihoods.

The options that farmers may employ are knowledge intensive, hence there is a need for investments to develop capacity to access, understand and implement these management technologies. The sensitivity of farmers to risks, which impedes intensification, raises the urgent need for the establishment of risk-reduction mechanisms, such as crop insurance.

Fertiliser rates to attain pre-set target yields

Site-specific nutrient management aims to apply the correct amount of nutrients in the soil to achieve uniform crop stands and achieve target crop yields. We estimated the amount of fertiliser (NPK) based on soil properties needed to achieve a national target rice grain yield of 5 t/ha for a range of sites, using a yield prediction model. These rates were field-tested to validate the recommended rates. The fertiliser rate generally recommended nationally for rice (60:30:30) gave the best economic returns. Model-recommended rates achieved target yield in some sites, but these rates were so high that they were uneconomical. Intensifying production through better fertiliser use efficiency has been tested elsewhere and proven successful.

The modelling approach employed in this work may need to be revisited to identify the assumptions and conditions for successful intensification through nutrient management. The key idea from this work and related research on dry season (DS) crop diversification and intensification is that incentives have to be set up for more efficient use of resources and enhanced productivity.

Improving soil characteristics

The logic of this line of research is that improving soil physical and chemical properties will lead to improved nutrient- and water-holding capacity, resulting in improved production. Low levels of bentonite clay were applied to soils in Thasano district of Savannakhet province and in Pakse district of Champassak province. Soil physical properties improved slightly in Pakse compared with Thasano. In contrast, soil chemistry was better at Thasano than at Pakse. Grain yield was consistently higher in plots treated with 1 t/ha of bentonite than the other plots in the 3-year experiment in Thasano. In contrast, bentonite application, at any rate, had little or no effect on rice grain yield in Pakse. These results indicate that the positive effect of bentonite on grain yield at Thasano was due to improved soil water-holding capacity rather than enhanced nutrient supply or holding capacity. Improving soil characteristics through the application of clay such as bentonite, organic matter and recalcitrant carbon (biochar) have been reported to have a positive effect on crop production (Asai et al. 2009; Mekuria et al. 2013). However, the rates of application of soil amendments in these reports were 5–10 times greater than those used in Savannakhet and Champassak.

There is an urgent need to embody management of soil and soil properties in the education and knowledge resources of land/agriculture managers and farmers. This may be implemented through the reform of agricultural extension and education to emphasise the role of land, soil and water resources, and how to manage them efficiently, productively and sustainably.

Post-rice crop production

Rice fields in rainfed lowland areas in the DS are usually fallowed and grazed by livestock because little or no water is available for crop production. On-farm reservoirs capture rainfall during the WS and carry-over to the DS water, which farmers utilise for multiple purposes including DS cash crop production. Some farmers use shallow tube wells meant to supply domestic water needs for DS cropping as well. DS crop systems in southern Laos are akin to multispecies home gardens rather than monoculture stands. Exceptions arise where surface water resources are abundant enough for parcels of land to be in pure maize culture.

In marked contrast to WS rice production, farmers willingly invested in fertilisers for their DS crop production. This may be because crops were targeted for markets, the land area and corresponding amount of fertiliser needed was small, and there were fewer risks involved in the enterprise. Significant amounts of residual fertiliser were found in some farmers' fields, mainly on sandy soils in Champassak, which had positive effects on rice production in the subsequent WS rice crop. Sweetcorn and long beans provided farmers with higher cash income compared with other crops. Crop prices, however, varied and differed significantly among the locations. Savannakhet prices for the DS crops were generally higher than in Champassak.

Stimuli to encourage farmers to engage in DS 'non-rice' production may include information and resources on how to save rainfall and efficiently use it in the DS, and technologies for enhanced use of ground and surface water resources. Programs to enhance marketing of DS produce coincident with campaigns to encourage the consumption of local over imported products would be beneficial to both farmers and consumers. Financial incentives to farmers may involve reduced and/or supported input prices for DS crops. Similarly, availability of better information on supply and demand trends for agricultural produce and inputs in local and distant locations would help in the choice of crops to grow and inputs to apply to crops.

Mechanisation and direct seeding

Labour-saving technologies have the potential to both improve the economic performance of rice production, and at the same time free up labour to be directed towards other activities. Mechanisation in rice production is still in its early stages in Laos, but with increasing scarcity of labour, farmers are beginning to turn to timelier, less labour-intensive and cheaper alternatives to human labour in farm operations.

Labour-saving, as a necessary requirement to intensification of rice production, may involve deploying direct-seeding technologies that may take the form of broadcast or drill seeding. Direct seeding does not require the establishment of a seedbed and the time required to establish a crop is significantly less compared with transplanting. Hence, there is much more flexibility in the timing of crop establishment and 'fitting' the crop into the season. Field data showed that broadcast seeding required similar land preparation to transplanting—ploughing, harrowing and levelling operations, with concomitant labour, time and water costs. In contrast, drill seeding requires less land preparation, and hence less labour, especially if reduced tillage methods are employed. Drill seeding needs a tractor and a drill seeder, which, through proper placement of the fertiliser with the seed, may use less fertiliser without a yield penalty. The drawback of drill seeding is that herbicides—and/or other labour, knowledge, management and resources-intensive technologies—may need to be deployed to control weeds.

There is a need to establish and institutionalise research and development on mechanisation for agricultural intensification in Laos. These will support the growth of local manufacturers and downstream mechanisation-related enterprises, such as spare parts and lubricants dealers and repair facilities. These are needed to ensure the growth and sustainability of mechanisation to support intensification of crop production.

Ecological intensification

Concomitant increasing of production and minimisation of the production system's environmental footprint—through sharply targeted and efficient use of fertilisers and other agricultural chemicals, lower emissions of greenhouse gases and contributing to the maintenance of environmental services and public goods (clean water, carbon sequestration, flood control, groundwater recharge)—are highly desirable outcomes, but are rarely achieved together.

Farmers target rice with the 'perennial' trait for one sowing, which is then left on the field to grow and develop over several seasons. During cycles of growth of perennial rice, grain and/or aboveground biomass may be harvested. These rice lines, by maintaining groundcover on sloping uplands, may minimise soil erosion and produce grain and forage for livestock, with the added convenience of minimised labour for crop establishment. Rice lines from crosses of wild rice (*Oryza longistaminata*) and an established rice cultivar (RD23) were tested in Savannakhet and Champassak. Grain yield among the rice lines differed significantly, but were low compared with inbred rice lines. This line of research is in the early stage of development, but foreshadows a more sustainable way of raising crops in the uplands. It raises the possibility of minimising soil erosion, and regulating run-off water and groundwater recharge, especially in the uplands. The research has a strong gender dimension as it holds the potential for reducing the drudgery of direct seeding rice by 'dibbling', done mostly by women, at the beginning of each WS on upland slopes. For this line of research to flourish, an official recognition of perennial rice as a promising approach for the uplands is needed. Establishment of scientific collaboration with international institutions for advanced research on perenniality in crops in China, Australia and the United States of America would enable Laos to participate and gain access to research programs, facilities, expertise and products.

Use of ecological principles to control pests such as rice gall midge (RGM)—an insect with a larval stage that causes rapid elongation and eventual death of the rice tiller it is infesting, reducing tiller numbers and eventually grain yield—offers opportunities to minimise or completely eliminate the use of insecticides, which may have effects beyond the time and place of application. The project investigated the following three approaches:

- resistance/plasticity centres on the screening of cultivars and lines for resistance to RGM and testing of agronomic practices to stimulate recovery from RGM damage (e.g. fertiliser application after the height of infestation to stimulate tillering)
- pest population control in large areas is the end goal of this work and revolves around testing the effectiveness of synthesised pheromones to attract male RGMs, which may lead to the manufacture of effective baits for trapping male RGMs and thereby skewing the local population structure of the pest
- ecological engineering or modifying the rice environment through the cultivation of profusely flowering crops (e.g. sesame) and/or other flowering plants to attract and favour population growth of predators and parasitoids of RGM, leading to control of RGM populations.

Intensification need not damage the resource base or the environment in which it is embedded; however, there is need for ecological concerns and perspectives to be aired widely, and ecologically based solutions to be adopted and implemented. Policies need not be based on single straightline approaches, employing single 'fragile and unstable' solutions, when multiple approaches may be more stable and more widely adopted.

Research–policy nexus

Intensification connotes increasing levels of production output. Research makes it possible to learn about basic principles underlying systems and to develop technologies that deploy inputs and resources efficiently and effectively to increase productivity. However, gaining knowledge and developing technologies are just part of the intensification equation.

Risk-averse farmers, for example, usually apply little or no fertiliser because drought or flooding may wipe out the crop. Volatile rice prices, unfavourable input/output price ratios, and weak market access also discourage farmers from spending on fertilisers and other agricultural inputs. Water collected and stored in small on-farm reservoirs and water pumped from rivers and/or from the ground make it possible for farmers to apply supplemental irrigation during drought events and engage in post-rice DS vegetable or pulse crops, or forage crop production for livestock. The availability of water during the DS which enables cultivation of high-value crops destined for known, defined markets may move growers to apply fertiliser and other agricultural inputs and invest in more-intensive management practices.

Similar considerations underpin farmers' use and management of other agricultural inputs, including their own labour, and determine the success and sustainability of agricultural intensification. The realisation of expectations for high returns and the reduction of perceived risks are necessary for farmers to transition from subsistence to commercial production. This requires consistent policies that mutually reinforce agricultural, rural development and environmental goals. It also requires comprehensive technical support to ensure that intensification yields not only increase production but also increase benefits for farmers now and into the future.

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‘Bring to market’: Cambodian rice—the experience of the International Finance Corporation in Cambodia

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Abstract

The International Finance Corporation (IFC) has implemented the ‘Cambodian rice’ project—Rice Sector Support Programme: 2012–2015—to engage in development of the Cambodian rice export industry. This project provides support to the rice production, milling, and marketing components of the industry in an effort to remove some of the barriers to expansion of the industry. Funding of new seed multiplication systems and implementation of low-cost/innovative technologies has created improved yields and rice quality. IFC has fostered investment into the milling industry to enable infrastructure upgrades to process greater quantities of rice to standards expected of the international market. This, together with food safety education programs for mill staff and managers, has enabled millers to meet the certification standards required in high-value export markets. The final component of the program focuses on identifying new and potential markets for high-value Cambodian rice. Once identified, IFC facilitates export promotion and advertising and increased exposure of Cambodian rice exporters to those markets. These activities have played a significant role in the rapid expansion of the Cambodian rice export industry; however, a lack of infrastructure, poor availability of finance and high transaction costs for exporters remain constraints that may be resolved by development of effective policy.

The International Finance Corporation

The International Finance Corporation (IFC), established in 1956, is a member of the World Bank Group. The institution focuses on private-sector engagement to promote development and reduce poverty (IFC 2013). The mechanisms that IFC uses to achieve these aims include the provision of business advice and education, mobilisation of financial resources to foster private enterprise, creation of access to new markets, and provision of expertise leading to improved production efficiency and product quality. IFC now provides investment and advisory services to more than 100 developing countries. The institution has a global portfolio of US$56 billion, with approximately 10% of that invested in agribusiness. It is estimated that IFC projects have reached more than 3 million farmers in East Asia and the Pacific (IFC 2013).

IFC established the ‘Cambodian rice’ project—Rice Sector Support Programme: 2012–2015—to engage with the public and private sectors of Cambodia to transform its rice market by improving product quality along the supply chain. This project aims to bring more Cambodian rice to international markets and in doing so will assist the Cambodian Government meet its target to export 1 million tonnes (Mt) of milled rice by 2015 (Hatsukano and Tanaka 2014).

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Cambodian rice production employs approximately 80% of the population (Arulpragasam et al. 2004) and is a rapidly developing sector of the economy. Improvement in rice varieties and production technologies have resulted in rice production in excess of local demand, thereby enabling an export industry to develop (Baldwin et al. 2012). France and Poland have been the largest importers of Cambodian rice to date (ARPEC 2014), yet more opportunities remain in other regions. Current barriers to further expansion of the Cambodian rice export industry include a lack of food safety certification, inconsistent supply of high-quality rice and incomplete access to developing markets. IFC has invested more than US$4.5 million from the European Union, the Enhanced Integrated Framework (EIF), IFC and the private sector (millers and exporters) to reduce these barriers (IFC 2014).

The Cambodian rice project has three main components focused at different levels of operation within the supply chain. These include using high-quality seed and improved milling operations and efficiency. Additionally, the project aims to facilitate access to high-value export markets.

Rice production

Successful marketing of rice requires the production of high-quality rice that differentiates itself from its competitors. Fragrant rice varieties suited to Cambodian soil, climate and production methods continue to be developed in conjunction with the Cambodian Agricultural Research and Development Institute (CARDI). IFC has assisted the acquisition of improved genetic material and supported seed multiplication systems to produce commercial quantities of high-value rice varieties. Education programs have been created to enable farmers to adopt low-cost, innovative and production-enhancing technologies. The footprint of these programs has been successfully expanded with the use of radio broadcasting to farmers in remote locations. The direct engagement with growers in this component of the IFC project has resulted in larger quantities of high-quality paddy rice entering the supply chain.

Milling

Cambodia does not have the capacity to mill all the rice produced by its farmers (Shean 2010). Paddy is currently sold across porous borders to Vietnam and Thailand, representing a loss to the government (Singh et al. 2007). Traditional milling equipment is dated and does not exhibit adequate hygiene standards to meet export specifications. As such, there is a need to improve the milling equipment used to refine rice to standards suitable for the export market. To be competitive with other countries selling rice to Europe and the United States of America, it is necessary to improve food safety practices and, importantly, meet the certification standards of those customers. To this end, the IFC project has worked with private industry to fund investment in new milling equipment to enhance milling efficiency and product quality. The provision of food safety training programs for milling staff and adoption of mill management software and food safety systems by rice mills and re-processors has enabled the introduction of International Organization for Standardization (ISO) standards to rice millers. This certification actively opens the Cambodian rice industry to lucrative export markets.

Export marketing

Once high-quality fragrant rice is grown and it is milled in facilities that meet certification standards, the success of the industry is reliant on superior marketing of the product. The IFC project involves the development and implementation of a strategy to increase Cambodian exports—targeting niche markets purchasing fragrant rice at a premium price. IFC provides advisory support on potential and emerging markets likely to be suitable for Cambodian rice. Once identified, IFC assists in the production of brochures and advertising to expand exposure of Cambodian products to those markets. Importantly, IFC has facilitated the attendance of Cambodian rice exporters at international trade fairs, such as THAIFEX. In recent years, IFC has enabled 25 Cambodian rice exporters to attend these important international trade fairs. Not only does this bring greater awareness of Cambodian rice to buyers, but the rice exporters also have the opportunity to learn from their competitors. With the support of IFC, The Rice Trader (TRT) conference will be held in Cambodia in November 2014.

Success

Improvements to the Cambodian rice industry at the farm, miller and marketing levels have resulted in great economic benefit to Cambodia. Improvement in the quality of rice produced and greater production of fragrant (jasmine) rice for export has increased net sector income. In 2010, only 10% of exported rice from Cambodia was fragrant rice. In 2013, this value increased to 45%. The higher value fragrant rice is sold for US$1,100/tonne (t), while white rice is sold for only US$440–580/t (Giraud 2013). The improvement in rice quality has received international recognition. Cambodia has been awarded the world's best rice at world rice fairs in Indonesia in 2012 and Hong Kong in 2013. This success has had a major impact on the marketability of Cambodian-produced fragrant rice. Thus, rice exports have increased substantially in recent years. In 2008, approximately 4,000 t of milled rice was exported from Cambodia. By 2013, this had increased to over 400,000 t, representing an enormous transformation in Cambodian rice marketing. The rapid gain in export volume and the estimated proportion attributed to IFC involvement are shown in Figure 1. Not only has the volume of rice exported increased but so too has the number of countries buying Cambodian rice—from 35 in 2010 to 75 in 2013—thereby enhancing the resilience of the industry.

Challenges and policy implications

The gains from research and extension have resulted in farmers producing high-quality rice in greater volumes than previously possible. However, these gains in productivity have resulted in only small income gains to farmers. Enormous growth of the rice industry within Cambodia and neighbouring countries such as Vietnam and Thailand has led to increased production, resulting in dumping of rice on the market that has lowered prices of the commodity in Europe, East Asia and even Africa. In addition, the transaction costs associated with rice export from Cambodia are very high compared with those of neighbouring countries (Arulpragasam et al. 2004). Owing to transport costs, and formal and informal fees, the export price for Cambodian rice is US$50 more than for Thai rice (Singh et al. 2007). The cost of energy is also relatively high in Cambodia compared with Thailand and Vietnam (Hatsukano and Tanaka 2014). The World Bank index ranks Cambodia 135 for doing business and it would seem that lower trade costs need to be created for Cambodia to become globally or even, locally, competitive.

Rice millers experience insufficient access to finance (Hatsukano and Tanaka 2014). Investment tends to be in mill upgrades, but this comes at the expense of short-term working capital. Thus, the mills of neighbouring countries outcompete the local mills for access to the best-quality rice (Shean 2010). Incentives for local investment and regulation of paddy rice trade across borders are topics of potential policy development.

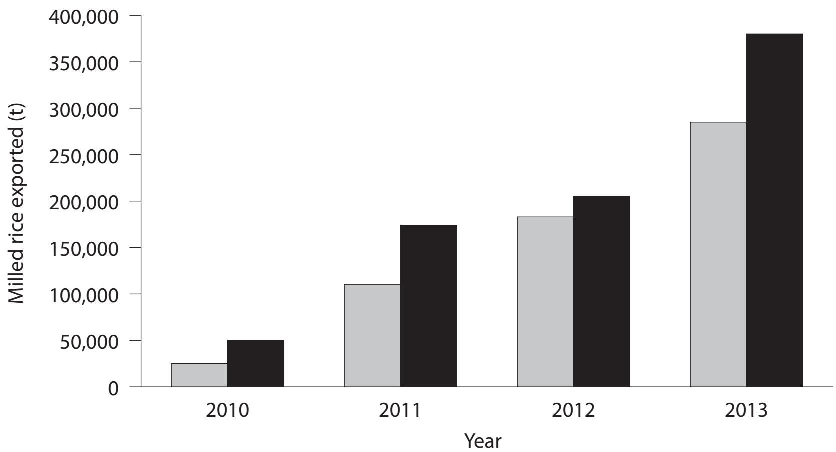

Figure 1. Milled rice exports from 2010 to 2013. Source: total national volume (black bars—adapted from Hatsukano and Tanaka (2014) and proportion attributed to the International Finance Corporation project (grey bars)

There is a lack of infrastructure within Cambodia—good-quality roads, bridges and ports—that inhibits the ease of trade flow (Baldwin et al. 2012). Even if that infrastructure was improved, rice exporters do not have access to enough shipping containers to export rice, as there are not enough containers coming into Cambodia. Government prioritisation of infrastructure on trade routes would enhance trade flow and aid efficiency of exports.

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Intensification and diversification leading to increased productivity and profitability of rice-based lowland cropping systems in Lao PDR and Cambodia

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Abstract

This paper describes factors determining crop intensification and diversification in lowland rice-based cropping systems in Cambodia and Lao PDR, and discusses how mechanisation may assist increased productivity and profitability in the region. The work is based on two recently completed Australian Centre for International Agricultural Research projects on crop intensification and diversification in these systems in Cambodia and Lao PDR, and a newly commenced project in the same context on mechanisation and value-adding for diversification. Both water and labour availability are identified as key resource limitations for intensification and diversification of rice-based cropping systems. The policy implications of these and other factors leading to increased productivity and profitability are discussed.

Introduction

We have recently completed two Australian Centre for International Agricultural Research (ACIAR) projects on crop intensification and diversification in lowland rice-based cropping systems in Cambodia and Lao PDR.

The first, ACIAR Project CSE/2006/040 (*Diversification and intensification of rainfed lowland cropping systems in Cambodia*), aimed to increase the range of crops grown under rainfed lowland conditions by promoting non-rice crop technologies that provide efficient water use and high financial return to the growers. Its objectives were to: (a) develop profitable double-cropping options for a rice/non-rice system for the rainfed lowlands in three provinces; and (b) define the water requirements for non-rice crops, determine the best use of small amounts of stored water, incorporate water use into available lowland models and predict the level of risk under mainly rainfed conditions of the diversified cropping systems.

The second, ACIAR Project CSE/2006/041 (*Increased productivity and profitability of rice-based lowland cropping systems in Lao PDR*), aimed to improve the productivity and profitability of the dominant lowland rice-based system, and to pursue diversification in suitable locations by adding non-rice crops under irrigation in the dry season. Its objectives were to: (a) select and test the best rice cultivars; (b) stimulate Lao smallholder farmers to evaluate direct-seeding options for rice; (c) develop profitable crop, water and soil-based management options for irrigated areas, and enable the addition of maize, soybean and other grain legumes into the rice-based lowland ecosystem; and (d) develop geographical information system (GIS)–based cropping suitability maps for defining the domains for deployment of the new technologies.

We have just commenced ACIAR Project CSE/2012/077 (*Mechanisation and value adding*

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for diversification of lowland cropping systems in Lao PDR and Cambodia), which aims to identify mechanisation options and postharvest technologies to enhance household livelihoods and food security in lowland rice-growing areas of Laos and Cambodia. The specific objectives are to: (a) assess crop mechanisation options for increased labour productivity; (b) evaluate agronomic and postharvest innovations for adding value; and (c) evaluate intensified, diversified and market-oriented cropping systems to take advantage of mechanisation and value-adding options.

In rice-based lowland systems, crop intensification can be achieved by double cropping of the rice crop, while crop diversification is commonly achieved by growing non-rice crops in the dry season (DS) following wet season (WS) rice. In general, rice crops in the WS are difficult to replace with non-rice crops, such that diversification is commonly achieved by replacing DS rice with non-rice crops, or adding a non-rice crop in the DS to the currently mono-cropped rice. General issues for achieving diversification and intensification in rice-based lowland systems in the Mekong region are described in detail by Fukai and Ouk (2012).

This paper summarises the main outputs from the two completed projects in relation to the topic of intensification, increased productivity and profitability of rice-based lowland cropping systems in Laos and Cambodia, using the framework we are developing for the new project. The paper describes factors determining crop intensification and diversification, and then discusses how mechanisation may contribute to crop intensification, increased crop productivity and profitability of rice-based lowland cropping systems. The policy implications of these matters are discussed.

Factors affecting crop intensification

The most common constraint for intensification, as reflected in the objectives of the Cambodian project (CSE/2006/040), is the lack of water available to grow a crop after WS rice. Commonly, WS rainfalls are not sufficient to have double cropping, and the lowland areas suitable for intensification are where canal irrigation or on-farm irrigation facilities are available. However, underground water is often not available for cultivation of crops later in the DS and the supply of water in the canal irrigation system may fluctuate. Common strategies for increasing cropping intensity in areas of limited water availability are as follows:

- *Reducing irrigation water use per crop, so that the limited irrigation water becomes sufficient to grow two crops*. For example, Vial et al. (2013) showed that irrigation water use can be reduced from the current furrow irrigation with high water input, and the maize crop can still produce a high yield in Laos (Table 1).
- *Growing quick-maturing crops or varieties after rice so that the irrigation water requirement is minimal*. The irrigation water requirement is almost proportional to the growing period, and hence a quick-maturing crop, such as mungbean, has a higher chance of success in double cropping than has a longer growing crop, such as cassava. Rice also consumes more water than most other crops of similar duration and hence it is common to be able to grow non-rice crops in areas where rice–rice double cropping is not possible.
- *Harvesting WS rice early so that the following crop may utilise some late-season rainfalls to supplement limited irrigation water*. This is commonly achieved by either planting quick-maturing rice varieties in the WS or planting WS rice early—enabling early harvesting, particularly for photoperiod-insensitive varieties. A number of promising lines that are up to 10 days earlier in maturity than commonly grown line TDK1 and produce comparable or higher yields are now available in Laos (Table 2), but even shorter duration rice can be developed with further breeding efforts (e.g. 100–110 days to maturity). One reason for late planting of rice in the WS is the use of transplanting, which requires soil to be saturated with water, and this may not be achieved for several weeks after the start of the WS. Earlier crop commencement and harvest can be achieved using direct seeding before soil saturation is reached. This may be achieved by drill seeding of rice. Our project in Laos examined the use of the seed drill for rice planting, as subsequent ACIAR projects have also done.

Another common constraint for crop intensification is the likelihood of rainfall events at the time of rice harvesting, which causes difficulty in drying paddies, particularly when harvested by a combine harvester. This prevents planting rice at particular times and reduces the chance of achieving crop

Table 1. Water input and maize yield under different irrigation methods

	Furrow – high water input	Furrow – low water input	Drip
Water input (mm)	850	584	536
Yield (t/ha)	7.8	7.3	8.2

Source: Vial et al. (2013)

Table 2. Grain yield performance of 26 rice lines compared with commonly grown TDK1 across different troposequences in Lao PDR

Line	No. of trials	Performance by troposquence (% compared to TDK1)			Overall Rank	Days to flowering
		Low	High	All		
VTE450-1	10	106	109	107	1	112
TDK10021-B-B-12-B	10	100	113	107	1	114
TDK10037-B-9-1-3-B	16	104	107	106	3	106
Sanpatong 1	10	105	105	105	4	108
TDK10049	16	102	106	104	5	104
VTE450-2	28	101	103	102	6	110
TDK10063-120	22	103	101	102	6	111
HTDK1	10	98	106	102	6	114
TDK10034-B-51-1-1	22	100	103	102	6	109
TDK10160-B-B-101-15	16	99	103	101	10	101
TSN3	16	95	105	100	11	114
TDK1	***22***	***100***	***100***	***100***	***11***	***114***
TDK8	22	91	107	99	13	106
TDK9	12	98	99	99	13	109
TSN1	16	96	101	98	15	104
TDK10063-64-B-1-B	12	90	107	98	15	106
TDK10036	16	90	105	97	17	111
TDK10078-B-104-3-1	12	99	95	97	17	107
TDK10246-B-B-39-13-1	14	86	106	96	19	108
TDK10025-B-14-3-B	22	89	103	96	19	111
TDK10223-3-3-B-B	12	97	94	96	19	109
TDK1-Sub1	10	93	96	94	22	113
TDK10192-2-B-2-B	16	89	100	94	22	111
TDK10198-21-B-1-B	12	88	101	94	22	107
PHRAE 1	12	89	94	91	25	108
TDK10246-B-B-60-19-5	10	83	96	89	26	107
TDK10042	12	81	94	88	27	107
Mean		2,869 kg/ha	2,505 kg/ha	2,687 kg/ha		109
TDK1		3,030 kg/ha	2,481 kg/ha	2,755 kg/ha	11	114

Note: Grain yield performance averaged across years (2008–11) for each toposequence—low and high—position across all years and provinces; and relative performance and ranking across all. Days to flowering averaged across environments is also indicated. Line order is displayed from highest to lowest based on relative performance across environments. Mean yields of all entries and TDK1 for each toposequence are shown at the bottom of the table.
Source: adapted from Mitchell et al. (2014)

intensification. This is especially the case with DS rice or early WS rice which often encounters rainfall events around harvest. This problem can be reduced if there are proper drying facilities available, providing flexibility of rice harvesting to increase total crop-growing duration.

Another major constraint for crop intensification is a shortage of labour, which often prevents another crop being planted immediately after the rice harvest. Reducing the period between the harvest and planting a new crop is sometimes not easy to achieve, as rice stubble may prevent the successful establishment of the new crop, and there also may be a labour shortage for planting the new crop when farmers are busy harvesting and processing rice. Contractor-operated combine harvesting can release the smallholder's labour resources from rice harvesting, drying and transporting and this can result in earlier planting of the following crop.

Factors affecting crop diversification

Addition of a non-rice crop to WS rice or replacing DS rice with a non-rice crop will promote crop diversification. The non-rice crop is often of higher value than the rice crop, and hence the diversification provides potential for greater profits to the farmers. Diversification also offers improved sustainability with sound crop rotation.

Although quick-maturing non-rice crops have a better chance of successfully growing after WS rice compared with DS rice—where some limited amount of irrigation water is available—crop diversification has additional constraints to those mentioned for the rice double-cropping intensification. One major problem is that non-rice crops are often not adapted to the soils of the lowland system, where soil compaction is common as a result of wet cultivation. Most non-rice crops are not adapted to grow under saturated soil conditions with limited aeration. This has often caused poor establishment of legume crops (Seng et al. 2008), plant death well before maturity and poor crop yield (Table 3). It may be possible to minimise the problem by deep ripping and breaking up hardpan—this could result in increased gross income, as was demonstrated with maize in Laos (Figure 1).

Other potential constraints for growing non-rice crops may be minimised by agronomic manipulation. For example, the growing environment of non-rice crops may be improved, crop establishment increased, weed growth suppressed and soil water saved by mulching these crops using rice straw (Table 4).

Another major constraint limiting crop diversification is that lowland rice farmers are not familiar with growing non-rice crops. Thus, to assist farmers with this, our previous projects in Laos and Cambodia developed best-management practices for non-rice crops. Lack of suitable markets is another common constraint for a number of potential non-rice crops.

Mechanisation for crop intensification, increased productivity and profitability

A major advantage of mechanisation is increased labour productivity with reduced labour requirement without much reduction in crop yield. This may be simply because the fees payable to a combine contractor are cheaper than the cost of employing extra labour for hand harvesting. Combine harvesting also releases family labour at the critical time of rice harvesting so that the resource can be utilised for planting another crop, as discussed above.

Seed drills can be used for planting not only rice but also non-rice crops. Our experience with the seed drill for mungbean planting in Cambodia indicated that it can produce as good establishment and high crop yield as achieved in hand-planted crops (see Table 4).

Another major mechanisation issue in rice-based lowland systems is the use of rice transplanters—which is being examined as part the new project (ACIAR Project CSE/2012/077). This is common practice in some Asian countries, but not in Laos and Cambodia. The machine is rather costly to purchase, and the labour cost for seedling preparation and transplanter operation is still high, so in the current price structure this can be most useful in high-value rice crops.

In general terms, mechanisation does not improve the productivity of one crop as such, but labour productivity increases and annual productivity may increase as a result of intensification. Whether this results in increased profitability depends on the cost/price of input and outputs. Mechanisation may therefore be adopted where the crop product can fetch higher economic returns. This is a main subject area of our new project.

Table 3. Plant density at various stages of growth and grain/fruit yield for mungbean, peanut and tomato grown in the 2009–10 dry season at the Cambodian Agricultural Research and Development Institute

Treatment	Plant density (no. plants/m^2)			Grain/fruit yield (kg/ha)
	Vegetative	Flowering	At maturity[a]	
Mungbean				
Drip irrigation, 3 times/week	12.7	4.1	4.3	212.2
Hand watering, 3 times/week	11.3	8.0	5.0	575.2
Furrow irrigation, 1 time/week	12.0	7.8	5.3	449.4
Furrow irrigation, 1 time/2 weeks	12.0	6.8	5.1	453.1
Mean	12.0	6.7	4.9	422.4
LSD (5%)	ns	2.91**	0.76*	115.04**
Peanut				
Drip irrigation, 3 times/week	10.0	10.6	9.1	380.3
Hand watering, 3 times/week	10.1	10.8	9.1	626.6
Furrow irrigation, 1 time/week	10.1	10.8	9.4	443.6
Furrow irrigation, 1 time/2 weeks	9.6	10.5	9.0	283.2
Mean	10.0	10.7	9.2	433.4
LSD (5%)	ns	ns	ns	155.05**
Tomato				
Drip irrigation, 3 times/week	4.1	3.6	2.0	10.6
Hand watering, 3 times/week	4.0	3.6	2.3	12.5
Furrow irrigation, 1 time/week	4.0	3.7	2.4	13.8
Furrow irrigation, 1 time/2 weeks	4.1	3.6	2.2	10.7
Mean	4.1	3.6	2.2	10.7
LSD (5%)	0.07 (P = 0.06)	ns	ns	2.82 (P = 0.08)

[a] 18 February 2010 for mungbean and tomato; 18 March 2010 for peanut
Note: LSD = least significant difference; ns = not significant; * = significant at (P < 0.05); ** = significant at (P < 0.01)
Source: Mitchell et al. (2013)

Environmental characterisation

The project in Laos (CSE/2006/041) developed a rice-field water balance model and, from the outputs of the model, characterised rice-growing environments, particularly water availability. Rice-growing duration in the WS is well determined, particularly for Savannakhet province in central Laos (Figure 2). Other projects have used the same model and developed maps for other provinces and also for Cambodia and Thailand. These maps can help identify areas where rice-growing duration is sufficiently long, and where there is a greater opportunity for crop intensification and diversification.

It is important to further develop this approach so that these maps may be refined to provide information that can be directly utilised by end users, such as district offices, extension offices and non-government organisations (NGOs). This can be achieved by including other factors that affect crop intensification, increased productivity and profitability—for example, irrigation water availability, land slope, particularly in the lowland paddy areas, and flood occurrence.

Policy implications

The intention of crop intensification and diversification is to provide opportunities for increased profitability to farmers on the basis that their food security issues are largely already met. The crops are therefore harvested primarily for sale, such that the major policy objective is that of promotion of the crop produce in the marketplace.

Ensuring quality control of produce that meets market requirements is an important policy issue. This may require the development and application of standards for different aspects of produce quality. Related to this is the need to recognise different crop varieties in the marketplace, so that varieties with high-quality attributes can be fully appreciated and valued. This may require specific branding of products.

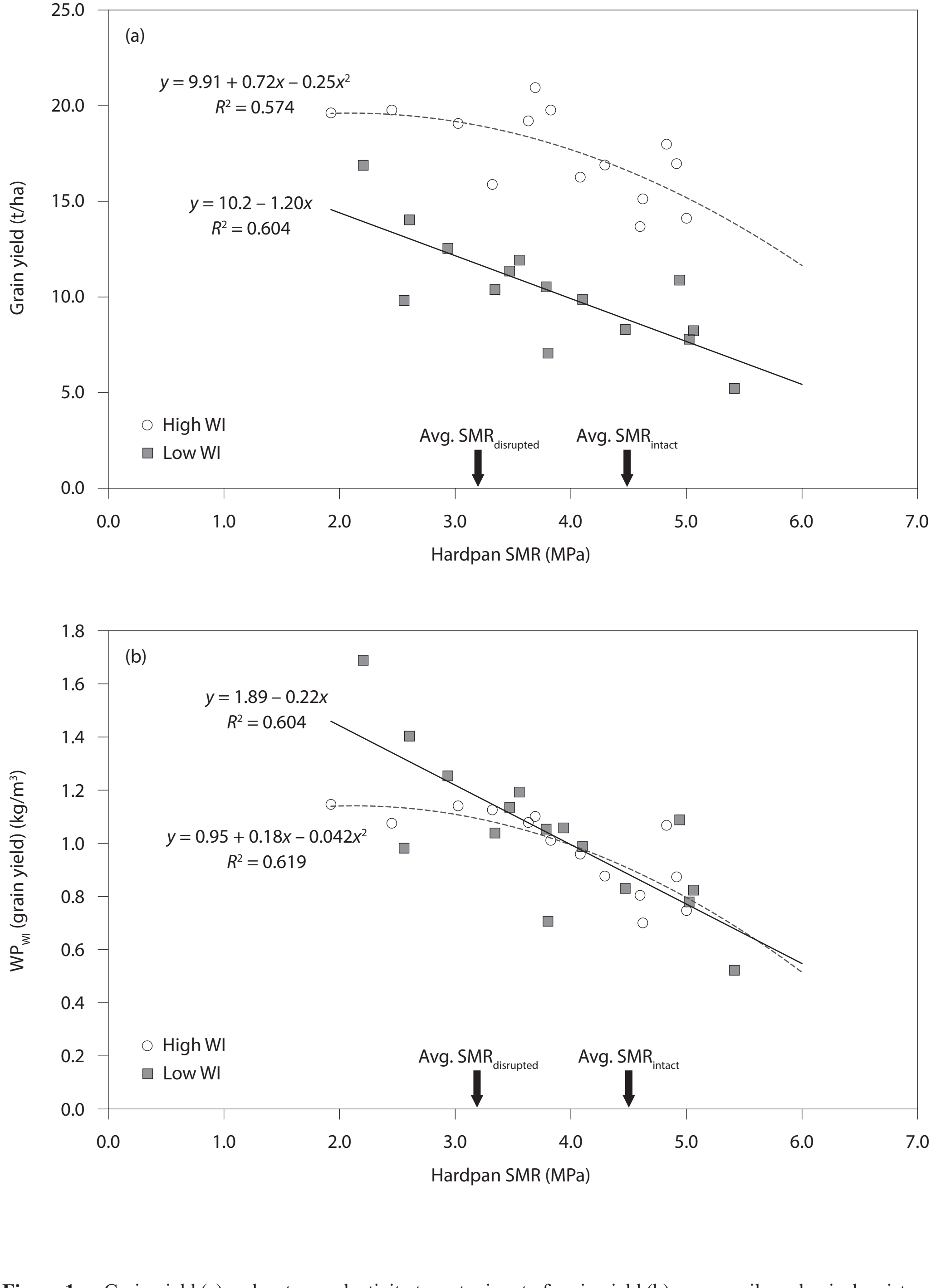

Figure 1. Grain yield (a) and water productivity to water input of grain yield (b) versus soil mechanical resistance (SMR) of the hardpan at seeding. The arrows represent the average hardpan SMR for each treatment; water inputs (WIs) are high = 850 mm; low = 584 mm. Source: Vial et al. (2013)

Market recognition of regional specialisation for certain products is an area of policy development with significant scope for beneficial outcomes. For example, Khammouane and Savannakhet could be recognised as rice export provinces in Laos, so that concentrated efforts could be made to promote marketing of high-quality rice. This may be further progressed through supporting the development of producer and agribusiness groups—for example, rice growers' association and millers' associations may work together in developing particular produce for target export markets. Government policy could support the establishment of such groups in promising regions.

Water is a major limitation for intensification and diversification, and water pricing policy is likely to impact significantly on the choice of crops that farmers grow. If water fees are charged on the basis of the quantity of water used, farmers may wish to grow crops that require less water in order to increase their profits. This would, in turn, promote crop diversification. Conversely, if water fees are charged according to land area, the incentive to save water would be limited, and result in double cropping of rice.

Table 4. Effect of planting method (*p*) and mulch (*m*) on mungbean establishment, weed biomass and grain yield at Kampong Thom, Cambodia, in 2008–09 dry season

Planting method	Establishment (%)		Weed biomass (kg/ha)		Grain yield (kg/ha)	
	Mulch	No mulch	Mulch	No mulch	Mulch	No mulch
Manual	85.5	71.7	26.3	37.5	405	175
Seed drill	81.5	73.7	17.0	44.0	317	232
Mean	*83.5*	*72.7*	*21.7*	*40.8*	*361*	*203*
LSD (5%) *p*	ns		ns		ns	
LSD (5%) *m*	3.2**		16.4*		40.4**	
LSD (5%) *p* × *m*	3.5 (*P* = 0.06)		ns		52**	

Note: LSD = least significant difference; ns = not significant; * = significant at ($P < 0.05$); ** = significant at ($P < 0.01$)
Source: Bunna et al. (2011)

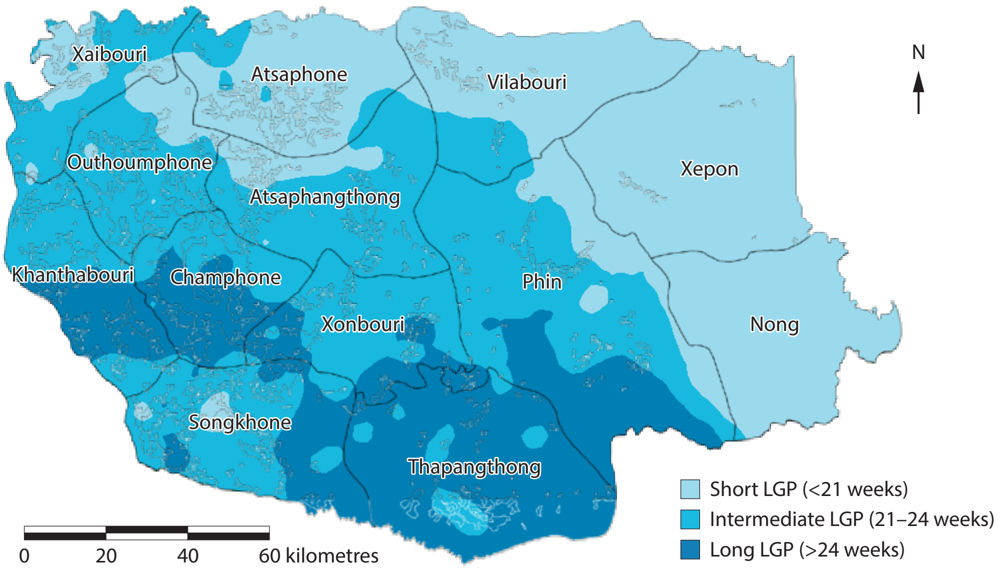

Figure 2. Map of length of growing period (LGP) for rainfed lowland rice across the districts of Savannakhet province, Lao PDR. Source: Inthavong et al. (2012)

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Forum C: Diversification

Rapporteur's synopsis

Robyn Johnston[1]

Forum C panellists

The five forum panellists were:

- Dr Mak Soeun (Director, Department of Agricultural Extension, Ministry of Agriculture, Forestry and Fisheries, Cambodia)
- Dr Mike Nunn (ACIAR Research Program Manager, Animal Health, Australia)
- Dr Clemens Grünbühel (School of Environment, Resources and Development, Asian Institute of Technology, Thailand)
- Dr Phil Charlesworth (Head of Agriculture, ASEA-Agri Pty Ltd, Cambodia)
- Dr Mak Solieng (Consultant, Development Sociologist, Cambodia).

Summary

Agricultural development policy for rice-based farming systems in South-East Asia is based on the three strategies of intensification, diversification and commercialisation. This session examined the drivers of, options for and constraints to diversification, and its role and importance relative to the other two strategies.

The discussions explored ways to achieve diversification, and the balance, synergies and trade-offs between different approaches. Diversification occurs at multiple scales. At the farm scale, livestock and non-rice crops are introduced as part of production systems accompanying or replacing rice. At a sectoral scale, the shift from semi-subsistence to commercial production, and the increasing importance of remittances and other sources of off-farm income, can also be seen as a form of income and livelihood diversification within rice-based systems.

Drivers of diversification include the need to increase productivity and profitability (as for intensification) but also the need for improved nutrition through access to more varied food sources. Diversification can offer the ability to spread production risks, and is an important form of adaptation to climate change. However, when governments rely on rice exports as a major component of economic growth, intensification of rice production is preferred over diversification. In such a context, there is debate about the extent to which diversification should be promoted. On the one hand, rice is a preferred crop for many farmers ('farmers grow rice'), yields have risen steadily and production of two or even three crops a year is increasingly viable in some areas. On the other hand, the profitability of rice remains low ('rice will never lift anyone out of poverty').

Presentations in the session described a range of options for diversification, including livestock and forages, vegetables, tree crops and aquaculture. Modes of diversification include integration with rice production (e.g. ducks and aquaculture within paddy fields, livestock to make use of crop residues); off-season production of non-rice crops and forages in rice-producing land; and conversion of some or all paddy fields to other uses. Each option involves different investments, inputs, risks and trade-offs.

The example of vegetable production in Cambodia indicates that vegetables can provide very high returns, but their cultivation requires high inputs and specialised knowledge, and there are risks associated with pre- and postharvest losses, access to markets and price fluctuations.

Small-scale livestock production can provide additional income as well as capitalising on crop residues and recycling nutrients, but can also require additional inputs (e.g. housing, vaccines) and knowledge. Small-scale cattle production can therefore be seen as an as entry point for diversification, but taking the next step—from livestock keepers with

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occasional sales to livestock producers with regular sales—requires a significant change in both farmers' mindsets and the farming system.

Constraints to diversification are similar to those for intensification (e.g. availability of land, water, labour, capital and knowledge) but with additional complexity in terms of markets and value chains. Although non-rice production can take place in rice paddies during the off-season, the suitability of many lowland paddy soils for non-rice crops is low, with restrictions in terms of soil structure and fertility, and the need to break the hardpan for non-rice crops.

Water requirements for non-rice options are often lower than those for rice, and forages and some non-rice crops can be grown on residual moisture following wet-season rice production. However, access to reliable water for dry-season production is a significant constraint for crops such as vegetables. Many of the options for diversification are labour-intensive, which is a constraint where labour is increasingly scarce.

Interventions for diversification often require specialised skills and knowledge, and agricultural extension is a critical success factor. To provide adequate support, a large number of trained farm advisers and extension officers is needed. There is a potential role for the private sector, and commercial farm advisers each working with about 200 farmers could be a viable model. Broadly based training for farm advisers is needed, so they are aware of and able to identify and support a range of options, and able to advise farmers on appropriate interventions for different conditions.

It is also important to develop new ways for making the results of research available to farmers, through extension approaches such as working with leading farmers and using new video and mobile phone technologies. It is important for both research and extension workers to understand the motivations and perspectives of farmers, who may be driven by incentives other than income (e.g. access to schooling for children, or a pathway out of farming).

Markets and value chains pose particular challenges for diversification, since these are not well developed where production volumes are small. Postharvest losses are high for perishable crops such as vegetables. Opportunistic production means that markets are often supply-driven, and not responsive to consumer demands. Conversely, it is also difficult to reward farmers for premium production to provide the incentive to improve quality and food safety. Markets in South-East Asia are developing quickly, particularly in response to demand in China, and market dynamics can change very rapidly (as illustrated by the example of trade in beef in South-East Asia).

Diversification can be developed either in commercial mode or to support home consumption, and it offers both advantages and disadvantages compared with intensification. Although diversification spreads risk, non-rice options may entail considerably more risk than rice.

There are potential synergies with rice systems, particularly in terms of capitalising on currently underutilised crop residues for livestock. However, there are no 'one-size-fits-all' approaches to diversification—interventions must be carefully targeted to local biophysical, social and economic conditions, with particular consideration of markets. A unified approach to landscape planning is needed, to optimise production systems in the context of landscape dynamics. Policies and research for markets and value chains, as well as for production systems, are critical to successful diversification.

Developing improved farming and marketing systems in rainfed regions of southern Lao PDR (forage–livestock subproject)

Tassilo Tiemann[1]*, Souksamlane Khamphoumee[2] and Viengsavanh Phimphachanhvongsod[3]

Abstract

Livestock production in South-East Asia cannot meet the rapidly increasing demand for meat in the region. Transnational livestock trade opens opportunities to smallholders but also brings threats such as disease spread, competition and stock drain. To counteract these threats, governments tend to act to protect national producers or consumers in ways that, despite good intentions, often inhibit developing market chains or discourage entrepreneurial activities. Smallholder farmers' understanding and knowledge is insufficient to judge potential opportunities and threats and there are few mechanisms in place to provide smallholders with the information needed or with visions of new approaches. Thus, change needs to occur at an institutional and organisational level to expose people to new methods and technologies and to provide the means to implement them. Such changes most urgently require education at the level of decision-makers, who themselves often also have limited knowledge and information. There is a need for systems that allow farmers to access resources, such as knowledge, credit and agricultural inputs, and that provide a market environment that encourages people to take the risk of exploring new opportunities.

Social and economic shifts: a regional perspective

Currently, South-East Asia comprises some of the most rapidly changing countries and fastest growing economies in the world. It encompasses countries, and regions within countries, at very different levels of development, resulting in diverse stresses at regional, national and subnational levels. These stresses include economic push–pull effects on demand and supply, increased competition for securing resources, increasing inequity between rural and urban centres, and many more. Economically, two major forces set the scene: China's booming economy and the Association of Southeast Asian Nations (ASEAN). The latter is aiming to accelerate economic growth, social progress and cultural development among its members. The resulting interaction between countries and increasing porosity of international borders and associated movements of material goods, human resources, and cultural and political influences can be both a benefit and a burden. The current development status, political vision and leadership of the governments of each country will be important determinants of how each country responds to these challenges.

The rapid expansion of industry and service sectors has fuelled the region's impressive economic growth during the past three to four decades. The

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lure of new employment opportunities has catalysed large demographic shifts from rural areas to urban centres, resulting in a large share of the rural labour force abandoning agriculture in favour of off-farm jobs. This phenomenon of peaking and declining of the agricultural labour force is common in countries with an abundant rural population and the beginning of what economists describe as reaching a structural transformation turning point (Tomich et al. 1995). Usually, the juncture in this process is reached when the national labour force working in agriculture declines to about 50%, a point that marks the transformation from an agrarian to an industrialised economy. To take advantage of the potential opportunities of such change, farmers need to realise a serious transformation. This requires change to their approach to farming systems, new thinking and improved management skills.

Drivers of and challenges to systems change

Growth in national economies has important implications for agriculture, including animal production. From the demand side, an expanding middle class devotes more of its disposable income to more-expensive food products, causing an upsurge in consumption of animal products and other high-value agricultural products, but also a shift towards increased demand for product quality (e.g. lean pork, tender beef or veal). This new demand is both an opportunity and a challenge for farmers. The transformation from being livestock keepers (with occasional sales to cover immediate expenses) to livestock producers (with the aim of optimising outputs for given inputs) confronts smallholders with the challenge of a major systems change. This is much more than only a technical change from an extensive, free-grazing or scavenging system with few or no inputs to a well-managed crop–livestock production system. Livestock, especially large ruminants, are perceived as assets and can act as an investment for money earned through other activities, especially where banks are absent and theft can be a problem. The offspring are seen as interest on investment in this asset and a welcome benefit rather than a major productive output. Hence, turning livestock into a commodity in a managed production system requires careful integration into the existing agricultural and social framework, with far-reaching consequences for individual households and, eventually, entire communities. To support this process, a good understanding of the traditional system is required on which advice and initial investment decisions can be based.

However, the way smallholder farmers think, especially in remote areas of continental South-East Asia, is often not yet shaped by modern economic concepts, such as profit maximisation, value of time, business models and thinking long term. Their reasons for changing or deciding not to change their existing system are often not obvious. The suggested change may not be convincing to farmers and their willingness to change their traditional approach is limited. Nonetheless, in South-East Asia, there are strong drivers in favour of, or even demanding, systems change:

- *Less time, less labour*—a diminishing rural population forces farmers to consider adoption of labour-saving technologies and intensification.
- *Initial investments*—new technologies often imply mechanisation and infrastructure, requiring monetary investment. As in other parts of the world, investment decisions often don't follow the objectively most profitable option but are influenced by desires, life pathways and social pressures.
- *Generational split*—most younger members of smallholder farmer households aspire to leave agriculture and enter a socially more accepted and resilient occupation. Off-farm labour is common for younger family members and smallholder farmers commonly invest in education to give their children more options. As a consequence, women and children are less available to take care of livestock and the elderly have to cope with higher workloads.
- *Land availability*—with increasing population densities, the carrying capacity of farm land is exceeded. Historical strategies of migrating into unclaimed forest frontiers are now less tenable as governments exert firmer control over state land and demand from smallholders to adhere to centrally developed land-use plans. This forces subdivision of the finite agricultural land base into smaller farm sizes.
- *New rules*—land management involving fire and fallow is sanctioned and remnant wildlands are declared protected areas (although in practice such declarations may not always be enforced).
- *Degradation*—in upland systems, swidden degradation is occurring at various degrees of severity. Shortened fallows and lengthened cropping

periods push swidden systems past their point of ecological resilience, as demonstrated by declining crop yields and decreased soil stability.

- *Climate change*—less predictable rainfall patterns and the emergence of vector-borne and other climate-sensitive diseases increase the risk of farming.

These drivers force farmers to find new ways of making a living from their land. Adopting livestock production can be one way that increases resilience to both economic and ecological shocks.

Livestock market opportunities

In traditional farming systems in Laos, Cambodia and Thailand, smallholders generally keep small numbers of livestock (e.g. 2–20 head). Livestock systems include free-range management, supplementary feeding and full confinement for fattening or breeding.

For large livestock, outputs are low due to long production cycles and poor management with such small animal numbers. The move to more continuous production requires an increase in animal numbers, and an associated increase in additional inputs and knowledge.

Large ruminants require a substantial amount of good-quality feed to grow fast, entailing a cut-and-carry system with a minimum of about 1,000 m^2 of well-managed improved grasses per animal. The initial establishment is labour-intensive and manageable for only a limited number of animals before grazing systems become the preferable option. However, once established, these systems require low monetary input and are quite time efficient, so that profit margins per animal are high. The technical knowledge required for the transition from traditional to more sophisticated animal production is little, making cattle the preferred entry point for remote areas with year-round available land. Its biggest downside is the necessity to fence off relatively large areas, which may be constrained by factors such as village regulations or the availability of labour or materials.

For smaller livestock such as pigs, goats and poultry, systems vary markedly between countries and areas depending on their overall economic, market access and policy environment. In more traditional systems, these species are often kept in small numbers for home consumption and occasional sales in low-input low-output systems. Monogastric livestock require higher quality feeds, with low fibre and high protein content, competing with human food production and limiting the options of perennial or longstanding feed crops. Although the price of crops such as soybean, maize or cassava is far below the price of meat, avoiding the risk of loss through animal diseases, feed scarcity or low animal prices at the time of sale makes it worthwhile for farmers to consider the best options for them. As high-quality crops often also demand more care (which translates into higher costs for agrochemicals, fertiliser, labour etc.), input costs for feeding monogastric animals are higher and profit margins lower. Compensating for low margins by raising large numbers of animals is hardly a feasible option for any smallholder outside a contract-farming situation.

The demand for animal products is constantly increasing (FAO 2012). In China, Vietnam and Thailand (and, to a much lesser extent, Cambodia and Laos), intensive fattening systems by peri-urban smallholders using exotic breeds is common. Although traditional systems cannot compete with these systems in terms of price and reliability of supply, the total demand is so high that traditional smallholder production can still supply value chains if the market infrastructure allows linking them to buyers. In some areas, especially in Laos, the development of production systems is often hampered by trade monopsonies (markets in which only one buyer interfaces with many sellers), export restrictions and control-oriented policies, as well as by limitations in physical and organisational infrastructure, including availability of vaccines, feed supplements and other inputs. However, during the past few years, considerable effort has been put into reducing these constraints, and change is gradually becoming visible.

Cross-border livestock trade in the region is significant and increasing. Trade directions, especially for large ruminants, are strongly affected by currency exchange rates. Depending on the rates between Burmese kyat, Thai baht, Cambodian riel, Lao kip, Vietnamese dong and Chinese yuan, the trade routes and directions may vary very quickly, even within a few weeks (ACIAR 2011). This creates a difficult market environment for farmers, which reduces the incentive to invest in, or even focus on, livestock production.

Policies to support smallholders

Farmer communities organise the management and use of their environment in a communal way, which influences many decisions and development pathways. Adopting new strategies is thus often constrained by communal rules. Although traditional smallholder animal production techniques may seem rudimentary and flawed, they are arguably rational in the context of the constraints and opportunities inherent in remote areas. Free-range grazing and scavenging by livestock allow farmers to capitalise on available feed resources and convert them into animal products with few additional labour inputs. However, this requires communal rules that make this possible without threatening other endeavours, especially crop growing. Village fencing rules are the most common measures and can often present an obstacle to forage-based livestock systems. Here, policy changes have to occur on a village level, which normally requires a critical mass of beneficiaries from improved livestock production.

One of the most important advantages livestock rearing has over growing crops is its versatility in terms of market timing, combined with constantly increasing prices. Unfavourable terms of sale can be rejected and marketing can be delayed more readily for livestock than for most crops. However, this requires that there are competitive market structures that allow farmers to sell to the highest bidder. Physical access is an important factor that often leads to reduced price offers for more livestock in remotely located villages. In Laos, local authorities commonly try to control the situation with the aim of protecting farmers from exploitation and consumers from rising prices. However, limiting negotiability of sales conditions often leads traders to buy livestock elsewhere, creating a lose–lose situation. Avoiding exploitation of farmers by strengthening their voice through farmer production groups has been proven more successful, although their creation often requires considerable facilitation. Farmers in more remote areas of Savannakhet province, Champassak province and elsewhere also face difficulties with accessing credit.

Linking livestock production to crop or processing residues, such as stalks, distillers' grain, oil cakes and cassava waste, presents an opportunity to improve resource use through livestock with many potential win–win situations. This also includes management of manure, which can play an important role in accumulating and recycling nutrients or in producing biogas for household consumption, especially where the cost of fuel and fertiliser is high. An enabling environment that links producers and processors and shows the potential benefits for both groups could enhance the efficiency of livestock and farming systems as well as increase profits in the value chain as a whole.

Two major problems of livestock intensification are biosecurity and food safety. Increased livestock production and trade increases the risk of disease spreading by livestock traders as well as by farmers themselves. The causes of disease, and its treatment and prevention (e.g. by vaccination), are not well understood by smallholder farmers. With extension services, drugs and vaccines often not readily available, livestock intensification can be a risky business. Appropriate policies and infrastructure (such as a cool chains for drugs and vaccines) are needed to overcome these constraints and give farmers confidence in the endeavour. Food safety is relevant for the consumer and its absence closes premium market segments that depend heavily on reliable product quality, including food safety. For example, pork and chicken from capital-intensive farms in Thailand are generally preferred by restaurants in Laos that target the tourist and expatriate sector because the meats are perceived as safe and of more uniform quality.

Conclusion

Demand for livestock products in South-East Asia outstrips supply and leads to rising prices and potential income gains for farmers. The major constraints to smallholders taking advantage of this opportunity are direct institutional barriers and access to knowledge and exposure to new ideas—both problems can be solved by strengthening and redesigning the institutional framework within which farmers have to act. This includes village regulation, support by extension services, improved capacity of extension services to deliver appropriate knowledge and technologies, provision of other sources of information, a competitive and enabling market environment, and the availability of inputs, such as seeds, planting material, fertiliser and machinery, at affordable prices. However, animal diseases and product safety are still widespread problems that increase risk, reducing the attractiveness of smallholder livestock production and posing threats to other livestock keepers and consumers, respectively. Intensive educational advertising and training, combined with accessible solutions, must be an integrated part of the organisational and institutional reforms needed to provide a market environment that encourages farmers to explore new opportunities.

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Diversifying with vegetables—improving profitability, nutritional food security and sustainability in Cambodia

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Abstract

The trend towards crop diversification in Cambodia has seen vegetables play an increasingly important role in rice-based farming systems. Diversification into non-rice crops has been driven by farmers looking to improve the profitability, productivity and sustainability of their farming systems. Vegetables offer a viable and profitable alternative to traditional crops. Nutritional benefits also accrue with diversification into vegetables. Despite the strong market incentives for crop diversification, horticultural production is not without its challenges. The vegetable industry in Cambodia confronts low yields (7 t/ha), poor competitiveness with regional neighbours (Thailand and Vietnam), high postharvest losses (25–40%), product that does not conform to the quality and safety demands of consumers, and difficulties meeting market demand during the wet season. Overcoming these challenges needs both the private and public sector, including policymakers, to create an environment conducive to industry expansion. For policymakers, this means a shift in emphasis to non-rice crops. Although rice will always be the mainstay of Cambodian agriculture, optimising vegetable and other non-rice crop production systems is essential for farmers to maximise returns from their land. New models for extension and upscaling will be needed to meet the 'information demand challenge' and to facilitate greater adoption. Delivering future extension resources at the farm level will need investment in vocational and internship programs that deliver to industry stakeholders.

Background

Although rice continues to be the backbone of Cambodian agriculture at 8.8 million tonnes (Mt) a year (MAFF 2012), farmers are increasingly looking to diversify into other crops such as vegetables. Vegetable production in Cambodia is expanding, with current production estimated at 400,609 t/year (MAFF 2013). This increase in production is still insufficient to meet current consumer demand, with domestic production heavily supplemented by imports (40–60%). The Royal Government of Cambodia has a long-term strategy to replace these imports with local production and to increase vegetable consumption to 83 g per capita a day (FAO 2009).

Despite its rapid expansion, the vegetable industry faces a number of challenges—low yields (7 t/ha), poor competitiveness with regional neighbours (Thailand and Vietnam), high postharvest losses (25–40%), product that does not conform to the quality and safety demands of consumers, and difficulties in meeting market demand during the wet season. These are some of the issues that two Australian Centre for International Agricultural Research (ACIAR) projects—ASEM/2012/081 (*Improving*

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market engagement, postharvest management and productivity of the Cambodian and Lao PDR vegetable industries) and its predecessor HORT/2006/107 (*Strengthening the Cambodian and Australian vegetable industries through adoption of improved production and postharvest practices*)—have been tackling. [A short film, 'Vegetables provide a new future for Cambodia' (Ingleton 2014), provided an overview to forum participants of past and current project work.]

Drivers for diversification

The trend towards crop diversification has been driven by farmers looking to invest in more-profitable crops, increase the productivity of their land (through multiple crops), and reduce risk and improve sustainability through diversified production. Additionally, diversifying into vegetables improves nutritional food security.

Profitability

Cambodia relies on vegetable imports from neighbouring countries to meet market demand. Although there are no definitive data, fresh vegetables imports are estimated to account for around 40–60% of the Cambodian market. Assuming a consumption rate of 45 kg/capita/year (P. Ypma, unpublished data, 2012), this equates to a market demand of 672,870 t/year or US$269 million (using an average price of US$0.40 kg). Taking into account local production (discounted for postharvest losses), we estimate that Cambodia imports around 372,400 t/year. Given that consumers have a strong preference for locally produced product, imports may be readily replaced by local production. A recent study in Siem Reap showed a clear price premium of between 5% and 20% for local production, depending on season (iDE 2012). Seasonal price fluctuations also result in premiums being achieved in the late dry and wet seasons, provided production and supply-chain constraints can be overcome. This is a research focus of ACIAR Project ASEM/2012/081.

Vegetables are also more profitable (on a per hectare basis) than other crops. A World Bank study in 2013 showed that for 1 hectare (ha) under cultivation, the gross margin for vegetables was US$1,362 compared with US$506 for cassava, US$349 for dry season (DS) rice, US$304 for maize and US$245 for wet season (WS) rice (ACI 2014). Given the diversity of vegetables produced in Cambodia, there is a large variation in the gross margins obtained for each vegetable. Table 1 shows typical gross margins for a range of leafy vegetables produced in Kandal province. The short duration of many vegetable crops allows their inclusion in the farming system, improving land productivity and enabling multiple short-term crops of a range of vegetables. However, given the intensive nature of vegetable production and its corresponding greater demands for labour, the return to labour is US$8/day compared with US$5/day for WS rice and US$22/day for DS rice (ACI 2014). The high return to labour for DS rice reflects that it is a highly commercial, mechanised operation with a very low input of family labour.

Nutritional food security

'Food security exists when populations have access on an ongoing basis to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (DFAT 2013). Although the three major staple crops (rice, maize and wheat) account for half of global human requirements for protein and calories, vegetables (and particularly indigenous vegetables) not only play an important role in food security but also contribute to nutrition security in particular (micronutrients). Thus, enhancing vegetable consumption is likely

Table 1. Profitability of a selection of leafy vegetables produced in Kandal province, Cambodia

Vegetable	Yield (kg/ha)	Price (US$/kg)	Income (US$/ha)	Variable cost (US$/ha)	Gross margin (US$/ha)
Chinese kale	9,340	0.70	6,538	3,898	2,640
Pak choy	12,986	0.28	3,571	2,412	1,159
Sprey chankeis	11,400	0.23	2,622	713	1,909
Sprey sor	10,000	0.30	3,000	1,700	1,300

Source: ACIAR Project HORT/2006/107 (*Strengthening the Cambodian and Australian vegetable industries through adoption of improved production and postharvest practices*), unpublished data to lead to improved dietary outcomes. Table 2 shows a range of nutrition values for a selection of Vietnamese indigenous vegetables. Khoi tu (*Lycium chinense*) and khoai tang (*Colocasia esculenta*) have extremely high levels of iron (>7.2 mg/100 g edible portion), while muop dang (*Momordica charantia*) and cai meo (*Brassica juncea*) have extremely high (>60 mg/100 g) and high (45–59 mg/100 g) levels of vitamin C (ACIAR Project AGB/2006/112, unpublished data, 2011). Although not all vegetables are as nutritionally dense, relative to staple crops they are certainly nutrient rich. The promotion of the nutritional benefits of vegetables is also likely to see an increase in market demand for these products.

Productivity and sustainability

The inclusion of vegetables in a rice-based farming system enables farmers to spread their risk and potentially improve the productivity of their land. In some locations, year-round vegetable production is possible, enabling farmers to use part of their land to produce a range of short-term vegetable crops throughout the year.

Challenges faced by farmers looking to diversify into vegetable production

Despite the considerable benefits that can be realised by incorporating vegetables in rice-based farming systems, farmers are likely to face a number of challenges. Horticulture is higher risk, particularly in a country where the dominant perception is that 'farmers grow rice'. Horticulture is not only more intensive, but it also requires greater investment and increased labour. Farmers also require different knowledge, skills and technology. To produce a range of vegetables successfully necessitates acquiring knowledge about their individual crop requirements to maximise returns.

Farmers face a number of other constraints when moving to vegetable production, including:

- limited access to technical and farm business specialists
- small-scale production with limited connectivity to market
- limited awareness of the value of using high-quality inputs (e.g. seeds)
- effective management of water resource during the DS and availability of land and drainage problems during the WS
- ineffective pest management programs leading to an over-reliance on chemical control—exacerbated during the WS
- poor postharvest management
- food safety risk (pesticide and microbial) posed by fresh produce
- poor understanding of market opportunities—supply-driven rather than demand-driven.

Implications for policymakers

The trend towards crop diversification necessitates a slight shift in emphasis by policymakers to non-rice crops. Although rice will always be the mainstay of Cambodian agriculture, optimising vegetable and other non-rice crop production systems will be essential for farmers to maximise returns from their land. To negotiate the challenges that vegetable producers face, a 'whole-of-chain' approach is necessary to ensure that both production and marketing constraints are considered. There is a need to foster public–private partnerships and to create an environment where this is encouraged; thereby promoting dialogue and collaboration.

Table 2. Nutritional values of a selection of Vietnamese indigenous vegetables

Vegetable	Scientific name	Average amount per edible portion (mg/100 g)				
		Calcium	Iron	β-carotene	Vitamin C	Vitamin B_2
Khoi tu	*Lycium chinense*	102	34.8	3.3	4.8	2.8
Bap cai xoe	*Brassica* sp.	233	1.1	1.1	25.9	0.1
Cai meo	*Brassica juncea*	22	7.7	2.0	48.0	5.6
Muop dang	*Momordica charantia*	26	1.7	2.0	148.0	0.5
Khoai tang	*Colocasia esculenta*	97	11.7	3.1	3.3	0.8

Source: ACIAR Project AGB/2006/112 (*Increasing the safe production, promotion and utilisation of indigenous vegetables by women in Vietnam and Australia*), unpublished data

New, sustainable models of extension and upscaling will be needed to meet the 'information demand challenge' and to facilitate greater adoption. Current and future higher demand for extension resources is also likely to result in a scarcity of horticultural technical and business advisers. As a consequence, greater investment will be needed in industry-focused vocational and internship programs. Further, investment in locally relevant applied horticultural research to provide a rapid response to future industry problems is critical.

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Increasing diversification with 'Cambodia HARVEST' (Helping Address Rural Vulnerabilities and Ecosystem STability)

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Abstract

Cambodia HARVEST (Helping Address Rural Vulnerabilities and Ecosystem STability) is a United States Agency for International Development initiative that engages with poor rural populations to implement practice change for improved productivity, food nutrition and diversity. In doing so, it seeks to enable improved food security, facilitate sustainable natural resource management and minimise environmental degradation. The initiative also acts to increase the capacity of the public and private sectors to support agricultural competitiveness. Cambodia HARVEST has had success in utilising leading famers to extend best-practice implementation of diverse vegetable production within the rice production rotation. Investment in labour-saving technologies, such as direct seeding and low-cost drip irrigation, together with private-sector support to create seed multiplication capacity, has made the transition to seasonal horticulture possible. The formation of grower groups, which can create greater scales of production, helps lower input costs and maximise negotiating strength with traders and buyers. As a result of the Cambodia HARVEST program, farmers who have diversified their cropping enterprises report substantial gains in income, while the consumption of nutritious vegetable crops provides benefits to many farmers and their communities.

United States Agency for International Development

The United States Government supports poverty alleviation through many regions of the world via the United States Agency for International Development (USAID). Within Cambodia, USAID has developed programs in four main sectors for the benefit of the Cambodian population. These comprise:

- *Democracy, human rights and governance*—USAID has helped create the National Anti–Human Trafficking Committee, which brings together the Cambodian Government, non-government organisations and community groups to combat human trafficking.
- *Health*—the quality and accessibility of health care available to the poor has been improved through USAID health programs. The organisation provides training to enhance clinical skills and health-financing programs for the poor. These activities have greatly decreased the spread of HIV/AIDS and improved access to health care by the poor. USAID also has projects aimed at overcoming malnutrition through the provision of nutrition education and access to nutritious food, with clear linkages to agriculture.
- *Education*—education is a key component of poverty alleviation and USAID continues to fund teacher training, especially in the fields of agriculture, aquaculture, horticulture and sanitation. Increasing the proportion of the population

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receiving education, especially women, has considerable benefits to adoption rates of agricultural technologies and enterprises.

- *Food security and environment*—USAID has sought to tackle food security challenges in Cambodia by fostering provision of finance for purchase of fertiliser and farm equipment, increasing productivity, and providing education and training in the cultivation of diverse vegetable crops, which offer nutritional benefits and gains in income compared with the traditional practice of growing rice. The activities of the organisation also aim to provide more efficient use of natural resources and to enhance sustainability. These activities are collectively undertaken within the USAID program called 'Cambodia HARVEST'—Helping Address Rural Vulnerabilities and Ecosystem STability.

Cambodia HARVEST

Cambodia HARVEST (Helping Address Rural Vulnerabilities and Ecosystem STability) is a 5-year agricultural program running from January 2011 until December 2015. It aims to decrease poverty and malnutrition by increasing the diversity and volume of food production in rural Cambodia. The project operates within the provinces of Kampong Thom, Siem Reap, Battambang and Pursat, which surround the Tonle Sap Lake. The percentage of the population in these provinces estimated to be below the national poverty line is 52%, 51%, 34% and 40%, respectively (WFP 2014). These areas were also selected due to the relatively high levels of estimated food deprivation and food poverty (WFP 2014). Within the area of operations, the stated objectives of Cambodia HARVEST are to: increase incomes for 70,000 rural households; create economic benefits for 150,000 people; develop income-generating activities for 8,500 'extreme poor' households; diversify cropping systems for 31,500 households; and generate US$25 million in incremental new agricultural sales (USAID 2014).

Cambodia HARVEST has implemented projects dealing with natural resource management, farm pond based aquaculture, social inclusion and nutrition, horticulture and the rice value chain. Often these areas are intrinsically linked and this paper reports on the integration of the horticulture, nutrition and rice value chain projects as they are particularly pertinent to the ACIAR Rice-based Systems Research (RSR) program. Within the rice projects, Cambodia HARVEST works directly with 40,000 rice farmers in 520 villages from the four target provinces. It achieves this magnitude of participatory engagement with the use of a leading-farmer extension system implementing a ratio of approximately 10 farmers to each leading farmer. The leading farmers were selected based on their technical abilities, community influence, and having a farm size of at least 2,000 m^2. Using this extension model, the program has created practice change related to diversification of crop production with the inclusion of vegetables in rotation with rice. The Cambodia HARVEST program also engages with the private sector to provide vital elements of the supply chain, such as labour-saving mechanisation and seed production.

Increasing crop diversity

Traditional rainfed rice production tends not to be very economical in Cambodia (Singh et al. 2007). Reported yields of farms involved in Cambodia HARVEST range up to 4 tonnes/hectare (t/ha). Without accounting for family labour, gross margins of US$450 ha/year are reported. However, yields are variable due to unreliability of early-season rainfall and excessive rainfall at flowering, which causes crop damage. Although improvements in rice production have enabled a shift to higher-value aromatic rice with improved yields, farm profit remains low. The Cambodia HARVEST program encourages farmers to integrate vegetable crops in rotation with rice in order to increase farm profit. This requires the provision of finance for inputs and equipment and training of farmers in the agronomy of short-duration rice varieties established with minimal soil preparation. Short-duration varieties enable early harvests, which facilitate preparation for vegetable establishment. Cambodia HARVEST also provides education for farmers in vegetable agronomy, safe and effective crop-protection options, and irrigation management using low-cost gravity-fed irrigation dripper systems (Bowman 2013). For example, the program co-invests in improved water delivery systems. This support has allowed farms that have access to available water to produce seasonal vegetables for household consumption. If the area of land suitable for vegetable production is greater than 1,000 m^2, commercial-scale horticultural production is possible for local and export markets. On these larger farms, cucumber, sweetcorn, watermelon and bitter gourd are commonly grown. Gross margins, excluding household labour, of US$3,400 ha/crop have been reported. In addition to the gains in income, the increased consumption of these nutritious vegetables has improved population health. Vegetable varieties recommended in the program are selected based on the highest content of iron and vitamins A and C (Bowman 2013). However, the Cambodia HARVEST program acknowledges that there are compromises between growing what is nutritious for the consumer and what is profitable for the farmer. Some farmers prefer to grow certain vegetables due to ease of production and sale at market. For example, farmers generally find sweetcorn easy to grow and sell compared with other vegetable crops.

Increased commercial horticultural production can result in increased employment opportunities and increased wages at various stages of the supply chain; input supply, on-farm or postharvest (Weinberger and Lumpkin 2007). In Cambodia, vegetable production requires approximately five times the labour input of rice (Abedullah and Farooq 2002). Therefore, implications for farm labour are significant and, as such, the cost of family farm labour needs to be considered. In most studies of small household-scale vegetable production, the cost of labour from family members is not taken into account and therefore gross margins for vegetable production appear favourable. However, it could be argued that to enable meaningful comparison of enterprises, family labour should be valued as an equivalent achievable off-farm wage. When all inputs and labour were accounted, the net farm income per family member producing horticulture in Cambodia was 117% of that for rice production (Abedullah and Farooq 2002). The benefit of diversification is greater when comparing enterprises based on profit per growing day, as vegetable crops generally exhibit shorter growing durations (Weinberger and Lumpkin 2007).

Introduction of labour-saving technologies

Labour migration and ageing of existing farmers has increased the demand for farm labour. Although the higher price of horticultural produce may justify hiring labour, the same cannot be said for rice production. Therefore labour-saving technologies, such as mechanisation, are required. Cambodia HARVEST co-invests with participants to purchase equipment for on-farm demonstrations comparing new techniques with traditional practices. At the start of the Cambodia HARVEST program, drum seeders for rice establishment were sourced from a neighbouring country. Owing to poor quality, breakdown of seeders was common and seeding rates of 300 kg seed/ha were required. Procurement of improved drum seeders has allowed much lower seeding rates (90 kg/ha) to be used with rice establishment similar to that possible using the traditional, labour-intensive transplanting techniques. However, in order to achieve this result, water management and field preparation need to be of a higher standard than for transplanting, so adequate training is provided.

Seed production

Expansion of any crop enterprise is reliant on the availability of high-quality seed (Weinberger and Lumpkin 2007). In order to produce the required volumes of improved seed varieties approximately 500 seed producers, each with a minimum of 5,000 m^2 of farmland, have been established with support from Cambodia HARVEST. This private-sector engagement is a crucial component to program success as the public sector does not have the capacity to meet the demands of the industry.

Market groups

Cambodia HARVEST has established horticultural production groups comprising 10–30 vegetable producers. There are currently more than 20 groups in operation (USAID 2014). These groups are able to secure bulk discounts on inputs to increase profitability. They build relationships with traders and buyers who seek the efficiencies of trading at larger scales. Through group consensus, they coordinate production and bulk products to gain greater strength in market negotiations. Successful involvement in these groups has provided some farmers with additional income that has made expansion of their farmland possible, further enhancing productivity.

Challenges and policy implications

Opportunities for diversification may not be available to all farmers. The quality of the land plays a role in the success of incorporating horticultural production within the rice system. Sandy clay soils enable post-rice soil structure improvement for vegetable production, whereas heavy clay soils tend not to be suitable for vegetable growth after rice. Farm size also plays a role in the successful implementation of diverse crops. The poorest farmers normally have small plots of land and therefore have limited scope for further income generation compared with wealthier farmers. In the past, smallholders engaged in horticulture had a comparative advantage over larger farms. Successful horticultural production tended to be a result of regular and careful agronomy, weeding, monitoring and irrigating, and the effort required was provided by family labour (Weinberger and Lumpkin 2007). However, due to labour migration, the smaller famers no longer have access to the necessary labour. Therefore, only farmers with more land have the scale of operation required to make the cost of hired labour effective. Notwithstanding the improvements in household nutrition offered by diversification with horticultural production, the long-term viability of smallholders within the existing business models is questionable. Opportunity exists for exposure to alternative farm management, such as share farming and collaborative farming.

Vegetable production carries greater risk due to high input costs and yield variability associated with water scarcity. Therefore, policy implementation to foster development of efficient irrigation resources will enable rural communities engaged in diversification enterprises to have greater reliability of production. Once production is secured, successful development of horticulture is dependent on the availability of, and access to, market infrastructure, including transportation access via road networks (Weinberger and Lumpkin 2007).

Development of commercial horticultural production should progress with the provision of food safety standards within commercial markets. This should include education about pesticide use and residues management, postharvest handling and record-keeping. Improved environmental and population health may result from greater regulation of pesticide use and advice services, together with improved information access.

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Market-focused integrated crop and livestock enterprises for north-western Cambodia

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Abstract

This project is evaluating crop–cattle integration options in north-western Cambodia. The region is predominantly upland, where land clearing for cropping expanded rapidly after the end of the civil war in 1998. The area under crops is now about 220,000 hectares (ha), producing US$190 million worth of crop production per year. Fewer than 20% of households keep cattle and the gross value of cattle sold is only about US$2.5 million/year. This is despite a huge local resource of crop by-products, residues and concentrate feeds. The project's crop research aims to preserve crop residues, minimise soil disturbance and encourage diversification. The traditional cropping system makes inefficient use of available water, especially if the land is ploughed between crops. The project is seeing results where small-scale farmers with brush-cutters, knapsack sprayers and hand-planting are adopting no-tillage farming because it is quicker, easier and cheaper than cultivation. The project is investigating the socioeconomic and technical reasons why, despite their abundance, non-rice crop residues are not used as feed for cattle. The reason for keeping cattle seems to be for financial security rather than for profit. Current cattle feeding is based mainly on cut-and-carry and tethered grazing. Better use of locally available crop by-products, residues and concentrate feeds provides an opportunity for expansion of cattle for breeding or fattening for beef production. The region has seen rapid and widespread environmental degradation due to illegal forest clearance followed by aggressive agricultural practices. An integrated whole-of-landscape approach is required to improve the sustainability of agriculture and at the same time promote forest restoration. The combined result is better mitigation of, and adaption to, climate change as well as watershed protection and reduced downstream impacts from flooding and sedimentation. The integrated whole-of-landscape approach can be achieved only if relevant government agencies work together.

Introduction

Australian Centre for International Agricultural Research (ACIAR) Project ASEM/2010/049 (*Market-focused integrated crop and livestock enterprises for north-western Cambodia*) commenced in 2012 and will conclude at the end of 2016. The project is identifying and evaluating novel options for crop–cattle integration to increase profitability and which are consistent with intensification, processing and marketing opportunities in north-western Cambodia.

Upland areas of north-western Cambodia have been subjected to rapid and widespread environmental degradation since 1998 due to illegal forest clearance followed by intensive production of maize and cassava. As a result, the soil fertility has declined and the soils have degraded by erosion. The region differs from most of Cambodia in some important ways:

- it is predominantly upland, with most of the crop land cleared since 1998
- the soils are fertile and the average farm size is large (3–4 ha)
- mechanisation has largely replaced cattle for draught and less than 20% of households keep cattle

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- there is a substantial resource of crop residues, by-products and concentrate feeds that could be used to improve and expand cattle production.

Regional context

The target area of the project is Samlout district in Battambang province and Sala Krau district in Pailin province. The area lies within a broader upland cropping region across eight districts along the Thai border, with an estimated 220,000 ha under crops that have a gross annual farm-gate value of about US$190 million (Table 1).

In 2008–10, the average total number of cattle in the area was about 42,000. Approximately 80% of the cattle were local breed and 20% crossbred. There were virtually no Haryana or Brahman cattle. A survey in Samlout and Sala Krau districts in 2012 revealed that the average number of cattle per household was 4.1. Annually, 15% of the herd were sold at an average price of about US$400 per head. These data suggest that the annual gross value of cattle sold is only about US$2.5 million.

The current cattle feeding practice is largely based on cut-and-carry and tethered grazing. The expansion of cropping in the region has resulted in reduced access by cattle farmers to grazing land. Better use of locally available crop by-products, residues and concentrate feeds provides an opportunity for expansion of cattle for beef production and fattening in the area.

Cropping systems

The average annual rainfall in Battambang province is 1,310 mm, with 85% of the rain falling from May to October. Farmers attempt to plant two crops per year with the first crop being sown after isolated falls of rain in January or February. These crops often fail when no follow-up rain occurs. The main wet season (WS) crop is planted in July–August and farmers frequently experience crop losses from wet conditions at harvest in October, which is the wettest month. The traditional cropping system does not appear to be well suited to the local climatic conditions and makes inefficient use of the available water, especially if the land is ploughed between crops.

The project has shown that drought-tolerant crops such as sunflower can be planted in November on the residual soil water after harvest of the WS crop. Best results are achieved with no-tillage, where loss of soil water is minimised. Planting the dry season (DS) crop means that the early WS crop will be delayed until March–April and this could reduce the risk from drought. Using no-tillage farming, the main WS crop can still be sown in July–August. These options are being investigated at long-term sites in Samlout district (>1,800 mm/year) and Pailin town (1,200 mm/year) in conjunction with a University of New England (UNE) PhD project.

Crop yields are generally less than 50% of the potential based on trial results (Table 1). The main constraints to achieving higher yields are declining soil fertility, poor water use efficiency and poor weed management. Field research is investigating alternative crop species, sowing dates, no-tillage farming and crop rotations. Crop simulation modelling is also being used to find the optimal cropping pattern. Another UNE PhD project is investigating cropping options for adaptation to climate variability and climate change.

Farmers are beginning to reduce the number of cultivations before planting and most now use herbicides to control weeds pre-sowing. Consequently, the amount of crop residues on the soil surface

Table 1. Average area, production, yields and value of crops in north-western Cambodia for 2008–10

Crop	Area (ha)	Production (t)	Yield (t/ha)	Yield potential (t/ha)	Value ('000 US$)
Maize	94,025	415,620	4.4	10.0	75,897
Cassava	27,050	717,558	26.5	50.0	35,878
Soybean	27,486	42,237	1.5	4.0	27,654
Rice	47,552	51,320	1.1	8.0	17,321
Sesame	9,596	10,660	1.1	2.0	14,728
Mungbean	11,951	11,836	1.0	3.0	13,525
Peanut	943	1,291	1.4	6.0	1,618
Total	218,603				186,621

appears to be increasing. Small-scale farmers with brush-cutters, knapsack sprayers and hand-planting are adopting no-tillage farming because it is quicker, easier and cheaper than cultivation.

Cattle production

The project is investigating the socioeconomic and technical reasons why crop residues other than rice are not used for cattle feeding despite their abundance. Soybean and peanuts are taken from the field for threshing and maize is husked at the roadside or at the house. Generally, these residues are burnt. The Royal University of Agriculture (RUA) is currently looking at options for making silage from maize husks and is analysing the nutritive value of crop residues.

It is feasible to cut maize stover for cattle feeding after grain harvest. However, the stover at this stage has little feed value and the best option might be to leave it in the field as mulch for soil improvement. Maize silage is potentially the base ingredient for an improved cattle ration. Making silage from drought-stressed crops and when the price of maize is low might be cost-effective, and the economics of growing maize for silage compared with using it for grain is being examined.

A 4-month cattle-feeding experiment has commenced to compare the growth rate of local cattle with Haryana cattle when fed a locally sourced, improved feedlot-style ration. It is expected that Haryana cattle will grow faster than the local breed when on an improved ration. The ration includes 69% maize silage harvested at the grain milk stage, 20% leucaena leaf, 10% soybean grain and 1% minerals. RUA will analyse rations for in-vivo rumen degradation, rumen ammonia-N concentration, digestibility and purine for microbial crude protein production.

Keeping four cattle per household is not profitable if the cost of labour is taken into account. A detailed survey of cattle farmers with a range of herd sizes has been conducted to determine the break-even herd size. Whole-farm budgeting will be used to determine the profitability of different enterprise mixes, such as field crops, fruit trees and cattle.

Marketing and future developments

Since 2005, rapid development of crop receival infrastructure has resulted in capacity apparently exceeding supply. The Thai company Charoen Pokphand (CP) will begin production of stockfeeds in Pailin province in mid-2014. Two cassava starch factories are under construction in Pailin with capacities of 500 and 600 t/day, and a 10,000-head piggery is also nearing completion. In future, oil-crushing plants could be established to process sesame, soybean and sunflower, with potential to provide valuable by-product meals for cattle. Establishment of cattle feedlots at a range of scales is also possible. The area of tree crops is expanding rapidly and with fruit growers reporting gross margins of US$15,000/ha, the longer-term future might see a decline in cropping in favour of expansion of fruit trees, and this would be a good environmental outcome.

Policy implications

An ideal upland landscape in north-western Cambodia would see field cropping retracted to deeper arable soils in valley floors, fruit tree cropping established on well-drained lower and middle slopes, and forest regenerated on higher slopes and hilltops. An integrated whole-of-landscape approach is required to improve the sustainability of agriculture and at the same time to promote forest restoration. The combined result would be better mitigation of, and adaption to, climate change as well as watershed protection and reduced downstream impacts from flooding and sedimentation. An integrated whole-of-landscape approach can be achieved only if relevant government agencies—such as those responsible for agriculture, forestry, fisheries, environment, commerce and law enforcement—work together.

The changing beef industry in south-eastern Cambodia

Ian Patrick[1]*, Sok Muniroth[2] and Geoff Smith[3]

Abstract

The cattle industry is Cambodia is at an important crossroads as it begins to move from a subsistence-based system providing draught services to the cropping sector to an industry increasingly driven by international demand for high-quality beef products. During the past 5 years, there have been significant shifts in the underlying bases of the industry that relate both to the change in motivations for keeping cattle and to domestic and international markets. Stakeholders in the beef value chain have identified that some potential influences on beef industry structure are price and exchange rate pressures, increasing demand for beef in Vietnam and China, declining use of cattle for draught, and increasing imports of cattle from Australia and India into Vietnam.

This paper summarises issues affecting the changing Cambodian beef industry, using information collected as part of Australian Centre for International Agricultural Research (ACIAR) Project AH/2010/046 (*Domestic and international market development for high-value cattle and beef in south-east Cambodia*). This project aims to assist Cambodian smallholder cattle farmers to begin the transition from subsistence to a more market-driven production system.

Introduction

This paper presents perceptions of the issues facing the development of an efficient value chain for cattle and beef in Cambodia. The information is gleaned from discussions, focus groups and formal surveys of the beef value chain stakeholders—including cattle smallholders (Pursat and Kampong Cham provinces), traders, processors, supermarkets and consumers—undertaken by Australian Centre for International Agricultural Research (ACIAR) Project AH/2010/046 (*Domestic and international market development for high-value cattle and beef in south-east Cambodia*)—referred to as the Beef 4 Market (B4M) project—between 2012 and 2014. The paper includes a brief overview of the value chain in one Cambodian province (Kampong Cham), a discussion of the changing nature of the transit cattle trade and the impacts of this on the domestic industry, and evidence of changing consumer demand for beef products. It concludes with mention of some other challenges facing the cattle industry in Cambodia.

The ACIAR project

The basis of the B4M project is that smallholder farmers who own cattle in Cambodia have limited access to domestic and export markets that are increasingly demanding high and consistent quantity and quality beef. Recent improvements in biosecurity practices and feeding technologies (ACIAR Projects AH/2006/025 (*Understanding livestock movement and the risk of spread of transboundary animal diseases*) and AH/2003/008 (*Improved feeding systems for more efficient beef cattle production in Cambodia*)) have raised the prospect of converting

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traditional cattle-rearing for draught power to breeding and fattening cattle for sale.

The B4M project aims to support the development of a market chain that encourages smallholders in south-eastern Cambodia to access the markets of Ho Chi Minh City, Phnom Penh and Siem Reap. The first step is to describe and value the cattle market chain and identify the factors limiting smallholder participation in new market opportunities (Objective 1, Years 1 and 2 of the project) and then define and facilitate the adoption of market chain improvements and interventions that assist market participation and improve smallholder livelihoods (Objective 2, Years 3 and 4). The project is currently at the end of Year 2.

The changing nature of the Cambodian beef industry

Transit cattle trade

Until early 2013, there had been a significant movement of cattle across Cambodia from Burma and Thailand and into Vietnam. This movement has since slowed and there is some indication that Cambodian cattle on the Thai border may be moving into Thailand rather than heading east. Traders indicated that between January 2012 and January 2013 the number of cattle moving through Cambodia from Thailand had dropped by 70–80%. In January 2013, only four trucks (180 head) of transit cattle had entered from Thailand. Although the number of cattle imported each week through the border town of Obey Choun from January to August 2012 was 300–500, from then until December 2012 this figure dropped to only 100–150.

Vietnamese traders are indicating that the price of cattle purchased in Thailand is increasing rapidly, meaning that there is increased demand for the traditionally more expensive Cambodian cattle. In Banteay Meanchey province, the liveweight price increased from 26,000 riel (US$6.32) in August 2012 to 30,000 riel (US$7.30) in January 2013. The increasing price of transit cattle may be due to a decline in cattle populations throughout the Mekong region, cattle from Burma not coming south but heading directly into the growing Chinese market, unfavourable exchange rates and the increasing cost of import or transport permits in Cambodia.

Traders selling cattle via Takeo province in the south-east of Cambodia also noted a significant decline in available stock. Normally, two to three trucks pass each day through Takeo to Vietnam but by early 2013 this was down to only one per day. The same shift in cattle availability had also been noted by these traders, with 70% of the cattle being sourced locally and 30% coming via Thailand. At a private cattle depot on the Vietnamese border, it was noted that the transit trade in Thai cattle had declined since its peak in 2008–09. This decline was rapid during 2012, with 100 trucks (of 45 head each) passing through in December 2012 but only 10 trucks passing through during January 2013.

The implications of this decline in the transit cattle trade is that Vietnamese traders have increased their demand for Cambodian cattle, resulting in increasing prices, a decrease in the size of the breeding herd and younger cattle entering the slaughter market. Five years ago, Vietnamese traders favoured older fattened animals ready for slaughter but as market conditions have changed, this preference has moved to purchasing younger Cambodian animals for fattening in Vietnam. Currently, 70–80% of the cattle traded in Phnom Penh are younger than 5 years; 5 years ago this was about 30–50%.

High transaction costs also influence the efficiency of the trade through Thailand. The average price of cattle purchased at the Burmese border (500 kg) in 2013 was 27,000 baht (US$900). Transportation from Burma to the Cambodian border costs 53,000 baht (US$1,765) per truck—with one truck carrying 20–25 head. At the Cambodian border, the licence fee is US$2,000 per truck. Although the cost of the licence has remained the same, the capacity of the cattle trucks allowed has decreased from 55 head to 45 head. The licence fee per head is thus higher than before. The transportation fee from the Cambodian border (Banteay Meanchey province) to Vietnam is US$1,000 per truck, and other expenses along the road are approximately US$600 per truck (January 2013 estimates).

Other international effects

Increasing prices of local cattle are making imports more competitive and consumers often regard imported beef as better quality than the local product. Australia is now supplying cattle to Vietnam—it is expected that 200,000 head will be exported from Australia in 2014. Continuing issues with cattle exports to Indonesia may ensure that this is viable and grows in the future, and this could take pressure off the tight supply situation in Cambodia. There have also been cattle exports from India and international companies are keen to evaluate the potential for investing in feedlots in the Mekong region. Australian companies are already investing in Vietnam and are looking at south-eastern Cambodia as a potential area for investment in feedlots and slaughterhouses.

The Cambodian cattle industry is not immune to the changing nature of international beef markets. Increasing demand from China is redirecting cattle from Burma and Thailand directly to China rather than to southern Vietnam via Cambodia. There is also demand for cattle from northern Vietnam to go to China rather than south to Ho Chi Minh City. Interest from international investors in southern Cambodia and Vietnam may also be aiming to supply the growing Chinese market.

Consumer demand

It is believed that the increased demand is coming from many sources both in neighbouring countries and in Cambodia. The B4M project undertook a survey of supermarket consumers to ascertain the potential demand and willingness to pay for improved-quality beef. In Ho Chi Minh City, 92% of interviewed consumers were willing to pay more for 'quality certified beef' and indicated they would be prepared to pay 33–37% higher than the price they are currently paying for domestic beef. In Phnom Penh, 66% of interviewed consumers stated that they would be willing to pay 7–10% more for 'quality certified beef'. It is expected that increasing interest in food quality and safety will lead to more market opportunities for better quality cattle in both southern Vietnam and Cambodia.

The market chain is Kampong Cham province

The Kampong Cham value chain is depicted in Figure 1. Similar information is available for Pursat province but not presented here. Approximately 50% of the cattle in Kampong Cham province are exported to Vietnam. Only 10% of cattle are sold for breeding and the remainder go for domestic slaughter within the province (15%) and in Phnom Penh (25%). Most beef is sold fresh in traditional markets with only a small proportion being sold in supermarkets.

There are estimated to be 20 large-scale cattle traders in Kampong Cham province. This has declined from 30 during the past 2 years. Traders are finding it increasingly difficult to source cattle to sell to the larger domestic and international markets. There are approximately 75 smaller scale traders who purchase and slaughter animals for the local markets and buy

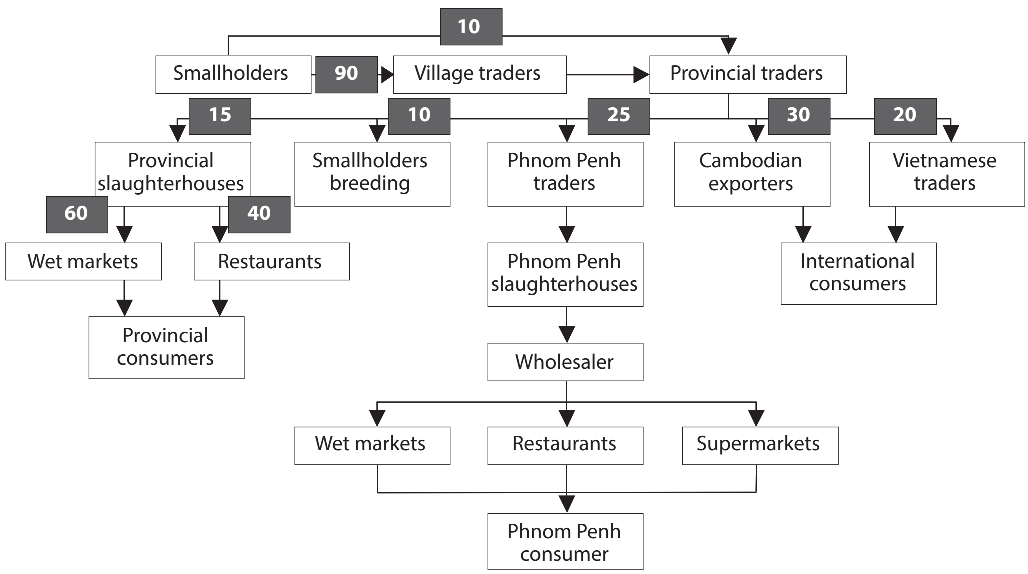

Figure 1. The cattle value chain in Kampong Cham province, Cambodia (numbers represent percentage of cattle at different steps in the chain)

stock for the large cattle traders. They either source cattle directly or rely on local village collectors. The cattle traders estimated that approximately 85,000 live cattle were traded within Kampong Cham province in 2013, down from 119,000 head in 2011—calculated on the basis of estimations by traders that 17 districts sold 7,000 head (average per district) in 2011, but that this declined to about 5,000 head in 2013.

Conclusion

There are significant opportunities for the Cambodian beef industry to take advantage of the changing South-East Asian cattle market. Increasing prices, decreased use of cattle for draught, and more specialised producers growing forage and using crop residues more effectively will improve the efficiency of the industry and livelihoods of all smallholders.

Although many smallholders say that they no longer own cattle, many others have realised that a more developed market with higher value animals will provide greater income opportunities for their households. One large trader believed that although the number of households that raise cattle has decreased, the number of cattle has actually increased because farmers are increasing the size of their herds.

The development of industry institutions that encourage the flow of information on price and quality will also assist value-chain stakeholders to negotiate with international buyers. It will be important that an industry approach is developed that returns market power to Cambodian cattle owners and traders.

Forum D: Climate change and natural resource management

Rapporteur's synopsis

Christian Roth[1]

Forum D panellists

The four forum panellists were:

- Dr Theng Tara (Director, Department of Water Resources Management and Conservation, Cambodia)
- Dr Monthathip Chanphengxay (Director-General, Department of Agriculture, Ministry of Agriculture and Forestry, Lao PDR)
- Mr Prasong Jantakad (Program Coordinator, Mekong River Commission, Lao PDR)
- Dr Nou Keosothea (Coordinator of Social Program, Cambodian Research and Development Institute, Cambodia).

Summary

Five overarching themes emerged from the presentations and the subsequent panel discussion—namely, resource use and yield variability, sources of irrigation water, best use of irrigation water, risks of rice intensification and climate-change adaptation.

Resource use and yield variability

There is a large body of work that describes the relationship between irrigation, nutrient management and rice crop performance, and how knowledge of this relationship can be used to increase yields. Work presented at the policy dialogue expands this knowledge base in terms of an assessment of other land management factors (e.g. land levelling) and climate risk management (e.g. supplementary wet season (WS) irrigation). Yield gap analysis based on simulation modelling, a concept widely used in Australia, was also presented as a method for systematically investigating the causes of yield variability, both from a perspective of managing spatial variability of soil and water, and from that of addressing climate variability. The yield gap analysis concept is not yet widely used in the Mekong region, and could prove a useful tool to help:

- identify and give priority to rice-growing areas with the greatest prospect of return on research investment
- determine the key biophysical and economic factors enabling or constraining higher yields, and their spatial distribution.

Sources of irrigation water

Recent and ongoing Australian Centre for International Agricultural Research (ACIAR) investments into quantifying water resource availability in Cambodia and Laos are starting to fill in some significant research gaps. However, these results are still patchy in terms of spatial coverage. In the case of groundwater, they are also still lacking in process understanding, limiting the utility of these results for policymaking.

Access to, and use of, surface water in Cambodia is still constrained by lack of functioning canal irrigation systems, poor governance, and weak institutional arrangements. In both Cambodia and Laos there is increasing debate about the merits of large irrigation schemes versus smaller, decentralised, farmer-driven irrigation systems.

With the advent of cheap pumps, 'water scavenging' to support early sowing or double cropping of WS rice is emerging as a strong, primarily farmer-led trend across most rainfed rice areas of Asia.

To inform future policy, these gaps and trends suggest a need for further research in:

- fuller understanding of yield and exploitability of key aquifers, shallow and deep aquifer interactions, and groundwater quality limitations
- sound policy responses into use and allocation of groundwater resources

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- the scope for natural and artificial water-harvesting structures to support supplementary WS irrigation.

Best use of irrigation water

The benefits of access to surface-water irrigation during the dry season (DS) for the intensification of rice production are well documented and were reinforced with new results presented at the policy dialogue.

Conversely, results were also presented that made the case that perhaps the focus of water research needs to be on supplementary irrigation in the WS. Supplementary irrigation can significantly reduce climatic risk of what is still the main rice crop in Cambodia and Laos. It also offers more cost-effective opportunities for rice intensification than capital-intensive investments into large canal irrigation systems for DS rice. This generated an intense debate on the relative value of WS and DS irrigation, leading into the following possible questions:

- What are the most profitable uses of irrigation water—forages for livestock intensification; drought-proofing of WS rice; other higher-value crops (e.g. pulses in the DS, vegetables)?
- Can we better design and match irrigation systems to local conditions and objectives of rice production (DS irrigated rice requiring large investments in canal irrigation versus WS irrigation for food security, with a smaller capital investment footprint)?

Risks of rice intensification

Although more efficient use of water and nutrients can raise rice productivity, some of the results presented at the policy dialogue pointed to the risk that intensification of rice production can also lead to unintended, negative environmental impacts. These include soil degradation, increased greenhouse gas (GHG) emissions (mainly from changes to irrigation regimes and nitrogen fertilisers), overuse of groundwater resources, and loss of paddy-field biodiversity.

Key knowledge gaps that may warrant additional investment and that are highly relevant to policymakers include:

- quantification and management of the trade-off between rice intensification and the intensity of GHG emissions mitigation (i.e. reduction of unit GHG emission per unit of rice grain yield)
- policy guidelines to avoid overexploitation of groundwater resources (e.g. central, southern and eastern lowland rice areas of Cambodia; Champassak province of Laos)
- minimisation of loss of rice-field biodiversity underpinning alternative, high-quality food sources (e.g. fish, ducks, frogs).

Climate-change adaptation

A key message from ACIAR's climate-change adaptation work is that incremental adaptation (i.e. better varieties, good rice agronomy, improved nutrient management) can compensate for any possible detrimental impacts of climate by 2030, and that current research and policy efforts aimed at improving rice productivity will most likely be sufficient to achieve this.

The concept of response farming (observing the early season and rainfall forecasts and, using decision-support tools, deciding what to grow) was introduced as a way of helping farmers better manage current climate variability, while at the same time building adaptive capacity for future climatic conditions. However, transformational adaptation that enables a step change in climate-proofing rice production and a concurrent intensification of rice system productivity will require a much more significant and sustained policy effort to establish widespread access to WS supplementary irrigation.

Research and policy interventions to support both short-term incremental and medium-term transformative adaptation comprise:

- development and establishment of agro-meteorological advisory systems that supply farmers with real-time climate, crop and market information to support response farming
- better understanding of rapidly changing rural household livelihood portfolios to support the development of more differentiated and targeted policy support measures that can help diversify livelihoods and increase resilience.

Improved irrigation water management to increase rice productivity in Cambodia

Touch Veasna[1*], Som Bunna[1], Men Pagnchak Roat[1], Lim Vanndy[1], Pao Sinath[1], Seng Vang[1], Oeurng Chantha[2], Noum Viraday[2], Men Nareth[2], Prum Kanthel[3], H.E. Pich Veasna[3], Theng Tara[3], Uch Hing[3], Marisa Collins[4], John Hornbuckle[4], Wendy Quayle[4], David Smith[4] and Roy Zandona[4]

Abstract

There is potential for Cambodia to increase its rice production and water productivity. This can be accomplished by an improved understanding of crop water requirements, more effective use of fertilisers, improving water management practices and the expansion of dry-season irrigated farming. However, an increase in irrigation activity may place additional pressures on existing water resources. This paper outlines key understandings, findings and insights from Australian Centre for International Agricultural Research (ACIAR) Project LWR/2009/046 (*Improved irrigation water management to increase rice productivity in Cambodia*). Results of the field survey and crop modelling clearly indicate that it should be possible to increase dry-season rice (DSR) yields to 6–7 t/ha. The most successful farmers were already achieving these levels of yield. Modelling suggests potential yields as high as 10 t/ha under ideal conditions, but these levels may not be achievable in the field due to insect pests and diseases or, indeed, be economically optimal when inputs are considered. Laser levelling has been shown to have significant benefits for farmers, with increased yields and reduced water demands for DSR crops. However, many areas have inadequate water distribution infrastructure and unreliable access to water. It is recommended to focus on policy that will increase farmer access to reliable water resources by enabling investment in the secondary water distribution networks or increase the use of new technologies, such as small low-cost pumps for transferring water.

Introduction

Irrigated agriculture in Cambodia is responsible for approximately 90% of total water extractions, although the estimate varies from between 80% (Nesbitt et al. 2004; Nesbitt 2005) and 95% (MOWRAM 2009). In 2010, approximately 2,795,892 hectares (ha) were under rice cultivation. Despite dry-season (DS) rice yields being significantly higher than wet-season (WS) rice—average yields 2.8 tonnes/ha (t/ha) versus 4.2 t/ha, respectively (MAFF 2011)—DS rice constitutes only about 20% of the total area grown. Farming in Cambodia has historically been dependent on rainfall and this remains the case. Several basin-scale studies have determined that overall Cambodian water resources are adequate now and into the future. However, temporal and spatial water availability are variable. The rice crop often suffers from stress related to drought periods during the WS in some parts of the

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landscape as well as poor irrigation management (e.g. timeliness and uneven water application).

Understanding the key drivers of rice production systems

As part of Australian Centre for International Agricultural Research (ACIAR) Project LWR/2009/046 (*Improved irrigation water management to increase rice productivity in Cambodia*), an intensive combined socioeconomic and biophysical survey was undertaken in the Takeo province of Cambodia. The main purpose of this survey was to study the methods farmers use to cultivate rice and manage water in their paddy fields. This is important because access to, and management of, water is one of the main factors that affect rice production and farmers' livelihoods.

The surveys were conducted in three districts of Takeo province—Koh Andeth, Angkor Borei and Kirivong. Three villages in each district were selected. The nine villages were Tapor, Krapum Chhouk and Pong Andeuk villages in Koh Andeth district; Ta Ei, Toul Sangkor and Toul Sangkhor villages in Angkor Borei district; and Khmol, Komnob, and Daom villages in Kirivong district. In each village, a subsample of 20 farmers was randomly selected for surveying.

In Takeo province, households have an average of 4.9 people and an average age of 37 years. There is an equal split between males and females. Household heads are predominantly male (94%) and 95% of family members are of working age (15–64 years). It is suspected that younger (<15 years) occupants were not included in the survey data as the proportion of household members under the age of 15 was unrepresented in the survey results (<1%). Elderly people (65 years and older) accounted for 5% of households. Most farmers owned the land they cropped (>99%), with an average farm size of 2.6 ± 0.2 ha. The largest farm surveyed was 14.3 ha and the smallest farm was 0.3 ha. Across the province, 70% of household income is generated from rice growing, with the remaining household income derived from off-farm work (11%), livestock (11%), non-rice crops (3%), other income (3%) and fish (2%). Average annual household income was US$3,363, which is equivalent to just under US$10 per day, or US$1.90 per household occupant per day (Figure 1).

There are small differences in household income between the three surveyed districts, with household income in Koh Andeth (US$3,700) the highest,

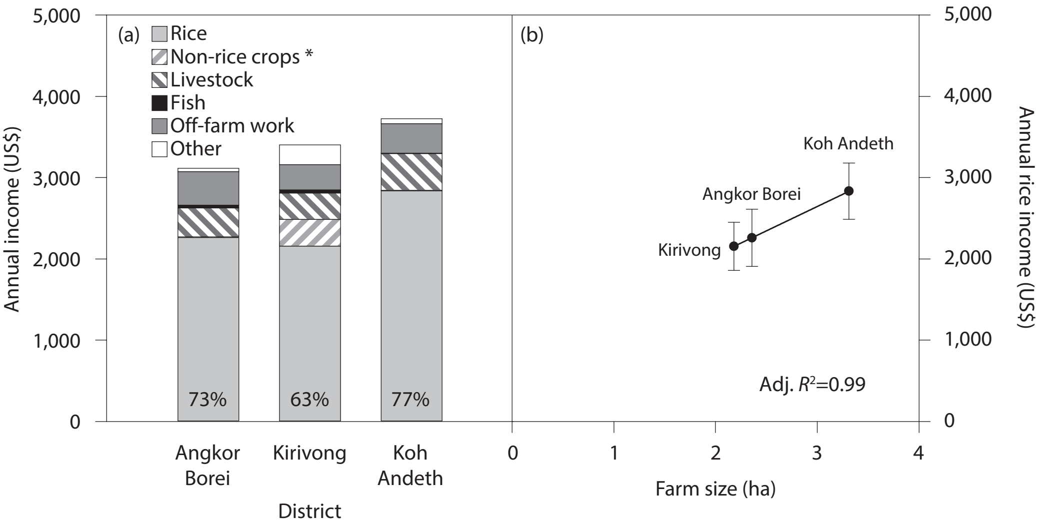

Figure 1. Annual household income in Takeo province by: (a) district, income source and amount; and (b) relationship with farm size between the districts. In (a), * indicates a significant difference, and income from rice crops is shown as a percentage.

followed by Kirivong (US$3,403) and Angkor Borei (US$3,116) (Figure 1a). With the exception of income generated from non-rice crops in Kirivong ($P < 0.01$), most of the differences, including rice and total household income are not significantly different between districts (Figure 1a). Overall, rice-derived income is closely related to farm size (Figure 1b, $R^2 = 0.99$), with increased income in Koh Andeth a consequence of significantly larger farms (3.5 ha; $P < 0.01$). Farms in Angkor Borei (2.4 ha) and Kirivong (2.2 ha) were significantly smaller compared with farms in Koh Andeth (Figure 1b). Across all 180 farmers surveyed, productivity in terms of rice income per hectare ranged from US$63/ha to US$3,750/ha. The extremely high figure was from a highly productive small paddy.

In order to understand the drivers of rice productivity, the combined socioeconomic and biophysical surveys were analysed to investigate the impacts of water availability, soils and fertiliser use on rice productivity from these surveyed farmers.

Water availability

The average distance between paddy and surface water sources (river/main, secondary and tertiary canal) appears to be a significant factor in farmers experiencing water stress (Figure 2). Farmers in Koh Andeth—where over 70% of farmers experience water shortages—are on average 480 m away from their nearest water source compared with farmers in Angkor Borei (208 m) and Kirivong (108 m), where the proportion of farmers experiencing water stress is lower. There is a very strong relationship between the distance to water source and percentage of farmers experiencing water shortages ($R^2 = 0.98$, Figure 2b), but this did not result in yield differences between the districts (data not shown). However, in the different seasons, distance to water sources was highly negatively correlated with yield ($R^2 = 0.98$, Figure 3). High-yielding (>5 t/ha) and irrigation-dependent dry-season rice (DSR) was grown less than 150 m away from water sources, while early wet-season rice (EWR) and main wet-season rice (MWR) were grown 500–800 m away from water sources (Figure 3). Farmers are effectively managing their risk of water stress/shortage by growing DS crops only in positions where supplementary irrigation can be used.

The data indicate that water availability is a major limiting factor in rice production in Cambodia,

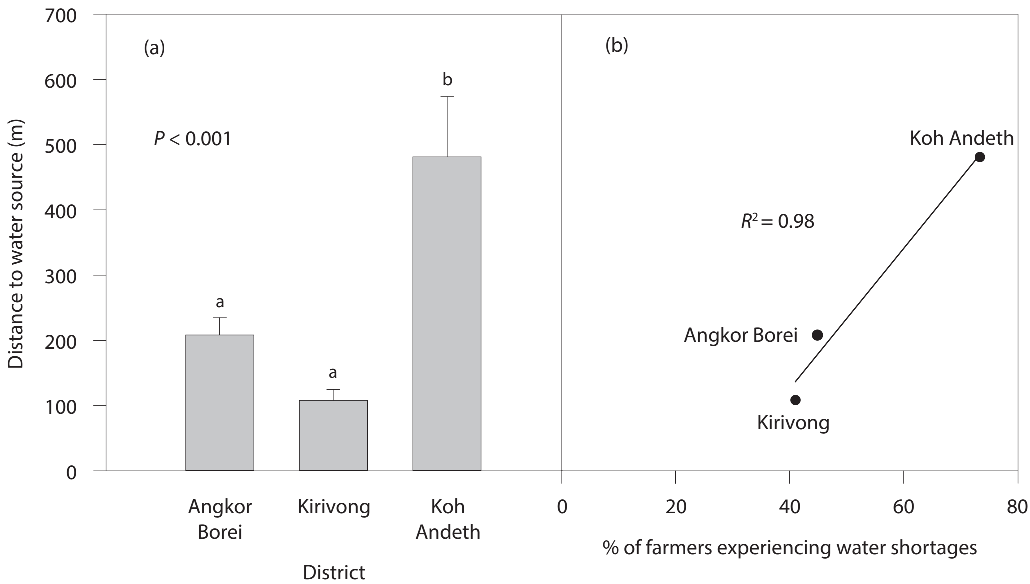

Figure 2. (a) Average distance to water source by district, and (b) relationship between distance to water source and percentage of farmers experiencing water shortages across the districts. Letters 'a' and 'b' indicate significant differences between districts shown in (a); linear regression shown in (b).

particularly for DSR. Although farmers are confident to grow MWR and EWR across a larger area away from water sources, DSR farmers are extremely dependent upon access to a reliable water source for irrigation. Efforts to increase DSR production could benefit by increasing the development of secondary and tertiary canal systems or small-scale, low-cost pumping systems, provided supply water availability is not limited. It is often the case that water supply infrastructure beyond the main canal development is not adequately financed in major irrigation area refurbishments or in new irrigation area developments. Additionally, operational and ongoing maintenance of water supply networks is often inadequately provided/financed leading to productivity constraints at the farm level.

Soils

In fields where corresponding yield data were available, significant differences existed in crop yields grown on the two dominant soil types ($P < 0.01$) with Kbal Po soils averaging 4.8 ± 0.1 t/ha ($n = 235$ fields) and Prateah Lang soils 3.9 ± 0.2 t/ha ($n = 87$ fields). There were also differences in yield by soil type in different seasons, with lower yields in the lighter Prateah Lang soils in MWR and DSR crops (Figure 4).

The sandier soils were characterised by lower yields, particularly with MWR and DSR crops. This is likely a function of increased leaching of water and/or nutrients, factors which, in isolation or in combination, can lead to lower yields. High percolation rates in the sandy soils of rainfed lowland rice are well recognised as a major limiting factor for rice production through loss of standing water and nutrient leaching (Seng et al. 2004). The selection of soils for intensive rice cultivation should therefore be an important consideration from a productivity perspective. However, potential adverse environmental or human health impacts associated with groundwater accessions may also arise. To date, there has been little consideration of the potential contamination risks of these inputs to ground and surface water resources despite recognition of rapidly increasing trends in fertiliser and chemical use in recent years (Ngo and Siriwattananon 2009). The significance of this issue has been deprioritised, probably reinforced by the findings of groundwater quality

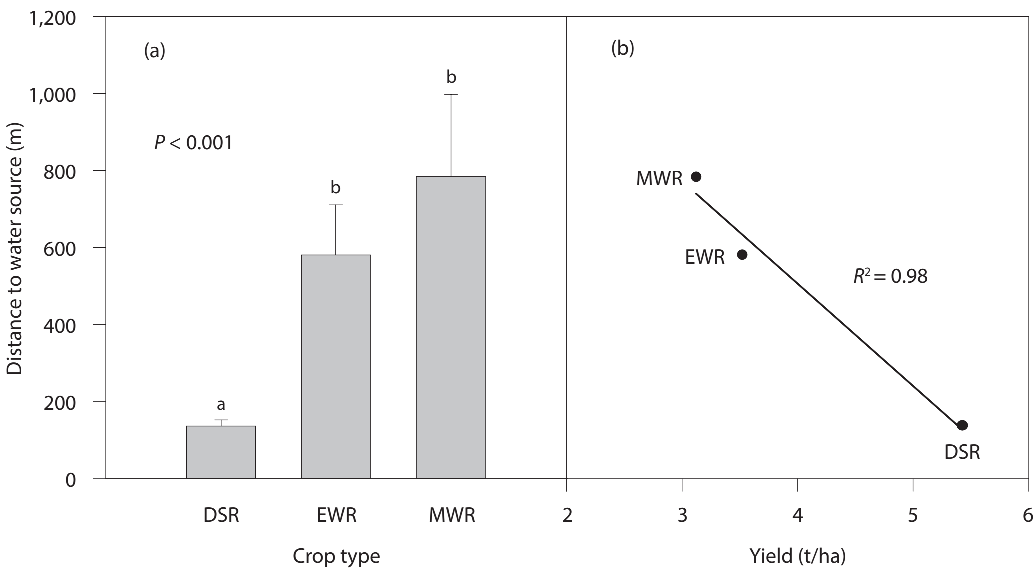

Figure 3. (a) Average distance between paddy and surface water sources by season, and (b) relationship between distance to water source and yield (DSR = dry-season rice; EWR = early wet-season rice; MWR = main wet-season rice). Letters 'a' and 'b' indicate significant differences between districts shown in (a); linear regression shown in (b).

studies, which typically show nitrate at negligible or undetectable levels with only isolated pockets of higher concentrations where livestock are tended. The trace levels typically encountered are a result of the groundwater environment tending to favour reducing conditions, which lead to the loss of nitrate through denitrification.

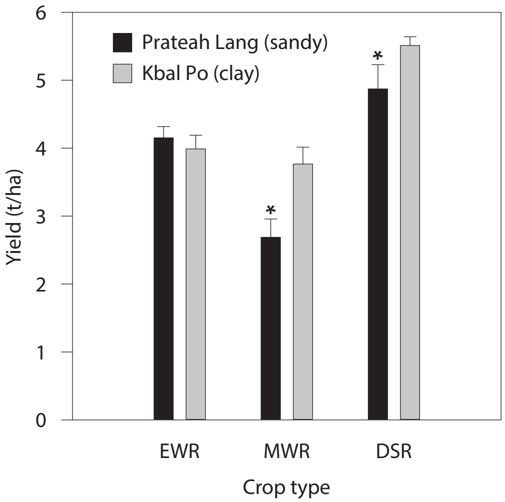

Figure 4. Influence of soil type on yield in early wet-season rice (EWR), main wet-season rice (MWR) and dry-season rice (DSR). Significant differences between soil types as determined by analysis of variance (ANOVA) are indicated by * ($P < 0.05$; $n = 354$ fields).

Fertiliser use

Farmers in Takeo applied both inorganic (chemical) and organic fertiliser to their crops in all seasons (Figure 5). In EWR and DSR, nearly all farmers (98%) applied inorganic fertiliser to their crops. For MWR, inorganic fertiliser application was slightly lower at 90%. Farmers applied inorganic fertiliser in the form of urea, di-ammonium phosphate and nitrogen–phosphorus–potassium (NPK) (in a ratio of 20:20:15) to crops in all seasons at an average rate of 101:46:11 kg/ha. The amount applied varied by season (Figure 5). Irrespective of source, the amount of chemical fertiliser applied to MWR crops was significantly lower for N, P and K compared with EWR and DSR (Figure 5a). As a rule, farmers applied 30% more N, 44% more P and 41% more K to EWR and DSR crops.

Across the districts, the amount of N and K applied was consistent. However, lower amounts of P were applied in Angkor Borei compared with Kirivong and Koh Andeth (Figure 5b). It seems likely that the lower levels of P application were offset by increased application of organic fertiliser in Angkor Borei (2–23 times higher) compared with the other two districts (Figure 5d). Use of organic fertiliser in Kirivong was particularly low at 0.1 t/ha compared with both Koh Andeth (0.8 t/ha) and Angkor Borei (1.7 t/ha). Application of organic fertiliser was 5–25 times higher in MWR compared with EWR and DSR, which offset low levels of chemical fertiliser applied (Figure 5). In addition to the seasonal differences in use of organic fertiliser (MWR > EWR > DSR), organic fertiliser use also differed according to soil type. Organic fertiliser was used in larger amounts on lighter sandy Prateah Lang soils (3.9 t/ha) compared with heavier clay Kbal Po soils (1.6 t/ha; $P < 0.001$) (data not shown). This difference was consistent across all seasons. Higher levels of P were also applied to DSR grown on clay Kbal Po soils (55 kg/ha) compared with the lighter sandy Prateah Lang soils (34 kg/ha; $P < 0.001$).

Figure 6 shows the relationship between inorganic fertiliser (NPK) and yield across the nine villages in the survey area. Although P and K rates did not seem to affect yield, there did appear to be an increase in yield with associated increase in N application across the survey sample. It is clear from the survey that farmers are modifying fertiliser application rates for different soils. However, greater knowledge about how rates impact on yields, particularly in higher yielding DSR has the potential to increase productivity further. The use of higher yielding varieties, increased mechanisation and improved water management is shifting the upper yield levels, so N use and management recommendations across potential yield goals would be beneficial.

Improving on-farm water management

At the farm level, one of the key constraints limiting rice production is the inability for many farmers to adequately manage water on rice fields. The LWR/2009/046 project has been demonstrating the benefits of laser levelling to increase field levelness and improve crop water management.

Three demonstration field sites have been established—one each at Angkor Borei, Koh Andeth and Kirivong districts in Takeo province. These demonstration sites have been used to compare laser-levelled fields with non-levelled fields and investigate impacts on yield, water use and weed growth. The treatments included both a laser-levelled field and a non-levelled field under the same management at each site and a neighbouring field. Water use was monitored by measuring water applied with a pump of 5.5 horsepower (hp) (20 m3/hour) capacity. All water applied for irrigation, yields and weed biomass were monitored. Pre-levelled field topographies indicated that fields ranged from 10 cm to 30 cm variation in surface elevation. After fields were laser levelled, there was a 1–3 cm variation in surface elevation.

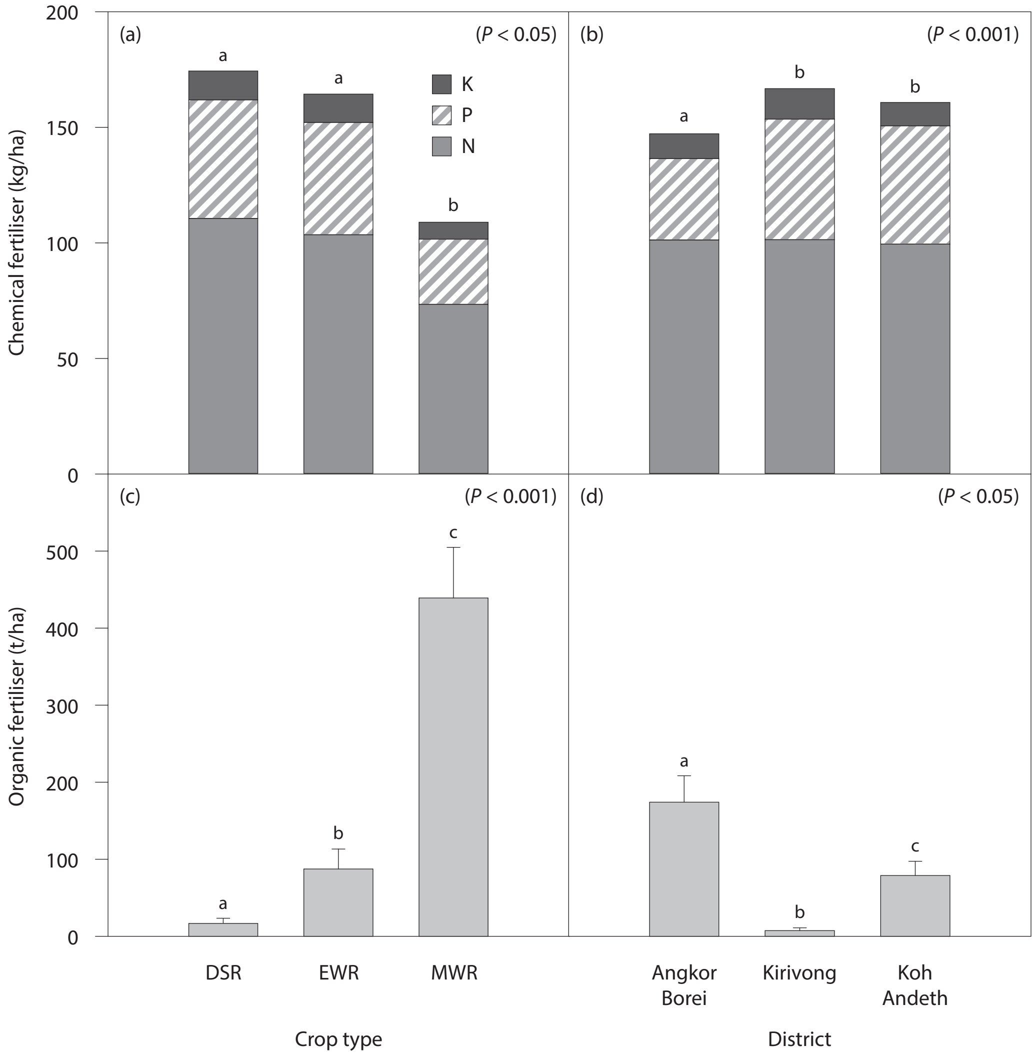

Figure 5. Rate of chemical (inorganic) (a, b) and organic (c, d) fertiliser application across seasons (a, c) and districts (b, d) in Takeo province (N = nitrogen; P = phosphorus; K = potassium; DSR = dry-season rice; EWR = early wet-season rice; MWR = main wet-season rice. Letters 'a', 'b' and 'c' indicate significant differences as determined by analysis of variance (ANOVA). Data were collected across 323 fields (*n* = 163 DSR, *n* = 90 EWR, *n* = 70 EWR).

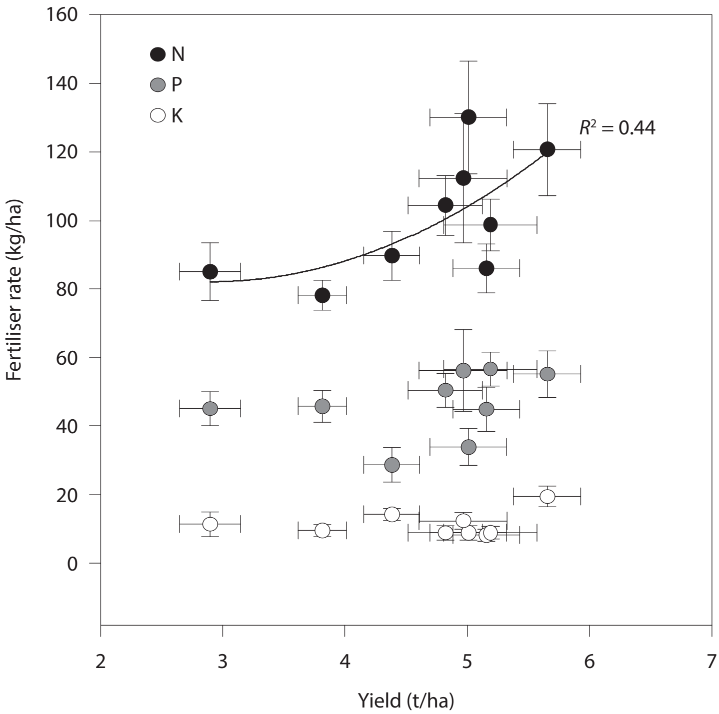

Figure 6. Relationship between inorganic fertiliser (N = nitrogen; P = phosphorus; K = potassium) and yield in nine villages in Takeo province (n = 9)

The field trial results indicated that weed biomass was approximately 50% lower (Figure 7), pumping-water requirements were lower and there was a 13% higher yield (Figure 8) in laser-levelled fields compared with non-levelled fields under the same management. The benefits of levelled fields on water use productivity are quite evident (Figure 8). Irrigation water applied to rice grown in laser-levelled fields was approximately 7,000 m^3/ha, about 1,300 m^3/ha less than non-levelled field (Figure 8). The field experiments show that there are significant benefits to water use productivity from the use of laser levelling to improve water management that, in turn, lead to improved water productivity. As increases in farm labour costs occur and farmers move to increase mechanisation, the benefits of laser-levelling technology will further increase, particularly in relation to direct sowing.

Understanding potential yields using crop models

Crop models provide a means by which to quantify the effects of climate, seasonal weather conditions, soil, management and genotype and their interactions on crop growth, yield, resource use efficiency and environmental impacts (Boote et al. 1996). A particular strength of crop models is their ability to quantify variability of crop performance due to variability in seasonal weather conditions and to predict the long-term impacts of climate change and land-use options (Timsina and Humphreys 2006). Simulation modelling is often the only effective and practical way to examine the enormous range of combinations of management, site and seasonal conditions that can occur, and to determine the likelihood of outcomes.

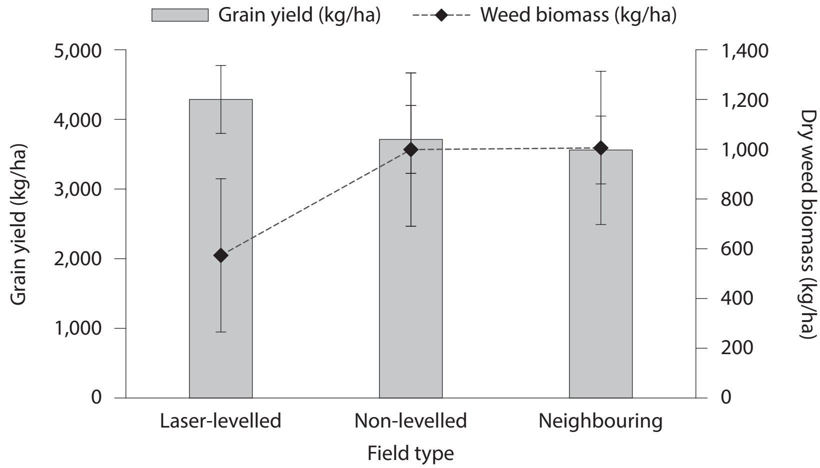

Figure 7. Average rice grain yield and dry weed biomass across field treatments. Plotted data are means of three demonstation sites in 2012.

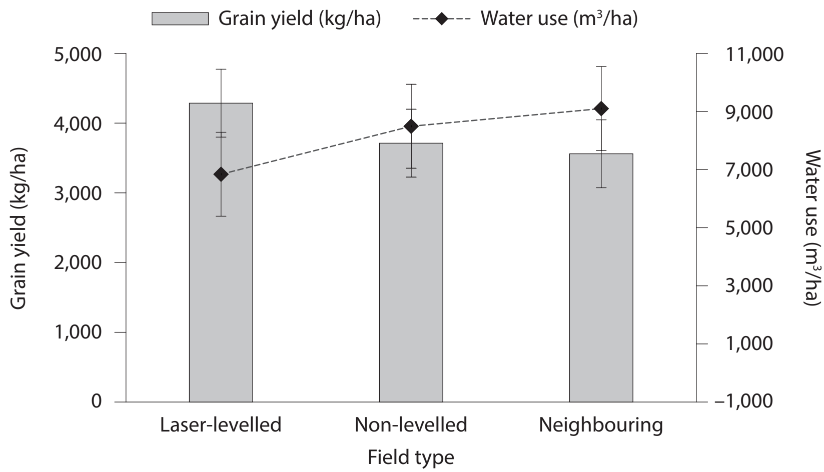

Figure 8. Average rice grain yields and water use across field treatments. Plotted data are means of three demonstration sites in 2012.

The objective of the modelling study was to firstly evaluate the performance of the APSIM (Agricultural Production Systems SIMulator)/ORYZA rice model in simulating the growth of rice in a rice monoculture experiment at the Cambodian Agricultural Research and Development Institute (CARDI) experimental station in Cambodia in the DS. The second objective was to examine the effects of continuously flooded rice (floodwater depth maintained at 50 mm throughout the growing season) under various N management applications. One of the key considerations when arriving at appropriate water management strategies for rice (grown in any season) is the impact on N availability, which has not been considered in any studies in Cambodia of which the authors are aware. Maintaining continuous flooding is desirable from the point of view of minimising N losses by cycles of nitrification/denitrification, but this has to be considered against the cost of supplying water to maintain it. Due to the close linkages between N loss processes, soil and floodwater status, water fluxes, and crop growth, models that are capable of describing N dynamics, water movement and availability as well as crop productivity can play a valuable role in ascertaining best management practice.

The model was calibrated (2012 experiment) and evaluated using the one independent dataset (2013 experiment) on phenology and yield. It is envisaged that a 2014 experiment will add further weight to the evaluation process. The model was used to estimate yield for a range of N management applications under continuously flooded conditions on the loamy sand soil at the CARDI experimental station. Initial conditions were set to the observations recorded in the 2012 experiment. Long-term, historical weather data in Cambodia are intermittent at best, with radiation data particularly difficult to source. As a result, simulations were carried out using the 2012 weather data only as a 'look and see' approach on how various water and N management regimes may affect DSR yield production. A longer-term weather database is currently being constructed to tackle this issue and the project has also established a real-time weather station network in collaboration with the Ministry of Water Resources and Meteorology (MOWRAM et al. 2014).

The continuously flooded treatment received an initial 90-mm irrigation as a pre-puddling event prior to sowing. After sowing, the floodwater depth was maintained at 50 mm until the end of the season. Three N rates were used in the simulations: 50 kg N/ha (as per CARDI-recommended practice), 100 kg N/ha and 200 kg N/ha.

Potential yield for the 2012 year simulated across the various N applications started at 7.6 t/ha using the standard 50 kg N/ha. A doubling of the N rate (100 kg N/ha) produced a simulated yield of 8.5 t/ha. A further doubling of N rate to 200 kg N/ha saw a further increase in yield up to 10.0 t/ha in the continuously flooded treatment (Figure 9). Note that these are simulated potential yields that may be possible using best water and nutrient management practices,

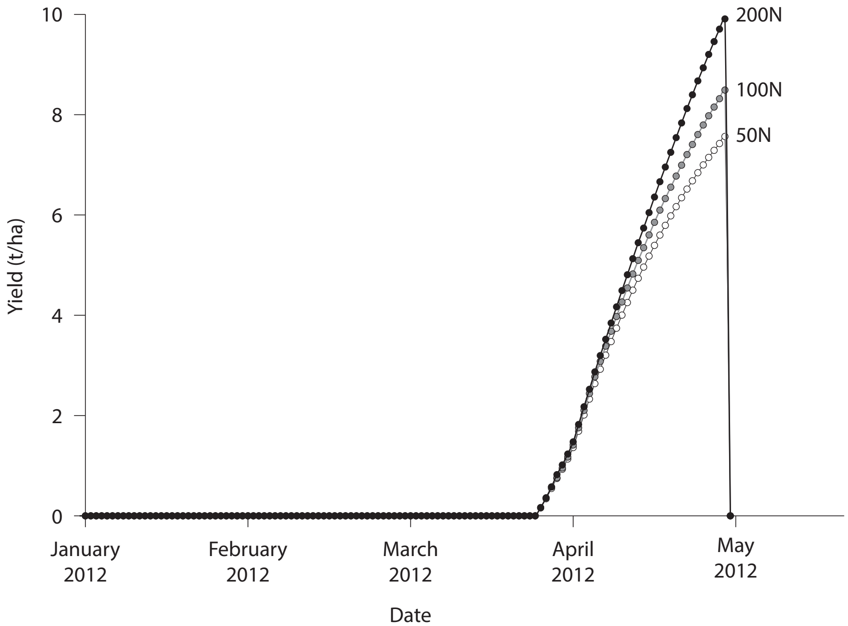

Figure 9. Simulated potential yields for 2012 dry-season rice (var. Chul'sa) under continuously flooded conditions with various nitrogen (N) applications (kg/ha) on a loamy sand soil at the Cambodian Agricultural Research and Development Institute

and assuming that water is available to maintain a floodwater depth of 50 mm and that there is no disease or weed pressure over the growing season. As mentioned previously, maintaining continuous flooding is desirable from the perspective of minimising N losses by cycles of nitrification/denitrification, but this has to be considered against the cost of supplying water to maintain it.

What is clear is that there is potential to lift DSR yields across Cambodia with improved water and N management.

Conclusion

There are a number of causes of low productivity of rice-based systems in Cambodia and also a number of potential solutions that have been developed and promoted in the project. The project's results from socioeconomic and biophysical surveys, field experimentation and modelling have shown that rice production in Cambodia can be enhanced by an improved understanding of crop water requirements, and how to plan, schedule and manage water and fertiliser at a field scale to increase production. Although there are several core constraints to rice productivity growth, the inability of many farmers to adequately manage water and water availability at the farm level is a serious challenge for improving agricultural productivity in Cambodia.

In order to overcome these constraints, policies will need to be implemented that achieve on-ground change at the appropriate level. It is clear from the survey data and modelling results that it should be possible to increase DSR yields to 6–7 t/ha. From the survey results, the most successful farmers were already achieving these yield targets. Modelling suggests potential yields as high as 10 t/ha under ideal conditions; however, these levels may not be achievable in the field due to pests and diseases or, indeed, be economically optimal when inputs are considered. An increase of 2 t/ha—from an average of 4.35 t/ha for DSR reported by MAFF (2013)—should be realistically achievable for many farmers. With approximately 500,000 ha of DSR grown annually in Cambodia, an additional 500,000 t of rice could be produced each year on the basis of 50% of farmers increasing yields to 6 t/ha.

In order for these increased levels of production to occur, policies will need to focus on increasing farmer access to reliable water resources in a sustainable manner. The project findings indicate that many areas have inadequate water distribution infrastructure and unreliable access to water. This could be overcome by policies that increase investment in the secondary water distribution networks or increase the use of new technologies, such as small low-cost pumps for transferring water.

On the technology front, laser levelling has been shown to have significant benefits for farmers with increased yields and also reduced water demands for DSR crops. Additionally, weed control is dramatically increased and water management becomes more precise. However, broad-scale adoption, initial capital costs are high (approximately US$500/ha) and there is no established laser-levelling industry in Cambodia, which together constitute a major barrier to broad-scale adoption. In order to overcome this hurdle, policies that allow this technology to be implemented, such as farmer subsidies for laser levelling, would assist in kick-starting the industry. Increased yields are not the only benefits anticipated. Water savings arising from less water applied to laser-levelled fields have the potential to be redirected into more irrigated rice area and its associated production outcomes.

In summary, there are several options to increase rice production in Cambodia. This project has been able to demonstrate options for increasing rice productivity at the field level through a range of water management options and to identify associated key constraints. The challenge now is to incorporate this knowledge into policy in order to realise on-ground impact at a broad scale to improve the livelihoods of farmers in Cambodia.

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The use of groundwater as an alternative water source for agricultural production in southern Lao PDR and the implications for policymakers

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Abstract

Groundwater is fast becoming an alternative source of fresh water for many rural communities in southern Laos in response to increasing rainfall variability and distribution, in conjunction with increasing competition for surface water resources, including for agriculture, hydropower and mining. However, characterisation of the region's aquifer system is based largely on information derived from hydrogeological studies in neighbouring parts of the Lower Mekong River Basin. The first objective of the research presented in this paper was to identify the nature and extent of the aquifer system, and seasonal groundwater behaviour, in the Soukhouma district, in southern Laos' Champassak province. The second objective was to explore the potential implications of overextraction of the groundwater resource. Our research findings highlight the need for well-informed guidelines and policy interventions for sustainable groundwater development in this region.

Introduction

Lao People's Democratic Republic (PDR) is classified as a 'least developed country' and a 'low-income food-deficit country'. In 2009, it was ranked 133 of 182 nations according to the United Nations Development Programme (UNDP) Human Development Index (World Food Programme 2011). Laos has a population of 6 million, 28% of whom are living below the poverty line (World Bank 2014a). The gross domestic product (GDP) per capita between 2009 and 2013 was reported to be US$1,417 (World Bank 2014b). The contribution of agriculture (including crop production, aquaculture and forestry) to GDP has decreased substantially over the past two to three decades. For instance, in 1992, agriculture accounted for 62% of GDP; in 2012, it accounted for 28% (World Bank 2014a). Despite this, agriculture remains a significant contributor to the national economy through employing ~76% of the population (MRC 2011). Historically, agriculture in Laos was largely driven by subsistence-oriented rice production (Manivong et al. 2014), but since the adoption of the New Economic Mechanism in 1986, there has been a drive toward commercialising agriculture, consistent with the philosophy of developing a market-oriented economy (Rasabud 2011). As such, there has been an expansion in the total area under cultivation in the past several decades. For example, results of the 2010/11 national census of agriculture showed that the area under agricultural production in 1998/99 was 0.98 million hectares (Mha); by 2010/11, this

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had increased to 1.6 Mha (Intharack 2014). Rice is the major agricultural commodity produced in Laos and, in 2010/11, accounted for ~0.99 Mha of total agricultural land use. Of this, 94% was dedicated to rainfed rice production, which is grown mainly in the lowlands; only 6% of land area was committed to irrigated, dry-season rice production (Inthrack 2014), primarily because rainfall is distinctly seasonal and access to adequate irrigation infrastructure in the dry season is extremely limited.

Cultivation of lowland, wet-season rice accounts for the majority of the total rice production by area in Laos (e.g. 72% in 2010/11; Intharack 2014) and plays an important role in the livelihoods of the rural population in these regions. Despite advances in technology (e.g. mechanisation of land preparation, improved varieties and the introduction of inorganic fertilisers) to overcome physical constraints (i.e. soil infertility, droughts and floods, pests and diseases) and to improve agricultural productivity, the incentive for farmers to produce beyond the individual household needs is limited. This is a result of increasing input costs, fluctuating output prices and uncertainties in trade policies (Newby et al. 2013, and is further exacerbated by weaknesses in the capacity of extension services, limited access to farm credit (Eliste et al. 2012) and the long-term migration of labour to neighbouring countries, where it is estimated that as many as 300,000 migrant workers (8% of the total workforce) are residing in Thailand alone (Manivong et al. 2014).

Water resources

In the Lower Mekong River Basin, the mean annual rainfall ranges from less than 1,000 mm/year in the central regions of Thailand to 2,500 mm/year in the mountainous areas of Laos (MRC 2010). Most of this rain occurs during the wet season (April–November), resulting in a distinct seasonal flow in the Mekong River. The average annual discharge is ~475 km^3 where a significant proportion (~40%) is derived from flow originating in the eastern tributaries between Vientiane (Laos) – Nakhon Phanom (Thailand), and Pakse (Laos) – Strung Treng (Cambodia) (MRC 2009; see Figure 1).

Fresh water availability in Laos is the highest in Asia, estimated at 53,000 m^3/capita (UNEP 2001). Despite the apparent abundance of fresh water, the high seasonality and non-uniform distribution of rainfall, together with the increasing demand for water from agricultural and non-agricultural uses such as mining and hydropower, are driving the search for other sources of water (Nhoybouakong et al. 2012). For instance, over the past few decades, the number of small surface water storages has progressively increased. These farm ponds provide a source of water that can be used to irrigate short-duration, high-value vegetable crops, or to support aquaculture (Vongsana et al. 2014). Additionally, the spread of electrification across the region in recent times has allowed the exploitation of groundwater for both domestic use and the small-scale irrigation of vegetables or other high-value dry-season crops. As the development of small, domestic-type groundwater bores across the region over the past decade has been so extensive, there is now an urgent need to gain a better understanding of the system so that future development does not compromise current use or system sustainability.

To date, few studies have been undertaken to assess the nature of groundwater in southern Laos. As a consequence, there is little knowledge upon which Lao policymakers can develop strategies to ensure the continuing, sustainable use of this resource. Literature searches have revealed a scarcity of information regarding the underlying hydrogeology of the Mekong alluvium in southern Laos, and of the accessibility, sustainability and quality of groundwater. Studies by the interim Mekong Committee (1986, cited in WEPA 2014) indicated that groundwater associated with the lower Mekong plain in southern Laos was likely to be associated with the Indosinian sediments geological formation. Aquifers associated with these formations, while exhibiting regional flow through rock of the Indosinian Moyennes and Superieures, were mainly freshwater sediments and yields of 12–24 litres per second (L/s) were possible (WEPA 2014). Two other studies undertaken in the past two decades (JICA 1995; Oriental Consultants Co. Ltd 2012) have provided a brief snapshot of shallow groundwater resources in the Champassak and Savannakhet provinces and indicated high seasonality of the depth to watertable and the close link between rainfall and recharge.

There is a growing need for further information regarding the nature of groundwater systems in southern Laos given the increasing dependence of rural communities on groundwater for domestic and cottage needs, combined with the increased rate of development of the resource and the temptation for high-production bores to enable dry-season irrigation.

Relevant, up-to-date knowledge will enable policy-makers and planners at both regional and national levels to develop appropriate strategies and legislation to ensure sustainable and equitable economic development for Lower Mekong River Basin groundwater resources. In this paper, we describe the groundwater resource research that has been undertaken as part of Australian Centre for International Agricultural Research (ACIAR) Project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*) in the Soukhouma district of Champassak province of southern Laos and consider the policy implications of our findings, especially for Lao policymakers.

Description of the study area

Soukhouma district was selected as the focus of this study as it is a major agricultural producing region in Champassak province (Figure 2) and poverty affects 70% of the population (Lao People's Democratic Republic 2004). It has also been identified as a priority area to improve livelihoods through research and development. Soukhouma district spans from the Mekong River in the east to Thailand in the west and covers 117,951 ha, of which about 10% is dedicated to rainfed rice production. Only 0.2% of the total area has access to irrigation infrastructure for dry-season production. Soukhouma experiences a tropical monsoon climate with distinct wet (Apr–Oct/Nov) and dry (Oct/Nov–Mar) seasons. Based on meteorological records obtained from the Department of Meteorology and Hydrology (2013), the average daily temperature is 27.8 °C, the average annual rainfall is 1,800 mm and the average annual reference evapotranspiration is estimated at 1,860 mm. The topography of the district is mainly represented by lowland plains, which extend approximately 20 km west of the Mekong River. Beyond the edge of the alluvial plain, elevation rises to gentle slopes

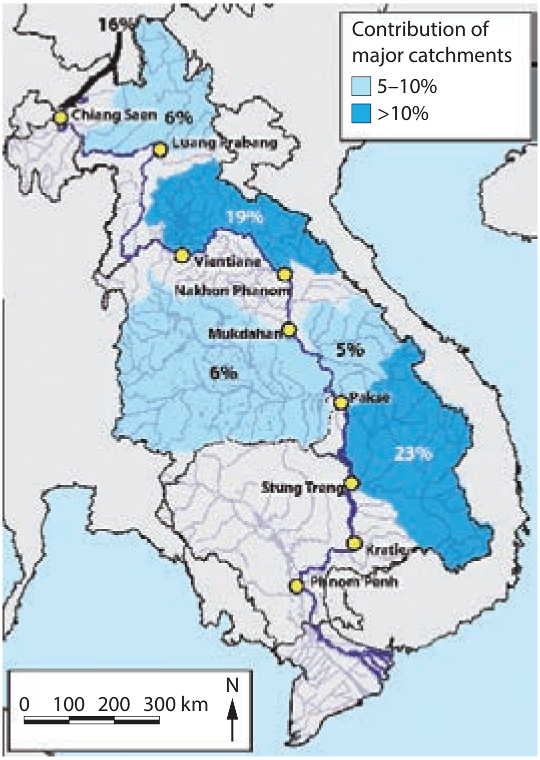

Figure 1. Contributions to flow of major catchments within the Lower Mekong River Basin.
Source: MRC (2009)

(~10–52 m above mean sea level, AMSL) while close to the mountainous border of Thailand, the elevation begins to rise from ~12 to 177 m AMSL along the border over a distance of less than 4 km. The network of streams within the district drains towards the Mekong River (Figure 3).

Figure 2. Map of Champassak province showing the location of Soukhouma district

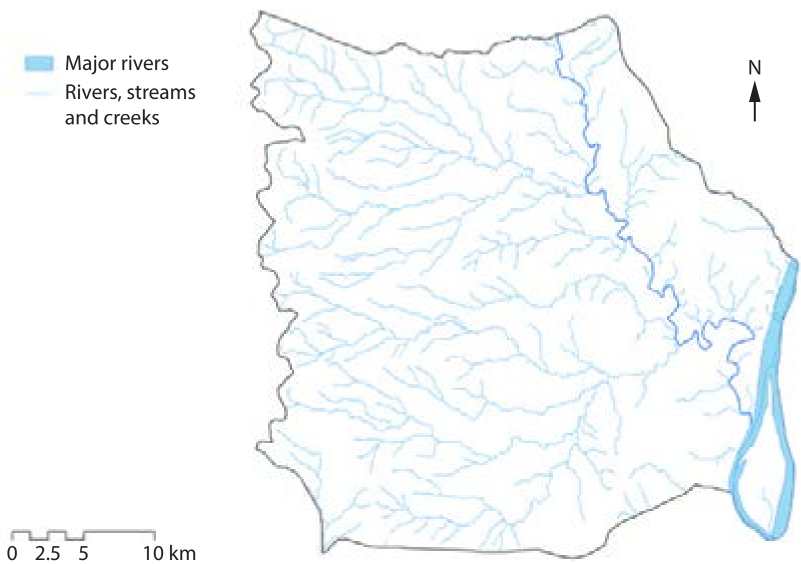

Figure 3. Stream network of Soukhouma district

Methodology

Groundwater and rainfall observation

Two approaches were used to understand the basic dynamics of the aquifer system within Soukhouma: the monitoring of 11 spatially separated existing domestic bores (Figure 4); and establishing a transect of five paired observation wells (Figure 5).

At each groundwater monitoring site, rain gauges were installed to enable rainfall to be measured daily. This information was used primarily to assess the

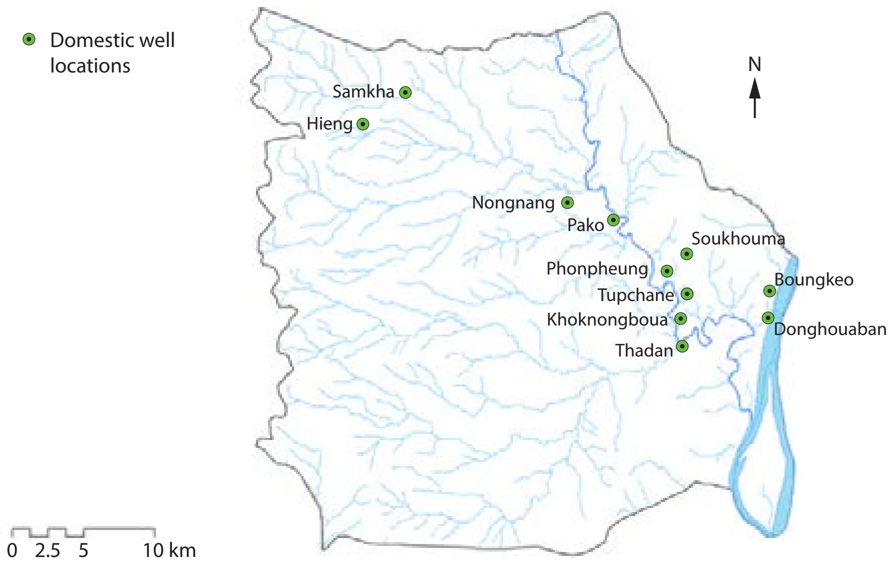

Figure 4. Location of domestic wells across Soukhouma district

Figure 5. Location of paired observation wells in Soukhouma district

response of the aquifer to rainfall; it also provided useful information regarding the distribution of rainfall across the district.

The shallow domestic wells—located along a transect from the Mekong River to the Thai border in a north-westerly direction—were monitored weekly for groundwater height and salinity (electrical conductivity, EC) using a water level meter (Solinst Canada Ltd, Ontario, Canada). Monitoring commenced on 2 October 2011 and ceased on 26 December 2013.

The paired observation wells were installed at five locations and were strategically placed to follow a north-westerly transect—from Boungkeo village near the Mekong River to the uplands about 2 km east of the Thai border (Figure 5). These sites were chosen as they appeared to follow a natural drainage line as determined from topographical (data not shown) and streamflow maps (Figure 3). The wells were developed between July 2012 (Boungkeo and Pako) and January 2013 (Soukhouma, Parkxang and Hieng). The shallow bores were approximately 25 m deep, while the deep bores varied in depth and ranged from 53 m at Parkxang to 120 m at Hieng. Further to the provision of additional groundwater-monitoring sites, the drilling logs and pumping tests conducted by the Department of Health and Sanitation (Pakse) provided useful information on lithology and discharge rates of each observation bore (C. Vote et al., unpublished report, 2013). Once established, these bores were monitored weekly for depth to water, salinity (EC) and temperature.

Characterisation of hydraulic properties and lithology of the aquifer

Based on well depth and lithological information provided by the drillers' logs, we concluded that most domestic and observation bores monitored during this project were drawing water from a deep confined sandstone aquifer located at depths of 25–70 m. Consequently, standard pumping test software (AquiferTest 2013.1) was used to characterise the hydraulic properties (i.e. hydraulic conductivity, transmissivity and storativity) of the aquifers using the Theis method (Theis 1935). The drilling logs also provided information to build a preliminary conceptual model of the aquifer system found within the Soukhouma district.

Determination of groundwater behaviour and regional groundwater flow

To determine areas of similar groundwater behaviour, geostatistical spatial interpolation methods (specifically, ordinary kriging) of the point-based groundwater data were employed to create a surface map of the area using standard tools within ArcGIS 10.1. Regional groundwater flow was analysed using the Darcy flow function. This model was used to generate raster data representative of groundwater flow vectors; the standard output being a groundwater volume balance residual raster, which is a measure of the difference between the flow of water into and out of individual cells (ESRI 2012). The inputs required to run the model include a set of raster data, which provide information regarding potentiometric surface, porosity (or specific yield) and saturated thickness of the aquifer and transmissivity.

Estimation of groundwater recharge

Groundwater recharge was estimated using the watertable fluctuation method. This is a simple, indirect method used to derive recharge in a shallow aquifer system, particularly in areas where there is a distinct wet and dry season (Andrade et al. 2005). It is based on the assumption that a rise in groundwater levels in an unconfined aquifer is attributed to recharge water arriving at the watertable (Healy and Cook 2002), where recharge (R) is calculated as in equation (1):

$$R = S_y \frac{\Delta h}{\Delta t} \qquad (1)$$

where S_y = specific yield; $\Delta h/\Delta t$ = change in groundwater level (h) over a period of time (t).

Specific capacity of boreholes

The specific capacity of boreholes was determined by dividing discharge by drawdown (Fitts 2002) as given by equation (2):

$$SC = \frac{Q}{s} \qquad (2)$$

where SC = specific capacity (L/s/m); Q = discharge (L/s); and s = drawdown in the pumped well (m). Since transmissivity is inversely proportional to drawdown, specific capacity is directly proportional to transmissivity.

Findings

Lithology, hydrogeology and hydraulic properties of observation bores

The drillers' logs indicated that the upper layer of the lithological profile within Soukhouma district comprised an unconsolidated material of silty sand and clay overlying a low conductive layer of mudstone and shale (4–40 m). At three locations, there was an additional layer of shale and sandstone (12–60 m). In all five instances, the underlying layer consisted of a sandstone aquifer that varied in depth and thickness. Artesian bore pressure observed during the installation of the wells implied that this particular aquifer may be confined.

The hydraulic properties of the aquifer system observed in this study are presented in Table 1. The storativity values ranged between 2.3×10^{-3} and 0.58, which suggested that the upper mudstone and shale layer may be only a weak confining layer. However, this information is inconclusive and more comprehensive studies are required to determine the precise nature of the aquifer system located within Soukhouma.

Temporal dynamics of groundwater levels

Fluctuations in watertable depth occur for numerous reasons, including recharge, changes in barometric pressure, evapotranspiration, lateral flow and pumping for industrial, domestic or agricultural use (Rasmussen and Crawford 1997; Crosbie et al. 2005). Figure 6 presents depth to the watertable and rainfall monitored at five selected domestic wells (Soukhouma, Pako, Khoknongboua, Tupchane and Phonpheung) from 1 October 2011 to 31 October 2012.

As illustrated in Figure 6, it appeared that groundwater levels responded to seasonal rainfall. Although the 2012 wet season began in April–May, groundwater levels in the bores did not begin to recover until June–July—by which time, 40% of total rainfall had been received. The 2–4 month lag is most likely attributable to the time taken to fill the soil profile following the dry season.

Maximum depth was recorded for all domestic wells, except Nongnang (data not shown), during the first few months of the wet season (late April–early July). Minimum depths were observed from early September to mid October, except for Tupchane where the minimum peak was reached on 7 August 2012. Domestic boreholes located further away from the river experienced less total annual fluctuation. The greatest differences in watertable heights were observed in those villages closest to the Mekong River (i.e. Boungkeo, Thadan, Donghouaban and Tupchane); this is indicative of the close linkage of surface–groundwater bodies between the Mekong River and the shallow aquifers in areas close to the river.

Initial observations of depth to groundwater indicated that the paired observation wells (both the shallow and deep bore) located at Boungkeo, Soukhouma, Pako and Parkxang appeared to penetrate the same aquifer system, as indicated by the similar depths to groundwater in both bores (data not shown). However, the paired bores located at Hieng appeared to be located in two different stratigraphic layers.

Estimates of groundwater recharge and groundwater flow

Groundwater recharge in this study, calculated using the watertable fluctuation method, appears to be overestimated, particularly for the bores situated at Soukhouma and Parkxang, which further implies that the sandstone aquifer may be confined rather than unconfined (see earlier section on 'Lithology, hydrogeology and hydraulic properties of observation bores'). Therefore, a predetermined value of 0.1 was

Table 1. Hydraulic properties of the aquifer estimated using the Theis approach

Site of observation well (village)	Transmissivity (m^2/day)	Storativity (dimensionless)	Hydraulic conductivity (m/day)
Boungkeo	173	0.01	3.76
Soukhouma	313	0.58	9.21
Pako	265	2.30×10^{-3}	8.83
Parkxang	174	0.58	7.57
Hieng	0.17	0.05	6.00×10^{-3}

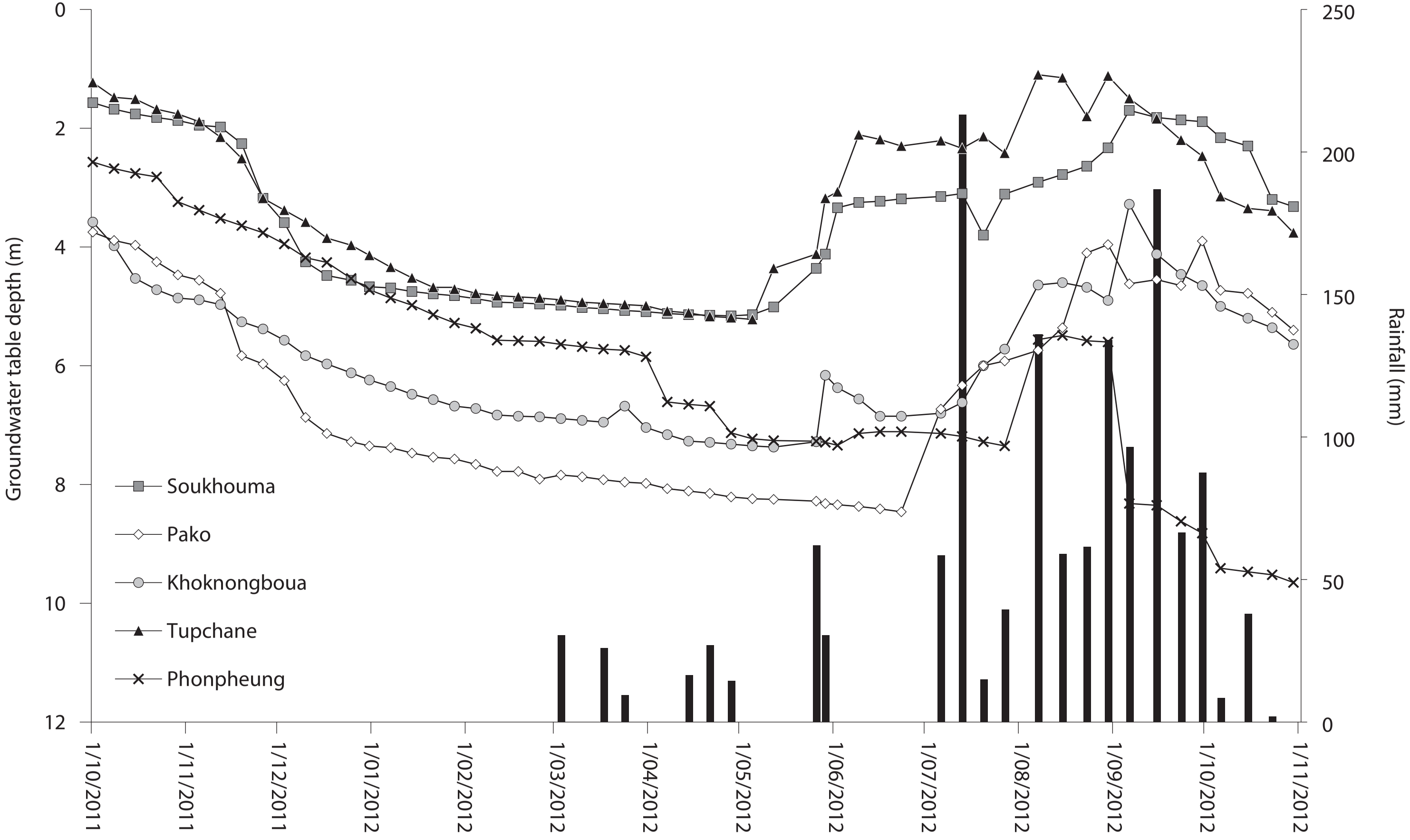

Figure 6. Rainfall and depth to the watertable at five domestic wells over the period 1 October 2011 to 31 October 2012 (vertical bars = rainfall)

substituted to estimate recharge. This value is based on known geological properties of similar sandstone formations (Fitts 2002). Estimated recharge values for the 28 April 2012 to 12 October 2012 period are presented in Table 2.

Table 2. Estimated groundwater recharge for the period 28 April – 12 October 2012

Site of domestic well (village)	Recharge	
	mm	%
Soukhouma	346	20
Samkha	371	22
Pako	456	27
Nongnang	158	9
Khoknongboua	409	24
Tupchane	412	24
Thadan	480	28
Boungkeo	464	27
Donghouaban	422	25
Phonpheung	352	21
Average	387	22

Note: percentage of annual recharge based on an average annual rainfall of 1,800 mm; Hieng was omitted from this analysis due to the difference in hydraulic properties.

As illustrated in Figure 7, the interpolated results indicated that recharge was greatest in the areas in the eastern part of the district. For example, the highest recharge estimate occurred at Tupchane (480 mm). There was also an area of high recharge at Pako (456 mm), which is situated on a tributary stream that drains into the Mekong River. Further to the west, recharge began to decrease and was least in Nongnang (158 mm). This is most likely attributable to a hydraulic gradient from the elevated areas in the north-west of the study area to the lowland plains in the east. The average recharge calculated across the region was 387 mm (Table 2) and represented ~22% of total rainfall received during this period.

Towards the end of the wet season (September 2012), the direction of groundwater flow calculated using the Darcy flow function showed that groundwater flowed predominately from west to east towards Soukhouma village (Figure 8). This model also indicated groundwater flow from the Mekong River back towards Soukhouma village (i.e. east to west); another indication of the strong surface-groundwater interactions near the river at this particular time.

Implications for policymakers

Numerous reports have indicated that substantial volumes of groundwater are believed to exist in the alluvial sediments associated with the Mekong River in South-East Asia. Although some aquifers probably contain salts, most are believed to contain mainly fresh water (WEPA 2014). These sources have great potential to supply the domestic water needs of rural communities. As electrification of the region proceeds, investment by many households and villages in shallow tube wells has ensured a supply of safe, reliable and comparatively cheap pressurised domestic water. As time progresses, rural communities will become increasingly dependent on shallow groundwater as their principal water source, of which signs are already evident. For instance, a household survey of three villages in Champassak province conducted in June 2013 indicated that water usage had increased beyond purely household needs, and that groundwater was more commonly being used to irrigate household gardens and small commercial vegetable plots. In the near future, this practice may become universal as householders identify groundwater irrigation of small plots as a means of improving food quality and deriving household income. Inevitably, this will lead to an increase in either the number of bores or expanding the size and depth of existing bores to access greater volumes of groundwater.

Global experience regarding the development of groundwater systems to ensure long-term sustainable use indicates that:

- it is easier and less stressful to plan and develop policy before a resource is developed
- system vision and knowledge, forward planning and policy development, together with supporting legislation, are necessary elements for enabling effective governance of a natural resource.

Groundwater use of the Mekong alluvial plain in southern Laos is in its infancy but pressures exist to increase usage of this resource. It would therefore seem timely, given the experience of others, for the Lao Government to develop policy and legislation to guide the sustainable development of this resource.

Interaction between surface and deeper groundwater systems

The research undertaken in ACIAR Project CSE/2009/004 (*Developing improved farming and*

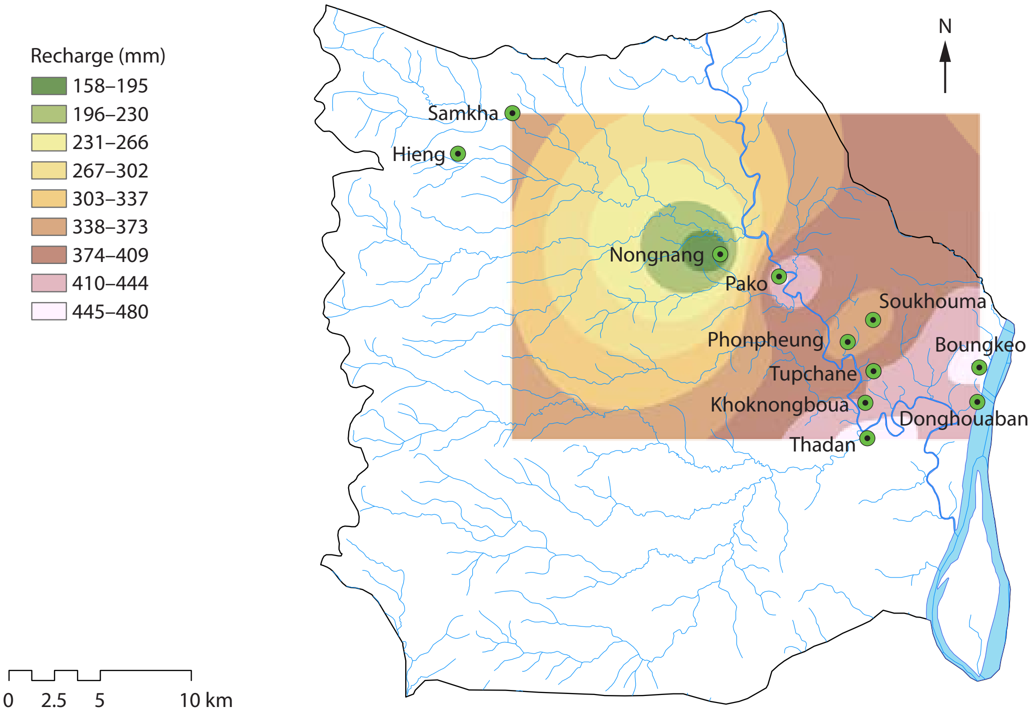

Figure 7. Spatial interpolation of regional groundwater recharge in the Soukhouma district for the period 28 April – 12 October 2012

marketing systems in rainfed regions of southern Lao PDR) focused on only the shallow aquifer of the Mekong alluvium. The intention in developing the deep observation wells was to drill beyond the surface system so as to understand the interaction between the deeper and shallow system. However, drillers' logs indicate that this intent may not have been realised; or that no tangible aquitard exists between the water-bearing layers. As indicated in Figure 6, watertable height across the alluvial plain is highly seasonal, clearly illustrating the relationship between rainfall and recharge after the onset of the wet season, and periods of discharge during the dry season.

Although it is probable that the aquifer system investigated in this study has capacity to allow for some irrigation using groundwater, extensive groundwater irrigation across the plain, particularly for crops with high water requirements (e.g. rice), is unlikely to be sustainable. This is particularly true for those areas where aquifers are replenished only by surface leakage and the lower average annual estimates of recharge do not meet crop water use requirements. This conclusion is based on several assumptions, including: the surface aquifer is fed only by surface recharge without appreciable lateral flow, and any subterranean system is separated by an impermeable aquitard from which upflow is negligible. As considerable knowledge gaps still exist, further detailed study of the groundwater systems within the region are required before adequately informed policy can be developed. At a regional scale, these studies should include:

- better estimates of recharge and lateral flow patterns
- the relationship between surface and underlying aquifers
- quality modelling to: (1) investigate various extraction scenarios on watertable levels, and recovery rates and impact on other users; (2) spatially distinguish areas and depths from where water can be extracted with minimal impact to other users; and (3) analyse impacts on groundwater behaviour and watertable levels based on regional climate-change predictions.

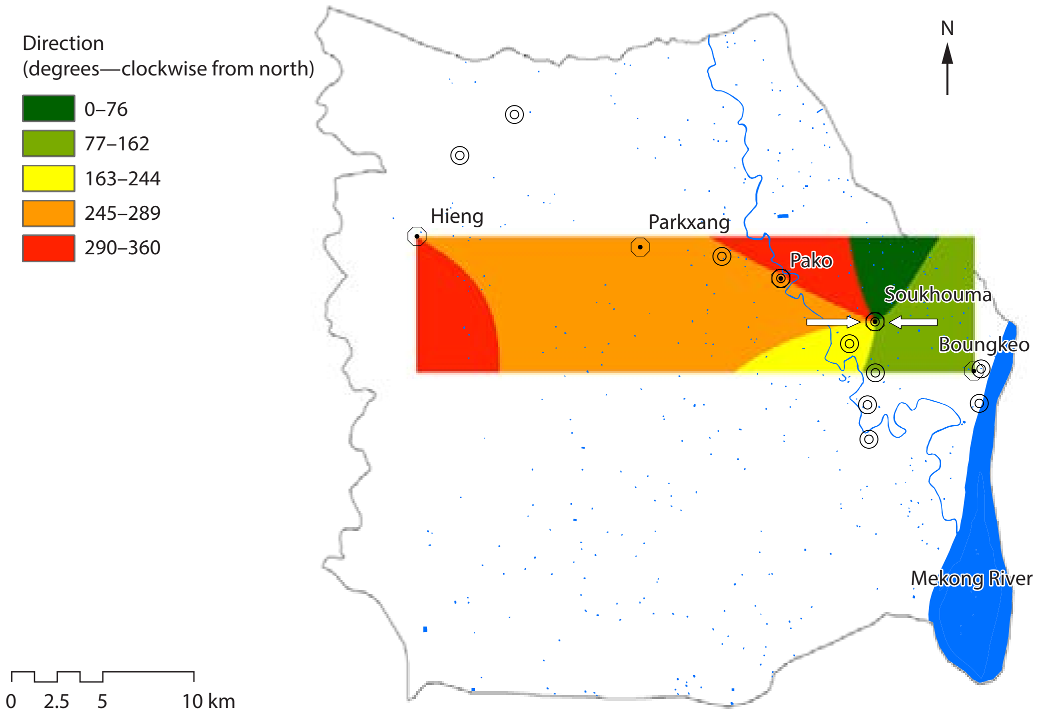

Figure 8. Modelled groundwater flow direction in the Soukhouma district, September 2012

These studies will also provide better knowledge about system behaviour at a more local scale, which will inform policy and guidelines on the specific installation of groundwater infrastructure, such as well depth for specific uses, distance between wells and distance to environmental assets (e.g. wetlands and rivers).

Risks regarding capacity of the system to deliver water to domestic users

Greater rates of groundwater extraction will increase the depth to watertables at times when recharge or other inputs of groundwater are limited, except in the case of groundwater bodies of exceptional size. Figure 6 illustrates the high seasonality of the depth to groundwater; greater consumptive use will result in further decline in watertable height, especially in the dry season. Watertable heights may drop to depths greater than the average depth of household domestic wells, preventing affected households from being able to pump water. Evidence obtained through the household survey showed that this is already occurring in some villages in northern Champassak province, although the exact cause is unknown.

Although the primary objective of developing groundwater policies is to ensure sustainable resource use, it is also important to establish access priorities for environmental needs, basic human needs (domestic supply), industrial use and irrigation. Accompanying policies for managing any conflicts arising are also needed. Mechanisms should be put in place to adequately protect higher priority uses from the potential adverse impacts from lower priority uses.

Licensing, metering and measurement

Future sustainable groundwater resource use, particularly where demand exceeds supply, will mean higher user costs and more bureaucracy. To achieve equitable access and use, certain procedures governing use are mandatory, including:

- establishment and maintenance of a regional register of infrastructure and individual bore capacity
- licensing of users, and allocation of volumetric entitlements
- calculation, or preferably metering, of water use.

Conclusion

Almost without exception, the experience of most countries regarding groundwater use has been that development and use has preceded the development of legislation governing use. Under these circumstances, the development of legislation that focuses on returning usage to sustainable levels commonly occurs in an environment of conflict and acrimony—with users losing both access to water and part of their investment. With groundwater use in southern Laos in its infancy and with growing demand, it would seem opportune to develop legislation that will ensure sustainable and equitable future access to groundwater reserves. However, as effective legislation cannot be developed in the absence of data, there is an immediate need for knowledge of the lower Mekong alluvial aquifer in a form that enables informed policy development. Although some studies focusing on the Mekong alluvium have been recently conducted, there is a need for wider and more strategic investment—incorporating scenario modelling—to enable the development of a regional groundwater model. The existence of such a tool may allow for the establishment of rules for access and use, so that future growth in use is legislated for without compromising the resource.

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Investing in water management to improve productivity of rice-based farming systems in Cambodia

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Abstract

This study reviewed trends, issues and constraints affecting investments in agricultural water management in Cambodia. Informed by a review of current programs and the literature, workshops were convened in March 2013 to explore four keys areas: investments in irrigation, local institutions for managing irrigation, use of groundwater for irrigation and impacts of intensification on rice-field fisheries. We present some conclusions and unresolved questions here to promote a more broadly based debate around irrigation policy and investment in Cambodia. Drawing on the results of these workshops, policy briefs were compiled and published in English and Khmer.

Introduction

Australian Centre for International Agricultural Research (ACIAR) Project LWR/2012/013 (*Investing in water management to improve productivity of rice-based farming systems in Cambodia*) reviewed trends, issues and constraints affecting investments in agricultural water management in Cambodia. We convened workshops in March 2013 to explore four keys areas based on a review of current programs and the literature (de Silva et al. 2014). Policy briefs were compiled and published in English and Khmer drawing on the results of these workshops (IWMI and ACIAR 2013a–d). We present some conclusions and unresolved questions here to promote a more broadly based debate around irrigation policy and investment in Cambodia. An extensive reference list is available in de Silva et al. (2014) and in the policy briefs.

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Investments in irrigation

Irrigation is promoted by the Royal Government of Cambodia as a major component of its poverty reduction and economic development strategies. In 2012, the Ministry of Water Resources and Meteorology (MOWRAM) listed over US$260 million in planned investments, in the form of loans and grants for ongoing irrigation investments with external partners, with a further US$868 million committed; mainly for large-scale infrastructure. The question facing the government is how to target its investment most effectively, given the possibly divergent goals of increasing rice exports at the national level and improving food security and poverty reduction at the local level.

The largest areas of existing irrigation in Cambodia are suitable for only wet-season irrigation and proposed new schemes continue this pattern—for example, the proposed Vaico River project will irrigate 108,300 hectares (ha) in the wet season (WS) and 27,100 ha in dry season (DS). Studies indicate that WS irrigation has very little impact on rice yields: irrigation of WS rice functions mainly to reduce risk of crop loss. It can be argued that investments in large infrastructure (canals and storages) for WS irrigation are unlikely either to significantly address poverty alleviation objectives efficiently or increase the availability of rice for export. Although there may be more efficient ways to promote food security, protecting the WS crop remains a very high priority for the government. Given the high establishment costs of formal schemes, and ongoing problems with operation and maintenance in existing schemes, small-scale pumping of surface water and/or groundwater, or small on-farm storages, may be more efficient ways to drought-proof WS crops.

Full irrigation of DS rice provides high yields, but requires high levels of inputs (improved seeds, fertilisers and pesticides), and so does not generally benefit the poor, who are less able to afford the inputs and less willing to take the associated risk. Three successful models for DS intensification were identified: reservoir schemes in the Tonle Sap basin; large canal systems such as those in Takeo province; and individual pumping of groundwater in Svay Rieng and Prey Veng provinces. In each of these contexts, cultivation of two or even three crops a year is possible, and yields of 6 tonnes/ha (t/ha) are not uncommon, but public investments have focused on the first two models, and opportunities to invest in smaller scale, farmer-based solutions have been largely ignored.

Investments by government and development partners have focused almost entirely on formal irrigation schemes, but a shift towards informal, water-scavenging irrigation is already underway, driven by individual farmer investments. Agricultural water management planning in Cambodia needs to support these new modes, as an adjunct to traditional formal schemes. Small-scale storages and pumping, with conjunctive use of surface water and groundwater, can improve water delivery both within and outside formal schemes. There are significant advantages in terms of flexibility and individual control over water access, allowing reliable, timely and adequate supply of irrigation water, but these pose a new set of challenges in terms of managing water resources.

Groundwater for irrigation

There has been increasing use of shallow groundwater for agriculture in Cambodia over the past 15 years, particularly in the southern provinces, but uptake has been relatively limited compared with other parts of Asia. Groundwater is available in most areas of the lowland plains of Cambodia, and is extensively used for domestic and urban supplies. However, the adequacy of flows for agricultural purposes and the sustainability of the resource are uncertain. Do groundwater resources provide an opportunity for Cambodia to go directly to an efficient model of small-scale irrigation, bypassing the need for the expensive infrastructure of formal surface-water irrigation with its attendant problems of operation and maintenance? Or is it inherently unsustainable, suitable for only limited applications?

Discussions at an International Water Management Institute (IWMI)/ACIAR workshop explored reasons why groundwater use for agriculture is limited, and the conditions under which it would be most viable. The greatest potential for groundwater was seen to be in supplementing surface water to extend the WS cropping period—as insurance against drought during the WS—and to provide flexible, farmer-controlled access to water for high-value crops, such as vegetables. Possible reasons identified for low groundwater use were: high pumping costs; returns too low to justify drilling wells; the extent of the resource is not well known; and MOWRAM has adopted a precautionary approach to groundwater use for agriculture because of the risks of aquifer depletion affecting domestic supplies.

The workshop concluded that a systematic national survey of well drillers—supplemented by existing geological studies and well databases held by the Ministry of Rural Development and the Ministry of Health/United Nations International Children's Emergency Fund (UNICEF)—could provide valuable insights into the viability of groundwater resources in different regions. This information, combined with an analysis of current patterns of irrigation demand, could provide the basis for identifying priority areas for groundwater development—accounting for the sustainability of withdrawals and targeting specific uses and sectors to ensure that the greatest value is derived from the resource.

Institutions for irrigated agriculture

Irrigation development in Cambodia has been accompanied by the formal adoption of 'participatory irrigation management' (PIM). Farmer Water User Communities (FWUCs) have been established to take responsibility for water allocation, and for operations and maintenance (in secondary and tertiary canals).

After 15 years of implementation, it seems that the PIM experiment has not lived up to expectations. Many schemes have failed to deliver benefits that justify charging fees large enough to cover operational and maintenance costs, such that FWUCs are unable to maintain, let alone improve, infrastructure. FWUCs operate within individual schemes and are responsible for only agricultural water use, but competition for water between upstream and downstream communities and between different sectors is a critical issue affecting the performance of FWUCs. In addition, FWUCs operate solely within the domain of water access; they do not address any of the other factors that constrain the productive use of water (including market chains).

FWUCs have evolved in the context of formal gravity-fed schemes using either storage or river diversion/pumping. Optimising Cambodia's water resources for agriculture requires a broader definition of agricultural water management with a range of supply and delivery options, varying between regions (e.g. conjunctive use of groundwater and small-scale pumping). Local institutions for water management will need to be responsive to these different mechanisms, with a shift away from the 'one size fits all' FWUC approach. A range of approaches for supporting agricultural water management is emerging in Cambodia, including agricultural cooperatives, private-sector rural water supply providers, farm business advisers and integrated value chains, and contract farming. These examples demonstrate the significant potential for small-scale private-sector service delivery models to overcome a range of current constraints. By way of example, operators of private pumping stations invest in the transfer of available river water to farmers' fields when it is beyond the capacities of farmers to do so, especially where collective action is lacking. It is imperative, therefore, to recognise the comparative advantages and limitations of what public institutions and private market systems can deliver, so that the best of both approaches can be more coordinated in delivering the services needed by smallholder farmers.

Rice and fish: impacts of intensification of rice production

Cambodia's paddy fields have traditionally produced fish and other aquatic animals (OAA) as well as rice. Fishing and foraging in flooded rice fields is important for food and seasonal income for almost all rural households for some part of the year. The economic value of the capture and collection of fish and OAA can approach, or even exceed, the value of the rice harvest, and rice-field fisheries represent up to 28% of the inland freshwater fisheries sector.

The traditional system of rice growing in Cambodia involves prolonged inundation of fields, with no or very low inputs of chemical fertilisers and pesticides. Intensification creates conditions which are less favourable for many aquatic organisms through increased use of agrochemicals, changes in water management (including shorter periods of continuous inundation) and barriers to fish migration due to irrigation infrastructure. Pesticides pose arguably the greatest threat to rice-field fish and OAA.

A range of measures is proposed to safeguard and enhance rice-field fish production, including:

- reduction in pesticide use, through enforcement of regulations, farmer education in the proper use of pesticides, and integrated pest management approaches
- in-field water management
- in-field refuges
- community refuge ponds (man-made or natural)
- reservoir and pond aquaculture.

Gains from intensification of rice production must offset potential loss of rice-field fisheries to be beneficial in aggregate terms, but the comparison is not a simple economic equation. Benefits from intensification of rice accrue to individual (mainly large-scale) farmers, while the rice-field fishery is, in the main, a common pool resource, providing a range of benefits, especially for poorer households. Measures to mitigate loss of the rice-field fishery must go beyond productivity and consider the social distribution of benefits and the wider environmental implications.

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Insights for policy from the ‘Adaptation to Climate Change in Asia’ project

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Abstract

The ‘Adaptation to Climate Change in Asia’ (ACCA) project brings together researchers, collaborating farmers, extensionists and policymakers in Bangladesh, Cambodia, India and Lao People’s Democratic Republic (PDR) to develop and evaluate farming practices to help smallholders reduce the impact of an increasingly variable climate. Locally promising practices that meet the needs and capacity of different types of households have been tested and evaluated on-farm and by modelling. This information is also used to support the design and delivery of climate adaptation programs at broader scales, using information on current and future climate scenarios. This paper provides an overview of the ACCA project and presents a few example results, before concluding with a suite of policy implications.

Introduction

The poorest farm households bear the brunt of climate change because they typically live in more vulnerable areas. Impacts of climate change are likely to be exacerbated where policy environments and capacity to respond are weak. Climate change is already impacting throughout Asia, with evidence of

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increasing temperatures and projected changes to the timing and frequency of rainfall and other extreme weather events (Cruz et al. 2007). As most Asian economies depend more immediately on agriculture than developed countries, and have less resilient institutions, they will be more vulnerable to climate change.

Understanding how to better connect the policy domain to the locus of adaptation (households, communities) has been identified as a key research gap (Roth et al. 2009). To achieve this bridging requires a multi-scale research strategy. The task is to firstly identify and test technically feasible adaptation options at the household and community level; and to secondly translate these local-level findings into information that supports policymakers and development organisations in the design and implementation of effective adaptation programs.

The ACCA project

Australian Centre for International Agricultural Research (ACIAR) Project LWR/2008/019 (*Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India*), known as the 'Adaptation to Climate Change in Asia' (ACCA) project, has been operating for 4 years in case-study locations in Bangladesh, Cambodia, Laos and India. The ACCA project is a transdisciplinary research partnership between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and 21 partner organisations in the above countries designed to address the following questions:

- What are the tools and methods required to select and assess adaptation strategies for rice-based cropping systems?
- How can we strengthen local research and extension processes that support the building of smallholder adaptive capacity in rice-based cropping systems?
- What are feasible crop, nutrient and water management adaptation options that align with smallholder livelihood portfolios against the backdrop of rapid rural change?
- What are the key design principles and stakeholder engagement processes that will enable a more effective implementation of rural adaptation programs at multiple scales?

To guide and underpin the work of the research partnership, an integration framework was developed with all partners (Roth and Grünbühel 2012). A generalised form of the framework is presented in Figure 1.

To expand on Figure 1, there are two main aims of the social research under (A): the first is to relate crop and water management adaptation options to diverse livelihood strategies. For this, a typology of households was developed in each country, which highlights access to resources, adaptive capacity and livelihood strategies (Williams et al. 2013). Using the household types as a filter, we can better understand if and how different agricultural adaptation options are relevant, and for whom. The second aim is to support targeted policy development for adaptation (E and F in Figure 1) that is informed by the varied capacities and challenges illustrated by the household types.

The second main pillar of the framework is the testing of potential adaptation practices on-farm (B in Figure 1). Choice of practices is determined by a variety of factors, but is strongly influenced by farmers' preferences canvassed in focus-group discussions and informed by (A). Benchmarking of current farmer practices against climate variability and evaluating the performance of adaptation practices under future climates is carried out through modelling in (C), constituting the third main project pillar. This requires the choice of an appropriate simulation model like APSIM (Agricultural Production Systems SIMulator) (Keating et al. 2003; Gaydon et al. 2012), parameterised to reflect local soil, crop and farmer management conditions using the on-farm data, in combination with the generation of location-specific climate projections (Kokic et al. 2010). The scenario analysis helps determine which practices can be scaled out with confidence through implementation partners (D in Figure 1), while it also underpins the extrapolation of practices to a broader range of environments (E). On-ground relevance and evidence of uptake (D) in conjunction with generalised adaptation strategies (E) will enable us to develop design principles to inform policymakers how to develop future climate-change adaptation programs that are better targeted and more effective (F).

Key results

The definition of household types has enabled stakeholders to conceptualise and discuss concrete options and measures for each household type.

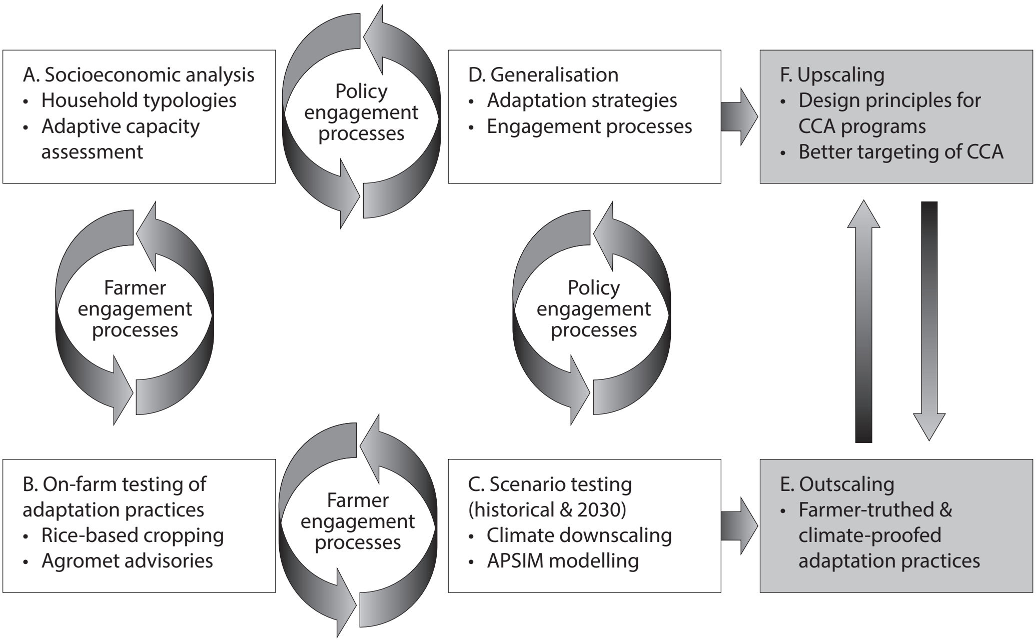

Figure 1. Adaptation to Climate Change in Asia (ACCA) project research framework (CCA = climate-change adaptation; APSIM = Agricultural Production Systems SIMulator)

Irrespective of household type, one driver of adoption common to all four countries emerging from the social research is the relative scarcity of labour, as opportunity costs for labour push people to pursue wage labour off-farm, either locally or through migration to urban centres. Hence, adaptation practices need to be matched to the capacity for uptake of different household types and need to be considered as part of a broader livelihood system, rather than in isolation. Results of the farmer engagement processes also indicated that although climate variability has significant impacts on farming households, it is not the only driver in their decision-making.

A wide range of climate adaptation practices was evaluated on-farm by the project. These included the testing of:

- improved wet-season (WS) rice varieties (salinity, drought, submergence tolerance and short-duration varieties)
- drum and direct seeding of WS rice
- double cropping of short-duration WS rice crops
- improved agronomy, including nitrogen management and weed control
- improved planting rules for rainfed crops
- supplementary WS irrigation from stored water.

The majority of these practices appear to perform as well or better than current farmer practices and seem to offer technically feasible opportunities for adaptation, as well as providing immediate benefits under current climate conditions. However, most of our results indicate higher yields alone will not be sufficient for farmers to adopt technical interventions. These practices are likely to be attractive only in combination with other benefits, such as reducing labour requirements and/or decreasing riskiness of production. A central concept we promoted was that of ‘response farming’, whereby farmers take a more flexible approach to decision-making in response to how a particular season is unfolding. Decision trees underpinned by crop calendars with detailed recommendations for different circumstances are required to support this concept.

The general trends exhibited by our modelling of the adaptation practices are that the 2030 climates in many cases do not suggest a major decline in yields. Depending on the climate scenarios (wetter or drier), by 2030, average yields may vary within ±10% of the current mean. Current variability in yields is much greater than the possible average reduction in yields in 2030, supporting our notion that helping farmers better manage current climate variability is very likely to increase their adaptive capacity to respond to future climatic conditions.

An example of results from on-farm experimentation and simulation is provided in Figure 2 for Cambodia. A comparison of current farmer practices (left-hand column in Figure 2) against improved practices (two middle sets of columns in Figure 2) indicates that simple improvements to crop management—like choice of short-duration varieties, better nutrient management and crop husbandry—can generate yield increases that will offset yield reductions as a result of climate change. However, system performance remains modest, and we term this 'incremental adaptation'. In the case of Cambodia, introduction of double-cropped, direct-seeded short-duration rice in combination with supplementary WS irrigation would greatly reduce climate risk under both current and future climates (right-hand column in Figure 2). Leading collaborator farmers were able to demonstrate the technical and economic feasibility of this strategy in our on-farm research. This constitutes 'transformational adaptation' (Rickards and Howden 2012) and its widespread introduction will require a sustained policy response in many domains.

Initial impacts

In Cambodia, adaptation practices developed by the project involving direct seeding using drum seeders and double cropping of short-duration rice varieties are included in a package of improved farming practices being disseminated across five provinces under the auspices of the Project for Agriculture Development and Economic Empowerment (PADEE), funded by the International Fund for Agricultural Development (IFAD). Initially, this extended our work to 40 communes in 2013, with the prospect of reaching out to 250 communes once PADEE has been fully implemented.

In Andhra Pradesh (India), the Department of Rural Development is supporting the implementation of Climate Information Centres (CLICs) as part of its Integrated Watershed Management Program. This was based on the project's concept of providing a range of climate information products tied to improved farm decision rules and the project's experience in facilitating Farmer Climate Clubs to promote exchange between farmers on crop and

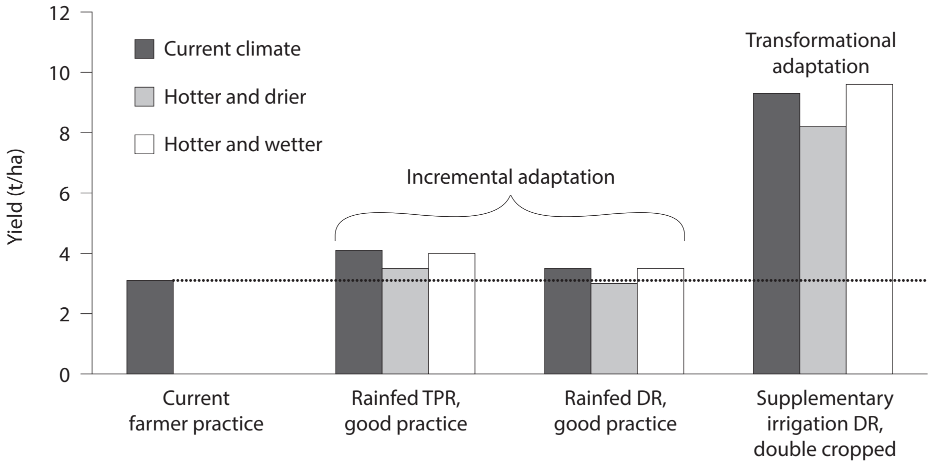

Figure 2. Performance of improved rice cropping systems developed in Svay Rieng province, Cambodia (TPR = transplanted rice; DR = drum-seeded rice)

water management practices. CLICs are being established in 15 villages with a potential outreach to 2,300 farmers.

In Laos, the Provincial Agriculture and Forestry Office in Savannakhet is actively promoting dry direct seeding and crop and nutrient practices evaluated by the ACCA project, and the IFAD-funded Sustainable Natural Resource Management and Productivity Enhancement Project is extending some of the direct-seeding results to rice farmers across the country's major rice-growing region in the five southern provinces. In addition to this, agroclimate advisories being piloted by the ACCA project are gaining the interest of key policymakers and other IFAD projects on climate risk.

Key policy messages

Based on the above results and the initial impacts observed, we conclude with the following set of key policy insights:

- up-skilling farmers in improved crop management (new varieties, efficient nutrient management) can compensate for any possible detrimental impacts of climate impacts by 2030
- new crop-establishment methods (e.g. broadcasting, drum and dry direct seeding) are attractive to farmers because of risk reduction, labour savings and increasing flexibility in cropping options
- more effective matching of new knowledge to farmer decision-making (e.g. agroclimate advisories, village climate information centres, SMS (phone text) messages) can support farmers in becoming better at responding to climate variability and changing markets
- access to supplementary irrigation during the WS could deliver a quantum jump in crop yields while at the same time reducing exposure to climate risk.

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Forum E. Policy and knowledge

Rapporteur's synopsis

Rob Cramb[1]

Forum E panellists

The five forum panellists were:

- Ms Ly Yann Kauv (formerly FLAIR Program, Oxfam, Cambodia)
- Dr Bounthong Bouahom (Director-General, National Agriculture and Forestry Research Institute, Lao PDR)
- Dr Hul Seingheng (Ministry of Water Resources and Meteorology – Institute of Technology of Cambodia)
- Prof. Dr Vo Tong Xuan (Acting Rector, Nam Can Tho University, Vietnam)
- Dr John Ward (Department of Foreign Affairs and Trade – CSIRO Research for Development Alliance, Australia).

Summary

Papers in this forum demonstrated that farm households are at the centre of the rapid change in rice-based agricultural systems in Lao People's Democratic Republic (PDR) and Cambodia. Hence agricultural policies need to be analysed and evaluated in terms of their impact on the decisions made by these farm households and their livelihood outcomes—in other words, 'policy in practice'.

The paper on rice-based farming systems in Laos showed how farm households utilise a range of key *inputs* (land, labour, water, seed, fertiliser, machinery, credit) to engage in a portfolio of farm and non-farm *activities* that, in turn, generate a range of *outputs* (rice, non-rice crops, livestock, forest products). Agricultural policies can influence (but not determine) these input–output processes that make up the farm household's livelihood strategies.

Some policies affect the farm household's access to inputs and resources (e.g. providing and pricing irrigation), others attempt to influence farmers' *activities* (e.g. proscribing swidden agriculture, or urging the cultivation of dry season rice), and others affect farmers' capacity to *appropriate* the returns from their outputs (e.g. marketing and trade restrictions and levies that affect the level and reliability of farm-gate prices).

From the farm household's perspective, these policies are experienced as part of the *context* in which livelihood decisions are made, along with other influences that may in fact have greater sway over decision-making than any single policy—influences such as the rising opportunity cost of labour or the recent sharp spike in the world price of rice.

The paper on the persistence of subsistence-oriented rice farming in the rainfed lowlands of central and southern Laos focused on the farm household and its decisions with regard to wet-season rice production in southern Laos. The research showed that farmers have selectively adopted improved technologies but that, given the economic and policy context, they are quite rational to adopt a low-input, low-yield cropping system that meets their subsistence goals, with possibly a small surplus for sale. This is because they have other uses for their resources, especially household labour, that can generate higher returns with less risk than by intensifying rice production to meet government yield and production targets.

Discussion in the course of the policy dialogue suggested that policymakers in Laos are now moving away from such a target-oriented approach that attempts to directly influence farm household *activities*, in recognition of the trend towards diversification of rural livelihoods.

A suggestion raised in discussion was that improved government extension could help farmers to apply intensive technology properly and make more profit, thus meeting the government's policy

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targets. Another suggestion was that the problem is with the government targets themselves—they have been set too high for what farmers can profitably produce. The issue is therefore more about a mismatch between the government's goals and farmers' circumstances. In particular, the price of rice is generally too low to justify planting irrigated rice in the dry season.

The papers and discussion on the constraints to rice intensification at the household level highlighted the need for policies that:

- assure the quality of rice seed supply
- provide improved varieties that offer greater resilience in the face of pests and diseases, rather than being selected for maximum yield
- improve the supply of credit for fertiliser (as previously provided through the Agricultural Promotion Bank)
- assure the quality of fertiliser
- provide advice to farmers on the efficient use of water (e.g. through crop diversification)
- improve access to postharvest technology (e.g. drying technology to improve grain quality and price)
- provide finance to millers to upgrade their facilities
- avoid sudden shifts in rice trade policy that damage farmers' and millers' incentives.

A question was raised as to whether analysis of this kind—tracing the links between input supply, production and marketing—was relevant to policy, which is concerned with deciding on priorities for the rice sector as a whole, including expanding into export markets. It was argued that this perspective assumes that the rice sector is part of the public sector and that rice farmers are merely 'instruments' to achieve government production and export targets. Forum presenters contended that policy contributes to the context in which rural households pursue diverse livelihood strategies, influencing but not determining their options and choices. Earlier in the policy dialogue, policy actors questioned whether pursuing an export-expansion policy in fact made sense for Laos, apart from specific, potentially profitable niche markets.

The paper on linking research and extension through on-farm research argued that the extension system is a key element in the provision of knowledge to farmers and that it complements their physical and financial inputs. This was further supported in papers on policy challenges for Cambodia's agricultural development and food security. However, the notion of 'technological transfer' from researchers to farmers is outdated. The concept of an 'innovation system', in which many actors (research-oriented farmers, astute extension workers, field researchers, input suppliers, agro-processors) contribute to a process of agricultural innovation, is much more realistic.

There has been much focus on the public-sector's role in providing knowledge and of the need to invest more resources in government extension services. However, it is clear that much of the information accessed by farmers comes through private-sector channels, such as through seed and fertiliser suppliers. The accuracy and relevance of this information is often dubious (e.g. labelling of fertilisers), and it may be that limited government resources are better directed at ensuring the quality of this information flow rather than continuing to focus only on conventional and costly public-sector extension.

The rapid adoption of mobile phones by farmers offers another potential means of knowledge transmission that is being successfully exploited in some developing countries.

Research presented demonstrated that lowland rice farmers in Cambodia, given more favourable market prospects and, in particular, a cross-border value chain driven by traders and millers from Vietnam, have been able to intensify production and expand exports. This export growth has not only been due to dry-season production of Vietnamese rice cultivars for the Vietnamese export market but also exports of premium-quality fragrant rices produced in the wet season, often in contract-farming arrangements that partly address the issues of access to inputs.

The research pointed to similar conclusions about the need for policy interventions to improve farmers' access to good-quality seed, irrigation, fertiliser and credit, along with improved extension services. The evidence suggests that in the Mekong region there is a lack of integrated service provision, such as found in some neighbouring countries. There are also problems of informal marketing arrangements with Vietnamese traders, resulting in unstable demand and prices.

Contract schemes with millers and exporters of high-price wet-season rice have also suffered from their reliance on contracts with individual farmers. The formation of production groups may ensure that farmers have more bargaining power with large agribusiness firms and that contract farming better addresses the input supply and marketing issues facing rice farmers in general in the Mekong region.

Subsistence-oriented rice farming in the rainfed lowlands of central and southern Laos—a policy dilemma

Vongpaphane Manivong[1,2]*, Jonathan Newby[1,3] and Rob Cramb[1]

Abstract

Despite rapid economic, social and political change in the Lao People's Democratic Republic (PDR) in recent decades, the cultivation of glutinous rice for subsistence remains the basis for rural livelihoods in the rainfed lowlands. Even with increased output from the partial adoption of green revolution technologies, lowland rice production in central and southern Laos remains an economically marginal activity, providing limited economic incentive for farmers to intensify production beyond household consumption needs, particularly as the opportunities for employment in non-farm activities increase. In this paper, we demonstrate that attempting to improve rural livelihoods and overcome poverty by increasing rice production per unit area through increased application of modern inputs and the commercialisation of rice production systems is unlikely to be a successful approach. Nevertheless, there is a need to improve the productivity and stability of this important subsistence-oriented activity to enhance the capacity of rural households to engage in both farm and livelihood diversification.

Introduction

Rural communities of Lao PDR have one of the highest per capita consumption rates of rice in the world, with rural households estimated to consume around 200 kg per capita annually (Eliste and Santos 2012). As such, the cultural and economic importance of paddy rice production for households in the lowlands of Laos cannot be overstated. Despite various processes of economic, social and political change over several decades, the cultivation of glutinous rice remains the platform on which rural livelihoods in the rainfed lowlands are based. Although rice production remains an important 'core' activity of the household, lowland farmers continue to face a number of constraints at the farm level, including low soil fertility, droughts and floods, and various pests and diseases (Linquist and Sengxua 2001; Schiller et al. 2001; Fukai and Ouk 2012). However, equally important are factors beyond the farm boundary—such as rising input costs, fluctuating output prices and uncertain trade policy—that continue to limit farmers' incentive to intensify production beyond that required to achieve household self-sufficiency.

Over the past decade, lowland rice farmers have adopted a range of technologies to improve the productivity of their farming systems, including the cultivation of modern varieties, use of inorganic fertiliser and limited mechanisation (Newby et al. 2013). This has enabled individual households, lowland rice-growing regions and Laos as a whole to achieve rice self-sufficiency. However, rice farming in Laos is subject to significant economic drivers of change, with the domestic economy increasingly integrated

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into the regional economy. Despite the achievements of the green revolution technologies in terms of increased yield and output, lowland rice production in many parts of Laos remains an economically marginal activity, providing limited economic incentive for farmers to intensify production beyond household consumption needs. This poses a challenge for the Lao Government, which 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. At the same time, there is also a trade-off between the objective of achieving rice self-sufficiency and the objective of promoting economic development and poverty alleviation in the countryside.

In this paper, we aim to explain farmers' livelihood strategies in the rainfed lowlands of central and southern Laos in the context of current resource endowments, product demand, and yield and market risks. We demonstrate that although the rainfed production system remains largely subsistence-oriented, farmers have selectively adopted a range of new technologies and continue to respond to changing incentives. To date, however, 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 argue that this strategy makes good economic sense in the context of a diversifying rural economy and does not necessitate government intervention to promote more intensive, market-oriented rice production systems.

Framework

Socioeconomic evaluation of various technical innovations is an essential part of the farming systems research cycle. Before recommendations are made to farmers and policymakers, results from farm trials need to be subjected to economic analysis. However, it is important that the metrics used in this process actually reflect the goals of farming 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' goals and circumstances and national government policies align, and the ability of farmers to influence research and development priorities. It is important to reflect on the extent to which farmers' needs are driving research priorities, and research is informing policy, rather than the other way around.

It has long been accepted that smallholders manage a 'portfolio' of farm and non-farm activities that contribute to the household's livelihood. Therefore, evaluating the impacts of a technology on a particular activity needs to be considered at the whole-farm scale. Activities in the livelihood portfolio contribute to various short-term and long-term goals, and so are subject to different evaluation criteria by farmers (with variation even between members of the same household). McConnell and Dillon (1997) identify two main operating extremes of farm households—profit maximisation (or expected profit where risk is also considered) on market-oriented farms, and household sustenance on subsistence-oriented farms. In reality, smallholders rarely operate at these extremes, with the relative importance of each objective varying between farm types.

Furthermore, different activities within a household portfolio may be more closely aligned to the different ends of the spectrum—for example, a subsistence-oriented wet-season rice crop (for sustenance), followed by a commercial non-rice crop (for profit), alongside long-term tree–crop investments elsewhere in the farming system (for the accumulation of assets, perhaps between generations), with livestock having multiple functions (sustenance, short-term income and capital accumulation). It is also clear from various adoption decisions that farmers also place value on having adequate leisure time or the avoidance of drudgery and are willing to trade-off the extra effort required against the potential benefits. These multiple objectives make evaluation difficult as the impact of a technology on one activity cannot be separated from the impact on the whole livelihood portfolio.

Beyond the two objectives of profits and sustenance, most farm households will have a range of other objectives, including the maintenance of their culture, customs and social norms. Farming households are embedded in formal and informal networks of social and economic relations. It is important to understand how current local institutions work and how they govern access to key resources and influence the relative advantage of various technologies.

The voluntary adoption of practices is a good first indicator that the technologies are meeting farmers' needs. Alternative technologies and farming systems have different characteristics in terms of productivity, profitability, stability, diversity, flexibility of product disposal, time-dispersion of costs and returns, sustainability, and complementarity with the existing farming system (McConnell and Dillon 1997). Pannell et al. (2006) identify two broad characteristics of a technology that influence the adoption decision: its relative advantage over existing practices and the degree of trialability. When recommended technologies are not adopted by farmers, researchers and policymakers are often confused as to whether there is a problem with the extension of the technology (related to its trialability as well as the extension process itself) or whether the technology does not offer a relative advantage to farmers in achieving their objectives.

Methods

This paper is based on the analysis of data collected in several phases of field work in the lowland plains of central (Savannakhet province) and southern (Champassak province) Laos, 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 in order to focus the analysis on the main form of rice growing in Laos and the one that is the target of rice-intensification policies—rainfed lowland rice.

Thus, for present purposes, the study region included six villages in Outhoumphone, Phalanxai and Phin districts in Savannakhet province and six villages in Phontong and Soukhouma districts in Champassak province. 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 Champassak. Survey and case-study data were supplemented with agronomic trial results in order to construct model enterprise budgets for various input scenarios. These included data from fertiliser response trials conducted by the International Rice Research Institute (IRRI) and the National Agriculture and Forestry Research Institute (NAFRI) over more than a decade (Linquist and Sengxua 2001, 2003; Haefele et al. 2010).

A range of indicators was used in an attempt to capture the criteria for farm-household decision-making with regard to input use. The gross margin (GM) was defined as the gross value of rice production at market prices, or gross income (GI), less variable input costs (VIC)—that is, the cost of all current inputs, whether in cash or kind, but not including household labour. This measured the income earned by the household's resources of land, labour and capital. When divided by the number of days of household labour (GM/day), it gave the best indicator of the relative advantage of the practice to the farmer as it could be readily compared with the prevailing wage rate (W)—an upper limit estimate of the opportunity cost of household labour. Hence, GM/day can be considered a useful proxy for the return to labour. The net income (NI) or, strictly, the margin after labour costs, was defined as the GM less the imputed cost of household labour (LC), valued at the rural wage rate (W). Total variable costs (TVC) were defined as variable input costs plus household labour cost (VIC + LC). Hence, NI equals GI less TVC, and can be considered a proxy for the return to land. Sensitivity, threshold and risk analyses were also conducted to take account of yield and price fluctuations. In 2013, the model budgets were presented to farmer focus groups for validation and updating with input and output prices relevant to the 2012 wet season. Farmers confirmed that measures such as GM/day that took account of their labour were particularly useful.

Intensification, mechanisation and diversification

A range of innovations has been investigated within the Australian Centre for International Agricultural Research (ACIAR) Rice-based Systems Research (RSR) program in Laos. These can be classified into three groups: intensification, mechanisation and diversification.

Intensification—more fertiliser?

'Intensification' is used here in the sense articulated by Boserup (1965) to encompass both greater use of labour and other inputs to increase yields per cropped hectare and increased utilisation of land—notably through irrigated double cropping—to increase annual production from the available area (i.e. increased cropping intensity). In other words, the term is used to indicate a 'land-saving' rather than a 'labour-saving' path of technical change (Hayami and Ruttan 1985). Pandey (1999) argued that, in situations with low population density and low-income levels, farms tend to be subsistence-oriented, with limited demand for improved nutrient management technologies that increase yields and returns to land. Such technologies will be adopted only if they also help save labour—the relatively scarce resource. He also argued that, in order to stimulate farmers' demand for yield-increasing technologies, policies need to focus on improving the profitability of rice production. In this section, we assess whether intensification strategies would in fact improve the profitability of rainfed lowland rice production in Laos.

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. Importantly, their recommendations recognised that the rainfed lowlands constitute a risky environment. As such, recommendations were formulated based on relatively low investment and high nutrient efficiency rather than attempting to obtain maximum yields. Although the percentage of households using inorganic fertiliser has increased significantly over the past decade in the study villages, the level of use remains well below these recommended rates. The limited use of fertiliser reflects the high cost of purchasing inputs, the limited access to credit, the high level of production risk and market uncertainty should a rice surplus be produced. Physical access, counterfeit products and limited knowledge about appropriate rates and timing contribute to the problems. The overall average fertiliser application rate (nitrogen–phosphorus–potassium, NPK) among the survey households was 15:5:1.5 kg/ha 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.

To help understand the adoption patterns for fertiliser use, enterprise budgeting scenarios were developed based on household survey data and agronomic field experiments. Four scenarios were developed, from no to high fertiliser use (Table 1). The no-input and low-input scenarios correspond to the range of farmers' practice as found in the surveys, the medium-input scenario corresponds to the current conservative fertiliser recommendation and the high-input scenario corresponds to the level of fertiliser needed to achieve the government's target yield for wet-season rice. In all scenarios, although the gross margin (GM)/ha is positive, the net income (NI)/ha is negative, indicating that the GM/day is below the wage rate of 40,000 kip/day. The highest GM/day is achieved under the medium-input scenario (37,000 kip/day). However, moving up to this level of input use achieves a low marginal rate of return (less than 50%)—that is, the increment in NI as a percentage of the increment in total variable costs (TVC). We note that the high-input scenario performs worse than the medium-input scenario on all criteria.

Though not shown in Table 1, the situation was made worse in 2011 and 2012 when the farm-gate price of paddy rice fell to as low as 1,200 kip/kg. At this price, the GM/day was less than half the market wage rate. On the other hand, during the price spike in 2010, when farm-gate prices reached 3,300 kip/kg in some regions, the returns to labour from intensification strategies looked promising. However, farmers in focus groups did not have high expectations that prices would again reach this level.

Threshold analysis was conducted on the farm-gate price of paddy rice (P_r) to determine at what price: (a) the NI would become positive; (b) the GM/day would be 50,000 kip/day (reflecting the trend to increasing wage rates); (c) there would be a positive marginal rate of return (MRR) from moving to the next scenario; and (d) the MRR would be greater than 50% (considered a minimum acceptable rate of return in this context). The analysis showed that the price of paddy would have to rise to unrealistically high levels (2,500 kip/kg) for the high-input scenario to just break even with current wage rates at 50,000 kip/day, and to 4,000 kip/kg for the rate of return generated by moving from the medium-input to the high-input scenario to be above the benchmark rate of 50% (Table 1).

Risk analysis was conducted to assess the stability of the results to fluctuating paddy prices coupled with uncertain grain yields. The risk modelling shows that, across all scenarios, there was a low probability of generating a GM/day comparable to the market wage rate (Table 1). The low-input scenario provides the best (or least bad) outcome on average, and the highest probability of achieving a positive NI, a GM/day above the market wage (whether 40,000 kip/day or 50,000 kip/day), and a marginal return over the next lowest input level of above 50%.

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. The analysis thus highlights the marginal nature of rainfed lowland rice production and hence the difficulties in finding a viable commercialisation pathway for rice-growing households in the current biophysical and economic environment.

Maintaining yields with less labour

Rising labour costs are arguably the factor that is currently most responsible for driving farming system adaptations in the lowlands. 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. Around 75% of households surveyed utilised two-wheel tractors for land preparation rather than relying on draught animal power (mainly buffaloes). 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. Currently, in order to minimise cash outlays, households tend to extend the period of transplanting to cope with the declining household labour resource rather than hire labour or transplanters (with obvious trade-offs in terms of yield). It is expected that mechanisation will continue to expand as labour becomes increasingly expensive, but the demand for contracted harvesting services will be determined by contracting rates relative to the opportunity cost of harvesting labour (and mechanical harvesting of the wet-season crop may still face technical problems). Thus, cash flow will continue to be a constraint to mechanisation for subsistence-oriented households without non-farm income sources.

The critical role of the cost of labour can be seen by returning to the analysis in Table 1. The data show that intensification consistent with the current fertiliser recommendation (the medium-input scenario) has the potential to improve the productivity of rice production and the economic performance of the crop. However, the return to labour was still only around 37,000 kip/day. As the opportunity cost of labour increases to 50,000–60,000 kip/day, rice production is becoming unattractive as a commercial activity under any of the four scenarios considered

Table 1. Analysis of fertiliser scenarios using enterprise budgets and risk analysis

	No-input	Low-input	Medium-input	High-input
Fertiliser applied (kg/ha of N:P_2O_5:K_2O)	0:0:0	31:10:0	60:30:30	120:60:60
Yield of paddy (t/ha)	1.5	2	3	3.75
Gross income (kip/ha)	3,000,000	4,000,000	6,000,000	7,500,000
Total variable cost (kip/ha)	4,180,000	4,950,000	6,335,000	8,265,000
Net income (NI) (kip/ha)	–1,180,000	–950,000	–335,000	–765,000
Gross margin (GM) (kip/ha)	2,320,000	2,770,000	3,825,000	3,725,000
GM per day (kip/day)	26,514	29,785	36,779	33,185
Marginal rate of return (MRR) (%)		30	44	D
Threshold analysis				
Threshold P_r for positive NI (kip/kg)	2,884	2,525	2,118	2,215
Threshold P_r for GM of 50,000 kip/day (kip/kg)	3,539	3,039	2,482	2,530
Threshold P_r for MRR > 50% (kip/kg)		2,335	2,153	4,011
Risk analysis	***Probability of occurrence (%)***			
NI > 0 or GM/day > 40,000 kip	20	32	30	23
GM/day > 50,000 kip	8	16	16	12
MRR > 50%		28	15	5

Note: Labour cost = 40,000 kip/day; paddy price (P_r) = 2,000 kip/kg; US$1 = 8,000 kip; MRR = change in NI over change in total variable costs from moving to next-most-costly scenario, expressed as a percentage; D = dominated scenario, i.e. NI of this scenario is less than NI of medium scenario and no MRR is calculated (CIMMYT 1988)
Source: Newby et al. (2013)

at current paddy prices. Threshold analysis shows that for the medium-input scenario, a GM/day of 50,000 kip can be achieved if the price of paddy increases to 2,500 kip/kg (Table 1). Similarly, the yield required to achieve a GM/day of 50,000 kip at current paddy prices is over 4 t/ha for the medium-input scenario and 3.4 t/ha for the low-input scenario, provided that costs remain constant (Newby et al. 2013). These are unlikely scenarios.

Alternatively, by reducing the amount of labour used by 28 days/ha, the medium-input scenario also produces a positive NI (equivalent to a GM/day of at least 50,000 kip) (Newby et al. 2013). Again, this assumes that yields are maintained and material costs do not increase. Direct seeding is one method that could produce these savings by obviating the need for labour for seedbed preparation, nursery management and transplanting. However, this gives rise to other trade-offs that need further assessment—notably, the extra time and cost needed for weed management. There may also be trade-offs associated with introducing herbicides into an environment where the paddy land is utilised for collecting fish, frogs and other wildlife for consumption.

If yields are not maintained at a comparable level to a transplanted crop, the allowable trade-off depends on the price of paddy and the actual opportunity cost of household labour. However, there is a range of realistic price and yield combinations that result in a profitable farming system, provided around 25–30 labour days can be saved—so long as any labour saved is employed and earns a return of at least 50,000 kip/day. The timing of labour saving is also important if it enables people to secure employment for longer periods rather than repeatedly returning for crop maintenance activities. Mechanisation and the timely establishment and harvesting of the wet-season rice crop may also enable further changes to the cropping pattern, which may be attractive provided the returns to labour are adequate, and yield and marketing risks are acceptable. However, there are many basic agronomic and postharvest issues that need to be resolved to ensure these significant changes in the farming system offer a clear relative advantage.

Farm-scale diversification

The diversification of the cropping and farming systems is an important means of improving household incomes. Crop diversification and improved livestock management are activities that can potentially generate good returns to family-owned resources. Again, we argue that this is tied to households being able to achieve household rice subsistence objectives in terms of the efficient utilisation of land, labour and capital.

Access to water is often the limiting factor for increased farm diversification. Water resources have traditionally been managed relatively successfully by informal community institutions—for example, the sharing of water resources and the redistribution of land close to water resources during the dry season. As market opportunities increase, some of these existing institutions will be challenged (Souvannavong 2011). The rapid increase in access to groundwater is one of the major recent trends in southern Laos. Households now have individual bores connected to electric pumps. With the exception of a few villages, this water has largely been used for domestic purposes and maintaining small home gardens. However, it is likely that households will expand production in areas with good market linkages, potentially putting pressure on the groundwater resource, which remains poorly understood.

Economic analysis of farmer field trials conducted by the crop component of ACIAR Project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*) has shown that the income from small-scale production of crops such as sweetcorn and vegetables can provide a very attractive return to household labour—often double the market wage rate. However, these crops are often associated with greater production and market risks. This was reflected in the results of field trials in which some households generated very low returns due to poor crop performance. Further, as production levels increase, it is also likely that local markets will become saturated and longer value chains will need to be exploited. Assessing the returns to directing land, water and labour into irrigated forage plots rather than vegetable plots is also ongoing. Several case-study farmers are just beginning this transition into more intensive livestock systems. These two activities (non-rice crops and intensive livestock) offer different characteristics in terms of flexibility of product disposal, the time profile of costs and returns, and complementarity with the existing farming system.

Livelihood diversification

Economic growth in Laos and neighbouring countries has created considerable employment opportunities away from the farm. Migrating to Thailand is now a well-established livelihood strategy for young people from lowland households—43% of households surveyed in Champassak had a least one member working in Thailand (Manivong et al. 2014). Likewise, in Outhoumphone, Savannakhet, 42% of households had at least one family member working in Thailand, with the incidence falling away as distance from the border increased (Newby et al. 2013). 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) are also drawing labour away from traditional, semi-subsistence agriculture. According to Manivong et al. (2014), the positive inducement of higher incomes from non-farm employment, especially through international migration, is transforming rural livelihoods, despite the risks and personal hardships involved.

To date, however, the diversification of livelihoods has not been associated with agrarian differentiation as such, but has provided an alternative to landed wealth or 'natural capital' as the basis for household prosperity. Nevertheless, it would not be true to say that the study villages have become 'de-agrarianised'—a mere 'shell' to accommodate non-farm labour—as argued by Rigg (2005). Rice farming still remains an essential foundation for the diversified livelihoods that rural households are pursuing. Hence, innovations and interventions that can enable households to achieve their subsistence goals in more labour- and cost-efficient ways will strengthen this foundation and thus give more scope to improve household livelihoods. However, such interventions are unlikely to be consistent with a policy focused on rice intensification.

Conclusion

The overwhelming impression from this research is that Lao farmers are caught up in, and contributing to, a much larger regional process of agrarian transition which government intensification policies will be hard-pressed to counter. To the extent that farmers' judgements about the relative returns to their resources are correct, rural households in Laos are spontaneously following trajectories that, if not exactly a 'pathway out of poverty', are at least making them somewhat better off, in the sense of having higher and more diversified income streams and greater food security. This does not mean farmers are abandoning rice, let alone agriculture—rice production for subsistence and perhaps a small surplus is still central to the strategies most households are following, as well as the production of non-rice crops and livestock. However, the changes underway are transforming the rural economy from one based almost entirely on rice production for subsistence to one that is increasingly integrated with, not just a rapidly developing Lao economy, but a wider regional economy. In this context, attempts to intensify and commercialise rice production by increasing per-hectare yields and cropping intensity need to take account of the implications for labour use and the returns to labour, and hence for household incomes. The opportunity cost of using family labour for rice production is increasing and labour has become the binding constraint. Hence, the level and reliability of returns to labour (rather than land) should be central to the assessment of new agricultural technologies and practices, as well as the evaluation of agricultural policies towards rice farmers. We conclude that the subsistence orientation and low intensity of rainfed lowland rice farming is not a reason for policy concern; rather, this activity provides the stable platform on which to build resilient livelihoods through both farm and livelihood diversification.

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Linking research and extension at the local level through on-farm research

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Abstract

On-farm research (OFR) is undertaken in 'real-life' settings, providing a unique opportunity for local stakeholders to participate in the research process. Such an approach can serve as a linking mechanism between researchers and local stakeholders, facilitating communication and improving design, acceptability, awareness and adoption of a particular technology. An OFR project was implemented in southern Lao People's Democratic Republic (PDR) from 2010 to 2013. A survey of researchers, local extension staff and farmers highlighted the importance of several aspects of OFR, including understanding and working within local systems, engaging with and strengthening links between multiple stakeholders and promoting good communication. Additionally, local stakeholders identified multiple benefits as a result of their engagement in the research project, including a diverse portfolio of improved skills and capacity beyond expectations of project design. In addition to technical and research skills, enhanced personal skills were highlighted, including communication, confidence, attitude and critical thinking. These skills were noted in improvements to staff capacity and working ability by project leaders, the staff concerned and farmer cooperators. Strategic support is needed to ensure that the benefits from OFR are optimised for all stakeholders. A macro-level approach to strengthening research–extension links is required, incorporating improvements to institutional capacity, infrastructure, service delivery and coordination between these elements.

Introduction

Effective agricultural research and extension relies on strong research–extension links and sufficient capacity at all levels of the agriculture sector, supported by appropriate policy measures. Extension approaches have evolved from a 'technology transfer' paradigm to more participatory-based approaches (Hellin et al. 2008), where the lines between research and extension are increasingly blurred. Research in a variety of forms has become a necessary part of current extension approaches; however, the culture of research is new for many local stakeholders—there are often different norms about acceptable working standards (Hall et al. 2003), and therefore a need to develop shared understandings of what constitutes research for development. Intensification of agricultural production, adoption of new technologies and strengthening market integration are all strategies that can help improve the livelihoods of smallholder farmers (Bouahom et al. 2004). One way to support these strategies is to undertake applied on-farm research (OFR), coupled with strong extension approaches.

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OFR is purposefully undertaken in 'real-life' settings at the farm level—it focuses attention on content understanding and process development, and also incorporates some degree of participation among stakeholders (Lawrence et al. 2004). Participatory approaches can help to enhance communication between researchers and stakeholders, and improve design, acceptability, awareness and adoption of a particular technology (Lilja and Bellon 2008). Such approaches also increase understanding of farmer decision-making (Snapp et al. 2003) and the processes by which technology is applied at the local level. In particular, OFR is valuable in smallholder farming systems which tend to be diverse and highly dynamic, where a 'one size fits all' approach is not appropriate (Wortmann et al. 2005).

The findings presented in this paper are drawn from Australian Centre for International Agricultural Research (ACIAR) Project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*). The paper focuses on research and extension links at the local level, as it is here that stakeholders play a critical role in maintaining direct links between researchers and farmers and their local communities. We evaluated stakeholder experiences with OFR and the capacity-building impacts resulting from a 4-year agricultural research project in southern Laos. Of particular interest were the experiences and perceptions of stakeholders, who had scant previous research experience, about the benefits of and constraints to conducting OFR. We outline some potential strategies for linking research and extension to improve results and outcomes for all stakeholders. Our findings may be used to inform future projects that engage in similar research and development.

Methods

This study focuses on assessing OFR experiences and capacity-building impacts of an agricultural research project implemented in the southern Laos provinces of Savannakhet and Champassak (Figure 1).

The survey used in this study was designed to generate feedback on project activities and triangulate responses in changes to staff development and experiences. Interviews were conducted with participants themselves, their supervisors (senior researchers) and their clients (farmers). The survey questions and constructs were validated by expert review; however, no focus group or in-field trial was possible due to the small size and specificity of the target population. Human subjects research approval and ethics review for this study were completed both at Charles Sturt University (Australia) and at the University of California (United States of America).

The survey was conducted as semi-structured interviews with project participants—this is a common approach used to review project outcomes (Posthumus et al. 2012). Interviews were undertaken with 10 key informants in the project leadership, 16 local extension (District Agriculture and Forestry Office, DAFO) staff and 16 farmers. DAFO and farmer interviews were conducted with the assistance of a translator.

The data collected in this study are primarily qualitative. Analysis of qualitative interview responses was facilitated by an iterative coding technique (Kotlarsky and Oshri 2005) that involved assigning codes to individual response phrases, creating categories for related codes and identifying the core concepts that emerged from these categories. Trends in the data are reported, but no statistical analysis was possible due to the small sample size. Results are presented as a percentage of total positive responses for a given category (%) or as the number of respondents out of the total (e.g. 4/10).

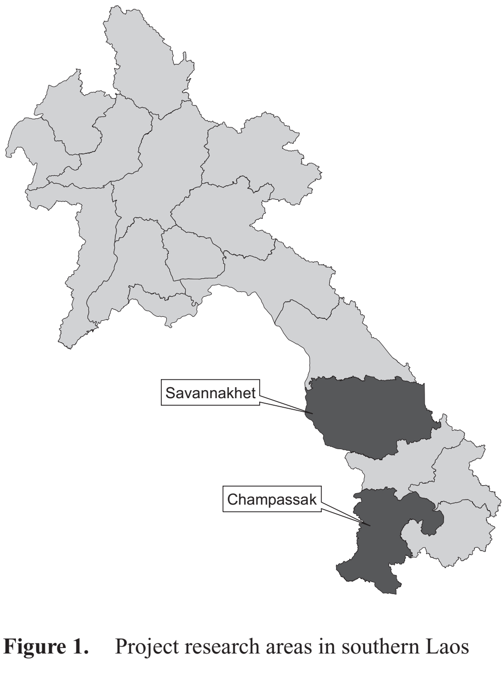

Figure 1. Project research areas in southern Laos

Results and discussion

Linking research and extension through on-farm research

Regardless of their role, all participants surveyed viewed the OFR process as beneficial. The major benefits noted by both farmers and DAFO staff were increasing knowledge and improving farm productivity (Table 1).

Understanding and working within local systems

It is important to recognise the strengths of all parties involved in the process. Local stakeholders (farmers and extension staff) often tend to have a good understanding of local systems, including the challenges and constraints that need to be overcome. This knowledge is useful for researchers, as they also need to understand farmers' needs in real time. Local extension staff are sometimes perceived as playing the role of 'local systems expert' (14%) and facilitator (11%). These duties ranked behind extension more generally (43%) and research (15%) as key roles played by extension staff—with the importance being that they understand local farming and district systems and their problems, select the right farmers and villages for research activities, and identify opportunities that are attainable within the local context. Indeed, in project districts where staff were seen to have a good understanding of the local systems, research and extension activities were most successful. Additionally, farmers mentioned specifically that OFR was beneficial because the results were directly applicable for their situation (Table 1). Because the results and information were generated locally, there was higher confidence among farmers that they would be relevant to their own situations, and because the research was planned to fit within the context of their existing production, farmers were able to see immediate application.

Engaging with and strengthening links between multiple stakeholders

Development of effective policy requires stakeholder engagement, and prior planning is critically important—when starting any research activity, representatives from multiple stakeholder groups need to be directly engaged in order to understand their specific requirements, including what is needed where and when. Feedback showed that one benefit from engagement with the OFR process in this project was building links among farmer communities and local extension staff; a critical aspect of long-term sustainability for agricultural knowledge sharing.

Building links between extension staff and farmers was not specifically mentioned by farmers in response to questions about the benefits of OFR and was only mentioned by 2/15 DAFO staff (Table 1); however, this issue emerged frequently in comments throughout the interviews. Farmers reported dramatically more engagement with their local DAFO staff than in the past. This is significant where many farmers reported having no interaction with DAFO before the project. As one farmer said: 'In the past [we] never contacted DAFO. We were not sure whom to call'.

Participation in an OFR project provided the financial and logistical means and imperative for DAFO staff to be more engaged and physically present in the farming community—and thus building stronger links and rapport with farmers. Through engagement with farmers in the course of the OFR, DAFO staff

Table 1. Benefits resulting from participation in on-farm research as identified by District Agriculture and Forestry Office (DAFO) staff (n = 15) and farmers (n = 16)

Farmer categories	No. of responses	DAFO staff categories	No. of responses
Learning by doing	7	Farmers gain knowledge	11
		Extension staff gain knowledge	4
		Building research skills	4
Applicable results	6	Improving production	4
Higher productivity	9	Linking extension staff and farmers	2
Other benefits	1	Farmers get inputs	1

gained recognition for their contributions and the important role they can play in supporting farmers.

Farmer participants also interacted with each other during the course of the project, both during cross-site visits to other farms and also within villages. These examples of building links between DAFO staff and farmers, as well as sharing knowledge among farmers and scaling-out new techniques and ideas, are likely to be among the more far-reaching benefits from the project's OFR efforts as they increase awareness of past project activities and work within the existing community and extension frameworks.

Promoting good communication

Where multiple stakeholders are working together, there needs to be constant and effective communication between the parties. Promoting research–extension links is a cyclical process—extension workers and farming communities identify problems and work with researchers to find a solution, with all parties incorporating feedback throughout the process. For this to work, extension agents need to understand the protocols or processes that form the basis of the research, and researchers need to present their results in a clear and simple way to make their new ideas understandable to other stakeholders.

In a review of extension staff performance assessments, communication and attitude emerged as the two critical elements needed in order to work successfully with multiple stakeholders to deliver research for development projects. It is interesting to note that technical skills, although important, did not factor most prominently. Communication, particularly with farmers, was one of the skills that most distinguished effective extension staff from others. Communicating research problems to farmers in the local context, and being able to explain both the experimental procedures and the potential benefits of the results, helped to generate farmer interest in participating with the project and also facilitated better collaboration. These results support the need for, and benefits of, building the capacity of local staff to improve their technical, research and interpersonal skills.

Supporting improved links between research and extension

Rapid changes are occurring within the extension sector, with farmers increasingly relying on services from the private sector, farmers' organisations and non-profit associations. Laos' extension service is expanding its role to include support for farmer learning and farmers' organisations, and greater market engagement (National Agricultural and Forestry Extension Service 2011). Jones et al. (2012) see potential for extension staff to take an increasingly facilitative role in a new network of service providers rather than providing direct services to farmers. The role and skills of local extension staff will need further development if they are to effectively adjust to these changing roles and expectations in agricultural development.

Although the core focus of ACIAR Project CSE/2009/004 was technical research, developments in staff capacity and skills were found to extend beyond project design expectations, as identified by project leaders, local extension staff and farmers (Figure 2). Capacity building can improve the technical, research and interpersonal skills of individuals, leading to greater institutional extension capacity and more-effective working approaches. Although research is not traditionally seen as the role of an extension worker, extension approaches have evolved to incorporate aspects of research, and the evidence here suggests that it can greatly benefit staff in these positions. For a research project, the purpose of investing in capacity building is to achieve better research results—whereas its purpose in a general sense is to help people and institutions perform their roles more effectively. Our results show that by improving research skills, local extension staff are better able to perform their job and are more motivated. They also report having stronger networks and improved communication, both with farming communities and their institutional colleagues.

For effective engagement of multiple stakeholders within the research and extension process, all actors must be able to participate in a meaningful way. It is important to keep in mind staff skills and experience, as in many cases local stakeholders have little experience with research, and often capacity will need to be built as research complexity increases. This should be incorporated into project design. Along with research skills, stakeholders need to have communication skills, confidence to participate and question, and opportunities to apply their skills. Our research shows that communication, particularly with farmers, is one of the skills that most distinguished effective local staff from the others. Additionally, 'attitude' was most frequently cited in DAFO staff self-assessments and in key informant responses as the characteristic most improved. Attitude in this case includes motivation, cooperation, willingness to learn, and confidence. Motivation has been previously recognised as playing a critical role in improved capacity (Okorley et al. 2009; Ifenkwe 2012). Farmers also reported positive changes in DAFO attitudes. For example, one farmer stated: 'DAFO are better than before; it is good because they are interested'. This improved attitude manifested in increased confidence over the duration of the project, with staff reporting that they are now 'brave to make decisions, talk in public, report to boss'. This self-assurance coupled with technical subject matter competency helps farmers have more confidence in the capacity of extension staff as well. Farmers reported this increase in staff capacity, saying that: 'DAFO are really different than before, better than before. They have more specific and relevant information to suggest'.

Institutional and policy structures in which organisations operate are important (Babu et al. 2007); capacity cannot be improved or maintained without institutional support for ongoing training and basic materials for carrying out expected work duties. But support is needed more widely than simply support for training and materials. 'Constraints by institutional settings' stood out as negative feedback from key informants on changes in capacity development and skills, and subsequently on project achievements in relevant districts. Many examples were given of individual staff doing a good job but being constrained by things like their age or experience (too young or inexperienced), which limited their authority; staff reassignment; having no support or involvement from their superiors; and being limited by the local environment in cultural terms.

Long-term sustainability of research–extension links should be considered from the outset of any project cycle. This means building capacity in communication, technical and critical-thinking skills. Recognising the role of local stakeholders in providing insights into local conditions is essential. Staff must have the means to work in terms of both financial and institutional support—this would help to ensure professional commitment and an ability to practice and develop coherent extension methods. Unfortunately, the challenge of maintaining continuity is exacerbated by the frequent reassignment of staff in terms of physical location and work tasks. Turnover and reassignment of local staff are a major limitation to project success and capacity building at all levels.

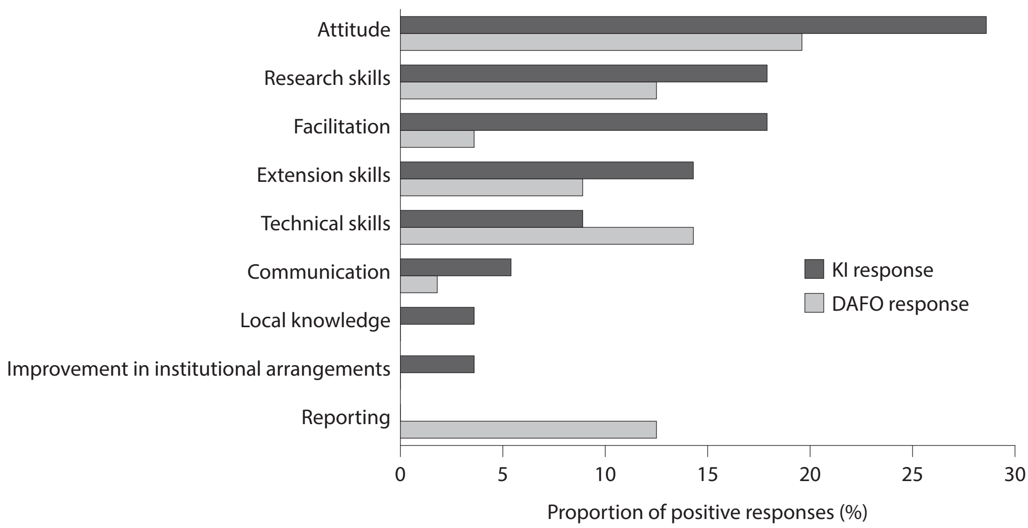

Figure 2. Improvements to working capacity and attributes, as reported by key informants (KI) (project leaders) and District Agriculture and Forestry Office (DAFO) extension staff

Conclusion and policy implications

In order to make OFR a viable method for linking research and extension at the local level, feedback from our project shows that there are several aspects of the process that could be improved:

- *Streamlining logistics and timeliness of project operations*—this is important for the research process and for results, and requires good communication between project counterparts. Facilitation has a key role to play.
- *Continuous improvement for local extension staff*—enhancing the extension skills of local extension staff and their ability to work with farmers is crucial, including ensuring a good understanding of local conditions and the ability to select the right partners who can deliver the required inputs into the process. This necessitates good communication skills in being able to convey complex messages to farmers and highlight the benefits and importance of research outcomes for them.
- *Farmer participants need to be well supported*—this program support extends to access to materials and labour availability, and highlights the need to select suitable farmer counterparts.
- *Alignment of institutional goals is essential*—there is a need to ensure that all stakeholders have a common understanding of project goals.
- *Ongoing investment in capacity building*—OFR success is dependent upon developing local-level skills and experience in research conduct. This capacity development needs to be factored in from the earliest stages of the research process.

There are significant benefits for local stakeholders in participating in OFR despite some very real issues that may constrain their engagement. The capacity-building benefits for both local extension staff and farmers include technical skills in research and extension, and personal skills and attributes (e.g. communication, confidence and critical thinking). Stakeholders reported improved work capacity and renewed motivation. For farmers, this was often reflected in improvements to incomes or livelihoods. A major benefit in participating in OFR was the strengthened engagement between local extension staff and farmers, which gave both groups greater insight into local farming systems. This range of benefits suggests that OFR provides particular value for local stakeholders where locally relevant technical knowledge is in short supply.

A macro-level approach to strengthening research–extension links is required, incorporating improvements to institutional capacity, infrastructure, service delivery and coordination between these elements. This includes creating a shared understanding, where roles and expectations of all partners are clarified (Bartlett 2013). Without such an alignment of goals, the likelihood of failure due to lack of support is high. However, experience from this project suggests that where extension staff commitment and farmer community interest align, there is substantial potential for progress to be made.

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Rice-based farming systems in Lao PDR—opportunities and challenges for food security

Silinthone Sacklokham[1]

Abstract

This paper presents results from research that focused on better understanding rice-based farming systems in Lao People's Democratic Republic (PDR) with the aim of developing appropriate and effective agricultural policies. The study took place in Savannakhet and Champassak provinces in southern Laos in selected villages in lowland rainfed and irrigated areas. Farmers, rice traders, millers and retailers were interviewed, together with authorities from provincial and district agriculture, industry and commerce, to understand production and trade systems in the study area. In total, more than 297 people were interviewed in this study. We found that rice growers have potential to produce rice for the market, but nevertheless face problems associated with seed quality, limited access to and inefficient use of fertiliser, high electricity costs for water pumping to the paddy field, and limited access to credit. These constraints lead to low rice yields. Furthermore, the low quality of rice combined with sudden changes in government rice-related policy adversely affects the incomes of farmers and millers, and acts as a disincentive to production and the improvement of postharvest facilities.

Introduction

This paper draws from Australian Centre for International Agricultural Research (ACIAR) Project ASEM/2009/023 (*Developing agricultural policies for rice-based farming systems in Lao PDR and Cambodia*), and its earlier small research activity ACIAR Project ASEM/2009/039 (*Agricultural policies affecting rice-based farming systems in Bangladesh, Cambodia and Lao PDR*). The aim of the larger-scale ASEM/2009/023 project was to contribute to improved agricultural policies for rice-based farming systems in Laos and Cambodia, while taking into account trends in Thailand and Vietnam. The research question focused on identifying how field research on farming and marketing systems can be used to inform more effective agricultural policy development. Decisions about household activities at the farm level depend on the inputs available to realise specific outputs, whether for domestic consumption or for the market. Policies that influence access to inputs will have flow-on effects for farm outputs. By studying farm households' access to their main inputs, we were able to better understand farmer decision-making processes and to develop policies that better respond to the needs of farm households in order to realise their desired outputs.

Overview of agriculture and farming systems in Laos

Laos is located in mainland South-East Asia, in the heart of the Indochina Peninsula. It has a surface area of 236,800 square kilometres (km^2) and a population of 6.9 million, which equates to a relatively low density of 29 people/km^2. Two-thirds of its surface area is mountainous and the remaining third is plains. These geographical and demographic characteristics present both opportunities and challenges for economic development in Laos. Much of Laos' economy relies on agriculture and natural resources extraction.

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Economic growth rates have been among the highest in South-East Asia, at an annual rate of 7.9% from 2005 to 2010 (Alounmai Journal 2011), as a consequence of regional and international economic integration since the late 1980s. Despite advancements in both economic and human development, Laos remains a 'least development country' (LDC)—a status classification that the Lao Government aims to surpass by 2020. According to the Lao Expenditure and Consumption Survey, progress has been made on poverty reduction, with the percentage of poor households reduced from 27.7% in 2002–03 to 20.4% in 2009–10.

Most of Laos' poor live in small farming households. Therefore, agricultural development and improving agricultural income are the focus of food security and poverty eradication. Agricultural production has increased by only 3.4% per annum on average since 2000–01, despite the fact that the agricultural sector employs 72% of the active population. Although other sectors have grown more rapidly, the agricultural sector's share of gross domestic product (GDP) declined to around 28% in 2011–12 (World Bank 2014) (Figure 1).

Farming systems

Farming systems in Laos are divided into five main types—lowland rainfed farming, lowland irrigated farming, upland farming, plateau farming and highland farming.

- *Lowland rainfed farming* is characterised by production of lowland rainfed rice during the wet season (WS). The land is used in the dry season (DS) for grazing of large animals (e.g. cattle, buffalo) or growing post-rice crops (e.g. sweetcorn, long bean, cucumber, tobacco). Fruit trees (e.g. banana, tamarind, coconut) and sugarcane are grown in the garden around the house or in the upper lowland for home consumption and the surplus for market sale. In many lowland rainfed farms, animals are variously considered as a source of income, for consumption, for soil fertility improvement and, in increasingly fewer cases, to support land preparation.
- *Lowland irrigated farming* is dominated by supplemental irrigation for rice during the WS and cultivation of a small area of rice and other cash crops during the DS. This is a more specialised rice-farming system, which uses more inputs (e.g. improved seed, fertiliser—for DS rice primarily) and is less reliant on livestock, due to limited access to grazing land and labour. Fruit trees can be seen in the garden around the house or in the upper lowland with limited surface area. Many farm households produce WS rice for home consumption while DS rice is produced for the market.

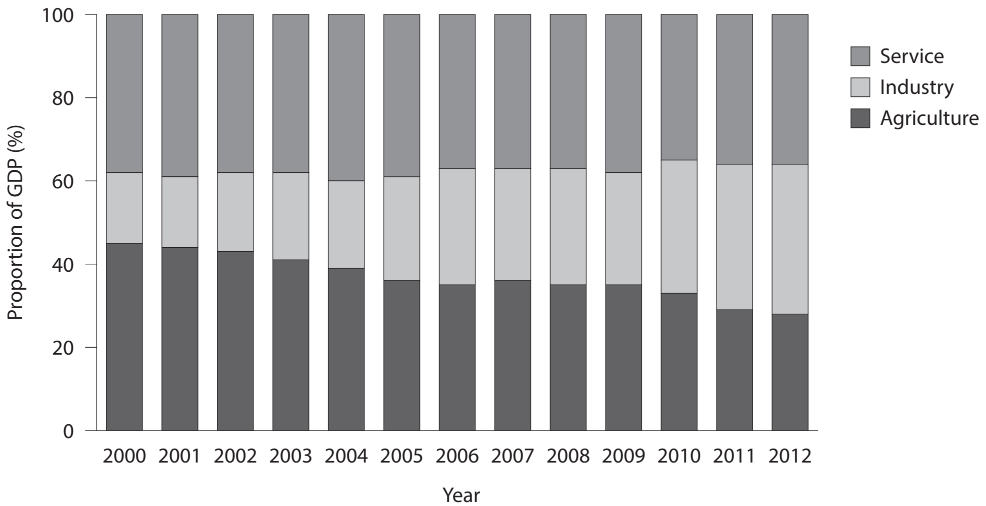

Figure 1. Proportion of national gross domestic product (GDP) by major sector from 2000 to 2012. Source: World Bank (2014)

- *Upland farming* includes upland rice, cash crops (e.g. maize, cassava), leguminous and agro-industry tree plantations (e.g. rubber, jatropha, banana, agroforestry trees). Upland rice cultivation is based on a short fallow period of 2–7 years. Rice is mainly produced for home consumption, while other crops are for cash income. Household income is also generated from other sources such as livestock and non-timber forest product collection. The young fallow land from previous upland rice cultivation plots is used as grazing land for cattle. More recently, upland rice rotation cropping systems have progressively transformed to permanent cropping systems like maize or rubber production in response to market opportunities. This transition reduces scope for livestock grazing.
- *Plateau farming* is practised mainly in the Boloven plateau. It is dominated by coffee cultivation and, to a lesser degree, tea, cardamom and some vegetables. Rice growing is used to clear fallow land for cultivation of cash crops and, in the case of some households, for rice security. Livestock serves as savings capital for households—the animals are used to graze the young fallow land or the coffee plantation to allow soil fertility improvement. Cultivation of coffee, tea and vegetables provides cash income to buy rice from the lowlands.
- *Highland farming* is characterised by sloping land and the practice of swidden agriculture associated with livestock. Subsistence farming, with some surplus for the market dominates, in this landscape; however, crops like tea and agroforestry (e.g. cardamom) have been produced for the market over more than two decades and this form of production continues to expand. Household income is mainly generated through the sale of livestock and non-timber forest product collection.

Agriculture in Laos is undergoing a process of transformation from subsistence farming to market-oriented farming. The agro-processing industry is in the early stages of development. Farm produce is either sold unprocessed in the domestic market or sold to regional markets, where value is added.

Overview of rice sector in Laos

Rice, as Laos' main staple food, is a core component of each of its five different farming systems. According to Ministry of Agriculture and Forestry (MAF) statistics in 2012, rice is grown on more than 49% of cultivated land. From 1986 to 2011, the total area of rice harvested increased by 47.7% from 619,000 to 914,540 hectares (ha). From 2005 to 2012, the area of rice harvested from lowland rainfed and lowland irrigated land increased by 29% from 630,780 ha to 813,995 ha (Figure 2). Over the same period, production increased by 39% from 2.35 million tonnes (Mt) to 3.27 Mt of paddy rice per year (Figure 3).

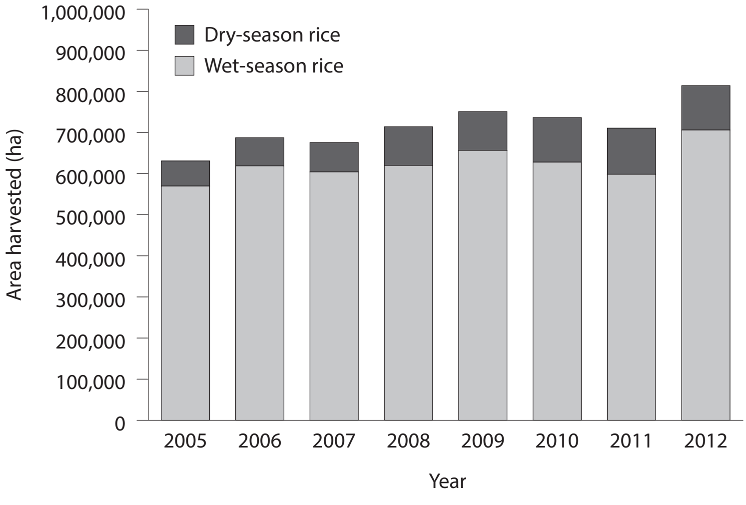

Figure 2. Lowland rainfed and irrigated rice cultivated area between 2005 and 2012. Source: MAF (2012)

According to MAF statistics in 2012, more than 51% of rice paddy was produced in central Laos (mainly in Savannakhet and Vientiane provinces and Vientiane Capital), about 27% in the southern provinces (such as Champassak and Saravanh) and 21% in the northern provinces (mainly in Sayaboury).

Statistics show a slight increase in the yield of lowland rainfed and irrigated rice since 2009, and stable yield in the case of upland rice (Figure 4). In 2011, the average rice yield in the northern provinces was 4.40 tonnes (t)/ha. The difference between lowland rainfed and lowland irrigated rice yield was about 1 t/ha (Figure 4).

We now examine the agricultural strategies and policies that have shaped rice production as it exists in Laos today.

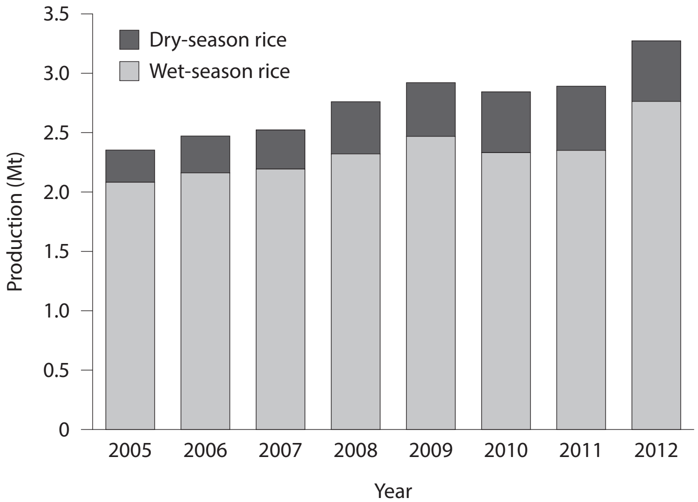

Figure 3. Lowland rainfed and irrigated rice production between 2005 and 2012. Source: MAF (2012)

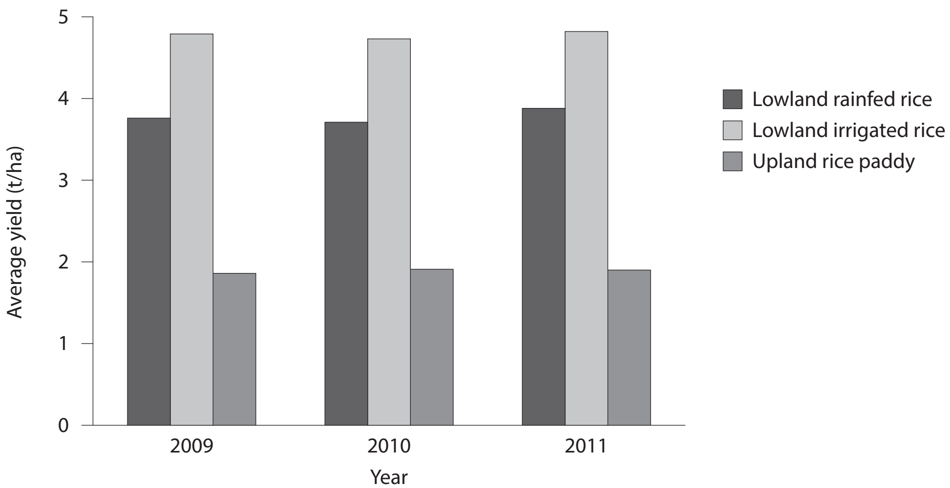

Figure 4. Average rice yield from 2009 to 2011. Source: MAF (2012)

Lao Government rice policy

Historically, Laos' rice production has been insufficient to meet demands from domestic consumers, especially from urban communities, and has imported rice from neighbouring countries. Shortly after the establishment of the Lao People's Democratic Republic (PDR), the country faced significant rice insecurity due to severe drought in 1977 and flooding in subsequent years (Sacklokham 2003; Paavo and Santos 2012). Border trade with Thailand was closed from 1976 to 1980 in order to ensure in-country rice supplies, and the Lao Government encouraged farmers to establish agricultural cooperatives, especially in the case of rice production. These cooperatives collapsed only a few years after their establishment due to organisational production difficulties and the inequitable distribution of benefits to their members. However, Laos' total area of land under rice production expanded under the system of cooperatives (Sacklokham 2003).

By the late 1980s, the Lao Government was accelerating the expansion of rice cultivation and production by investing in lowland irrigation development, in research on new rice varieties, and in facilitating the importation of agricultural inputs and equipment, such as chemical fertilisers and tractors. This policy doubled rice production from 1.7 Mt in 1991 to 3.3 Mt in 2011 even though many irrigation schemes did not function well technically. Laos became self-sufficient in rice at the national level in 2000—based on 6.5 million inhabitants consuming 216 kg/year/person of milled rice (or almost 450 kg of paddy rice).

The Lao Government has set a target of 4 Mt/year for paddy rice production in its 7th socioeconomic development plan (2011–15). The objective of the target is to ensure in-country rice security and a surplus for export. The specific policies and measures for reaching this target are not clear, apart from improving irrigation schemes and implementing fertiliser and rice varietal trials. Problems that continue to confront current rice production in Laos are ongoing rice insufficiency from climatic disasters—with annual losses of 10% of harvested rice (Paavo and Santos 2012)—and transportation difficulties in moving rice from surplus to deficit areas.

Rice production and trade

Rice production inputs (e.g. seed, fertiliser, access to water, credit, technology, information) are highly important factors in successfully meeting the Lao Government's target for rice self-sufficiency and surplus export. Some lessons for policy on rice production inputs, including opportunities and challenges, are drawn here from studies on rice-farming systems in lowland rainfed and irrigated areas in Savannakhet and Champassak provinces.

Rice seed

Three key institutions—the Crop Research and Multiplication Centre in Thasano, the Rice Research and Seed Multiplication Centre in Phon Ngam and the Agricultural and Forestry Research and Extension Centre in Nong Deng, Saravanh—produce and distribute rice seed to millers, rural development projects and farmers in the southern Laos. Most seed varieties produced and multiplied by these centres are Thasano (TSN) and Phon Ngam (PNG), and are not yet certified.

Improved rice seed (R2 varieties) flows from the centre to farmer seed production groups to produce R3 seeds. The centre buys back R3 varieties from these rice production groups and sells them to the Provincial Agriculture and Forestry Office (PAFO), the District Agriculture and Forestry Office (DAFO), millers and rural development projects. R3 seeds produced by rice seed farmers can also be distributed to neighbouring farmers or those in nearby villages (Figure 5).

For seed production, the centres still confront a range of constraints, notably lack of rice breeding specialists, inadequate infrastructure, poor pest management systems and insufficient resources for purchasing inputs and buying back R2 and R3 seeds from farmer seed-production groups. Systems for tracing and certifying rice seeds are also lacking (NAFRI and Helvetas 2011). The centres, millers and development projects have sometimes distributed seed of poor quality to farmers.

Fertiliser

In Savannakhet, our study showed that 94% of farmers applied chemical fertiliser for DS rice production and around 75% in the case of WS rice production. In addition to applying chemical fertiliser, producers in the study area continued to apply animal manure to their rice fields; however, sourcing animal manure is made increasingly difficult with declining livestock numbers.

The different types of chemical fertilisers used by farmers were applied in differing proportions of nitrogen (N), phosphorus (P) and potassium (K), as well as for a variety of purposes. For example, NPK fertiliser ratios of 16:20:00, 16:08:08, 46:00:00 and 15:15:15 are commonly used for rice production. The average quantity of fertiliser application by farmers was 72 kg/ha in the WS and 128 kg/ha in the DS, representing 18–20% of total rice production costs. The quantity of fertiliser applied by farmers is determined by climatic risk factors coupled with the household's cash availability. Only 5% of producers applied fertiliser type 15:15:15 NPK, while the majority (68%) applied the more inexpensive type 16:20:00 NPK—the price difference between the two fertiliser types being about 20%. The choice of fertiliser application type by farmers was not due to soil type.

Fertilisers used in Savannakhet and Champassak are mainly sourced from neighbouring countries such as Thailand, Vietnam and Taiwan (Kousonsavath 2012) through border checking points at Savannakhet–Mukdahan (Laos–Thailand), Lao Bao (Laos–Vietnam) and Pakse–Chongmek (Laos–Thailand). The suppliers of fertilisers to farmers include Laos' rice research and multiplication centres, millers, Lao and Vietnam traders, and rural development projects (Figure 6). In the case of development projects, supplies may be free of charge, whereas payment in cash, in kind or by credit is needed when sourcing fertiliser from traders. Rice producers without residual cash to buy fertiliser directly from the market may seek credit from traders and make progressive repayments, often with high interest rates and long payback periods.

Irrigation

The development of irrigation systems in Laos started in the late 1980s, initially by the Lao Government and later through the participation of villagers, international development aid and international loans. In 1996–97, the government's investment alone in irrigation scheme development was around US$235 million (Department of Irrigation, MAF, cited in Sacklokham 2003). These low-to-moderate cost irrigation schemes were referred to as *son la pa than beb leng lath*; that is, shortcut or urgent irrigation. Water users have experienced problems with the technical design and implementation of the schemes (Somphou et al. 2010), which are based on pumping or gravity feeding water into irrigation canals from rivers, streams, lakes and dams.

Most pumps and spare parts are imported from foreign countries, such that repair or replacement by DAFO and PAFO as the responsible authorities is often protracted. In the Vientiane irrigated plains study area (Sacklokham 2003), there are examples of delays in field irrigation of 3–7 days due to lack of spare parts.

In Savannakhet province, there are two main types of irrigation systems: pumping water from rivers and streams, and gravity feeding from dams and reservoirs. One of the major concerns of rice producers in the DS is the cost of electricity to pump water into the irrigation scheme, and related management costs—gravity-fed irrigation costs were approximately US$50/ha compared with pumping system costs of US$65/ha (Sacklokham 2012). These

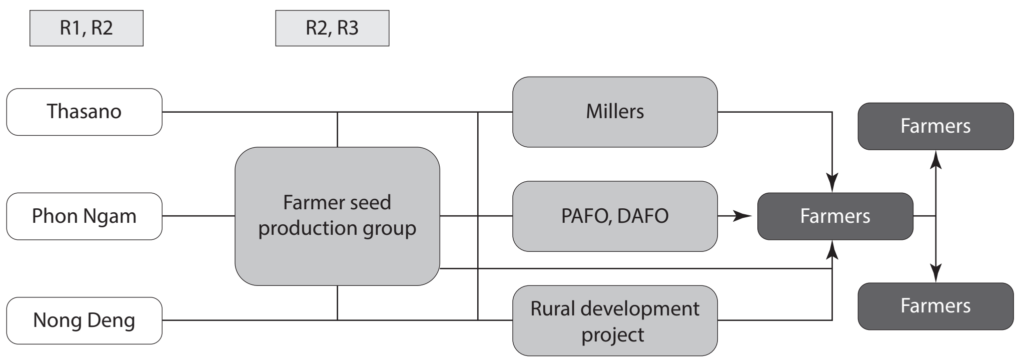

Figure 5. Production and distribution chain for rice seed (R1, R2, R3 = rice selections at different levels of improvement; PAFO = Provincial Agriculture and Forestry Office; DAFO = District Agriculture and Forestry Office). Source: data from 2011–12 field work in Savannakhet, ACIAR Project ASEM/2009/023

costs are very high when compared with current rice yields at 2,800–3,000 kg/ha (i.e. irrigation costs are about 10% of the production yield per ha). Water user groups also experience tensions arising from disputes and inefficiencies, such as the staging of water access and canal cleaning. Some disputes arise because the users of water and the landowners are not always the same people.

Credit

The Agricultural Promotion Bank was established to provide government-subsidised credit to farmers for agricultural production. The Na Yo Bai Bank was subsequently established to extend loans at a subsidised rate of interest to farmers in Laos' poor districts. Since 2008, the Agricultural Promotion Bank has privatised its services and its clients are no longer exclusively farmers. Before the bank's reform process, farmers could borrow funds based on the formation of a group and a business plan signed by the village chief. Now, farmers require collateral to access a loan, in line with the usual practice of commercial banks. However, few rice producers have land title or other assets to advance as collateral, such that farmers are increasingly borrowing money from traders with exorbitant interest rates (exceeding 30% per year).

Rice yields

Our study found that the average yield in Outhoumphone and Champhone districts for 2010–12 was 2,200 kg/ha for WS rice, which increased to 3,000 kg/ha in the DS. This average yield was much lower than the national average (3,500 kg/ha for WS rice and 4,500 kg/ha for DS rice) and far behind the national target of 5,000 kg/ha. The total cost of rice production for the aforementioned average yields represents 51% of total rice production in the WS and 66% in the DS. The labour productivity of rice production was about US$3.00–3.50 per working day. This remuneration was lower than selling labour in the villages for rice transplanting and harvesting at US$4.50–5.00 per working day, and much lower than selling labour in the town of Savannakhet at US$6.50–10.00 or in Thailand.

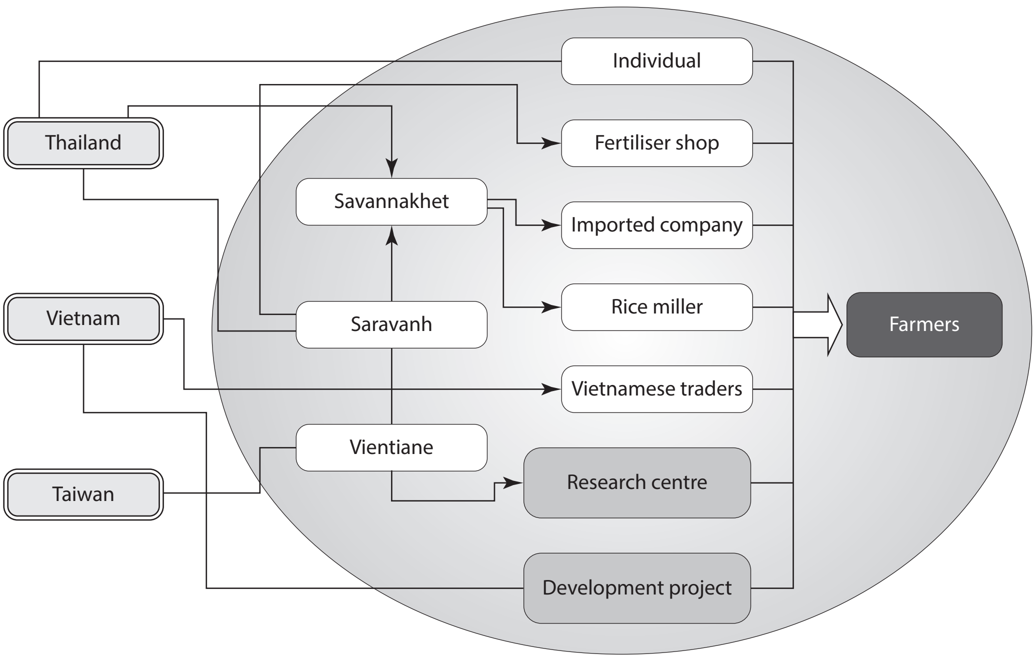

Figure 6. Input chain studies in Savannakhet. Source: Kousonsavath (2012)

Rice markets

A study by the National University of Laos showed well-developed rice marketing chains in the areas of Savannakhet and Champassak over the period 2011–12. Some buyers were found to purchase products at the farm gate, which reduced transport costs for farmers who did not need to take their goods to marketplaces. In addition, an increase in the number of prospective buyers has enabled farmers to link to the new markets, which has increased the quantity of produce sold. The marketing chain comprised collectors, millers, retailers and consumers. Horizontal integration was found between traders, enabling collective marketing approaches to influence trade negotiations. The geographical position of Savannakhet province was seen as particularly advantageous for the expansion of exports to Vietnam.

The main constraints to the rice marketing chain in the study area were (Sacklokham and Manivong 2011; Sacklokham 2012):

- the difficulty in setting up quality standards recognised by international actors—the quality of polished rice in the study area is not up to export standard due to poor processing procedures and facilities (most rice mills in study area are small scale)
- the market is fragmented—the lack of horizontal integration at the production level limits the bargaining power of farmers and causes the market to fragment
- millers have little incentive to invest in their rice mill facilities to improve rice quality—the price of rice is too low and bank interest rates are too high
- sudden changes in rice policies create significant financial losses for millers and rice producers.

Policy priorities

After studying rice-based farming systems and marketing in the southern provinces of Laos, we propose the following policy priorities for improving the livelihoods and wellbeing of rice-based farmers:

- *Improve the facilities in, and the knowledge base of, Laos' research and multiplication centres*. These centres need capacity to research new rice varieties, establish quality assurance systems for seed supply, and increase seed production. Rice-breeding objectives should be for greater resilience in the face of pests and diseases rather than for maximum yield.
- *Improve access to credit for fertiliser*. Producers need access to formal credit systems, as previously provided by the Agricultural Promotion Bank, rather than the informal system of loans from traders with exposure to very high interest rates.
- *Provide information and training on fertilisers to rice producers*. Farmers need information and advice on the potential benefits of fertiliser use, together with appropriate fertiliser selection and effective application for their particular soil type. Practical training for rice producers is needed on how and when to apply fertiliser.
- *Advise farmers on efficient water use practices*. The price of local rice is not high and irrigation is expensive, so it is imperative that irrigated water is used efficiently. Some research on growing alternative crops on paddy land has been conducted in southern Laos, as a diversification option for improving farmer incomes, but replicated trials and on-farm testing are needed.
- *Improve access to postharvest technology*. To increase the volume of rice sold in the domestic and international markets, there is a need to enhance access to postharvest technology (e.g. drying technology) from farm to miller level to improve rice quality and increase prices.
- *Provide finance to millers to upgrade facilities*. As our study found, the quality of rice in Savannakhet province did not meet recognised international standards and the rice price was therefore low. Providing rice millers with better access to credit in order to improve rice-milling quality may be an effective policy option.
- *Clarify government rice policy*. Policy linkages between food security and rice markets are not clear (what type of rice, and what quality and quantity?) and change from one year to the next: The incentive to invest in rice production and trade will increase in the absence of sudden shifts in rice trade policy that adversely impact on rice producers and millers.

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Policy challenges for Cambodia's agricultural development and food security—a review of the rice sector

Theng Vuthy[1]

Abstract

This paper reviews the key policy challenges inhibiting Cambodia's rice commercialisation. Impressive progress has been made over the past two decades with 4.8 million tonnes (Mt) of surplus paddy rice in 2013. However, there are still constraints to Cambodia's global rice market ambitions of supplying a brand recognised for its high quality, and exporting 1 Mt of milled rice per year by 2015. Currently, rice productivity is hindered by inefficient input markets and the structure of paddy markets. Furthermore, current policies promoting contract farming and farmer organisations have addressed some of these obstacles, but rice production constraints in the main rice-growing areas should be addressed as a matter of urgency. Improving the value chain, upgrading milling capacity, developing export infrastructure and reducing bureaucratic export procedures should be priority areas if export targets are to be achieved.

Introduction

Cambodia's economy has undergone profound transformation—a shift in the sources of growth away from agriculture towards labour-intensive industrial and service sectors. In 1994, agriculture accounted for 46% of gross domestic product (GDP), with industrial output contributing 13% and services 35%. By 2010, agriculture's share had fallen to about 27%, while that of industry had doubled to 27% and the service sector's share had risen to 39% (NIS 2011). The decline in the share of agriculture to total output has been accompanied by a decline in the share of employment in agriculture from about 81% in 1993 to about 59% in 2011. Although its contribution to GDP has been steadily declining over the past 20 years, agriculture continues to be a critical sector for the country's economic growth and poverty reduction efforts (CDRI 2013).

This structural transformation has been intertwined with solid gains in productivity in the agricultural sector. Between 1990 and 2013, crop and food production increased nearly fourfold, while cultivated land areas increased one-and-a-half times. Growth in agricultural output has been largely driven by gains in crop yields. For instance, rice yields more than doubled, from 1,360 kilograms per hectare (kg/ha) in 1990 to 3,160 kg/ha in 2013 (NIS 2008; MAFF 2014), driving a steep increase in output, with paddy rice surplus reaching 4.8 million tonnes (Mt) in 2013. Yet, there is still considerable scope to enhance the sector, which lags behind major regional producers Thailand and Vietnam in both yield and output (CDRI 2013). Policymakers are promoting a dual-pronged approach to turn Cambodia into the world's third-largest rice exporter by 2015 by improving productivity and yield, in particular on small family farms, and shifting production to higher value commercial products. This paper examines the policy options for bringing about these transformations.

Around 85% of the population lives in rural areas, where the majority are engaged in agriculture, mainly growing paddy on small family farms. The government has earmarked this demographic in efforts to release pent-up agricultural production capacity which will, in turn, significantly increase rice output and provide a stable source of long-term economic growth. Equitable, smallholder-driven expansion of the rice sector through an inclusive growth paradigm rooted in transformative and sustainable development

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of the agriculture sector is the key to realising that potential—driving down poverty rates and bolstering food security. Further up the value chain, increases in paddy rice production must be supported by development of processing and export capacity if Cambodia is to produce high-quality, competitively priced rice to penetrate the global market.

Over the past two decades, national and sectoral policy frameworks have been mobilised to boost productivity, translate increases in output into export revenue, and channel capital to smallholder farmers to invest in further increasing their productivity. Cambodia's Rectangular Strategy Phase III 2014–2018 reaffirms the government's goal to export 1 Mt of milled rice per year by 2015 (RGC 2013). This paper identifies the remaining challenges to the development of Cambodia's rice sector and offers policy suggestions that detail how those constraints can be removed.

Farm input challenges

Fertiliser

High cost

Like other countries in the region, Cambodian smallholder profits are eaten away by significant production costs. Fertiliser in particular constitutes a large share of total costs, about 21% in the wet season (WS) and 37% in the dry season (DS) (Figure 1; Chhim et al. 2013)—a rate similar to that in neighbouring Vietnam and the Lao People's Democratic Republic (PDR) (no recent information is available for Thailand). In Vietnam, fertiliser accounts for about 29% of total production costs for transplanted rice and 22% for direct-seeded rice. In Laos, fertiliser constitutes about 23% of total production costs for WS rice and 39% for DS rice In addition, low-quality inputs, underdeveloped extension services and expensive credit constrain the development of the rice sector.

Problems with supply and quality

The fertiliser market, although well-structured at a foundational level, exhibits deficiencies that hinder increases in crop yield. Many of the issues stem from ineffective inspection procedures for imported fertiliser. The systems in place are not sufficient to ensure that substandard and counterfeit products are barred from entering the Cambodian market. Customs inspections at the border are characterised by unclear lines of responsibility, poor coordination between agencies and petty corruption. In particular, the current import-licensing system has created opportunities for permit-issuing officials to benefit from exacting 'unofficial fees', undermining the integrity of the system (IFDC 2010; Theng 2012).

Restrictions on the volume of fertiliser that can be legally imported into Cambodia, currently capped by the Ministry of Agriculture, Forestry and Fisheries (MAFF) at 30,000 t/year/licence, have placed a significant supply-side constraint on Cambodia's fertiliser market. The import quota impedes economies of scale and encourages informal, unregulated cross-border trade with Vietnam and Thailand—key routes for counterfeit and inferior-quality products flooding the domestic market through both importers and local traders (Theng 2012).

Imperfections in fertiliser markets in Cambodia are another reason behind the flow of a high volume of counterfeit products entering the supply chain. It is estimated that around 10% of fertilisers used on Cambodian crops have been either adulterated or mis-sold—frequently, low-quality fertiliser is re-bagged in sacks labelled with a higher quality brand. These products have detrimental effects on rice yields and undermine the livelihoods of smallholders; farmers have reported income losses in the range of US$285–350/year arising from fertiliser underperformance.

There are clear, actionable policy measures that could improve the supply of reliable, affordable fertiliser to Cambodia's smallholder rice producers. First, and most straightforward, is the removal of the fertiliser import quotas imposed by MAFF. Second, and slightly more complex, is reforming and simplifying import-licensing procedures to allow small and new importers to enter the market—the resulting increased competition would drive down costs and drive up quality. Third, and most important, is to delegate responsibility and powers that would enable MAFF to carry out spot checks on fertiliser samples at the border, including laboratory tests that can definitively determine quality. Currently, CamControl of the Ministry of Commerce is authorised to check only import volume and quality-assurance certificates issued by testing laboratories before products are allowed to enter Cambodia. These limited checks have enabled—indeed encouraged—the flow of counterfeit products from supplier countries (Theng 2012).

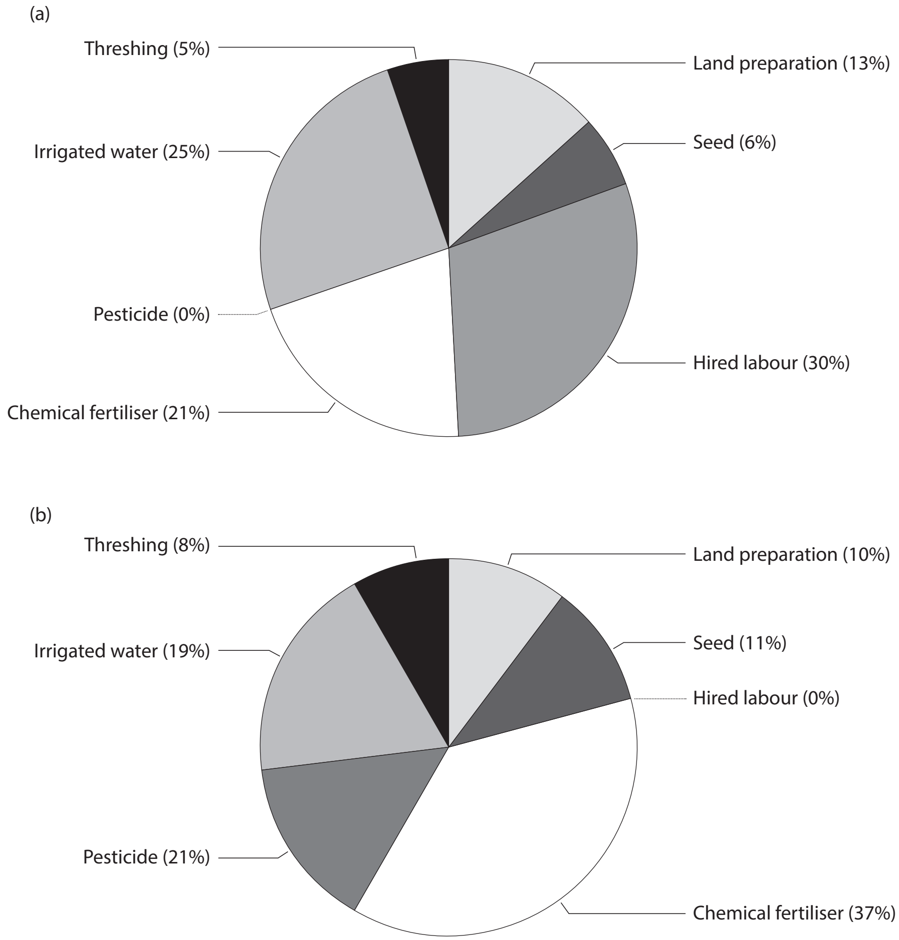

Figure 1. Production costs for (a) wet-season and (b) dry-season rice crops in Takeo province (in 2012). Source: Chhim et al. (2013)

Seed

Improvements in rice cultivation techniques have been curtailed by the supply and demand characteristics of seed markets, resulting in poor seed quality and low yield potential. Low-quality seed is either a mix of different kinds of rice seed, or farm-saved seed, that generally has a low germination rate and produces weak seedlings, lowering yield potential and quality. There has been general apathy among farmers about switching to the new improved high-yielding and high-quality rice varieties because of scepticism about markets for such products. A recent project by MAFF aimed to introduce 10 new high-yielding varieties into the supply chain, but farmers preferred to continue with seed types they knew they could grow and market. However, even if farmers were to embrace improved high-quality rice seed, there are supply-side constraints that need addressing. Currently, the supply of high-quality rice seed remains only 20% of demand (CEFP 2011, p. 12).

Extension services

Limitations in seed and fertiliser markets are compounded by poor extension services constraining the propagation of modern agricultural techniques across rural Cambodia. There is a disconnect between agricultural research and practice—many modern rice-growing techniques tailored for Cambodia have been developed by research institutes, yet there are insufficient extension institutions to channel this knowledge to the grassroots level. Furthermore, impact assessment of extension services on rice productivity found that they have a positive impact on rice yield, but not a statistically significant difference (Keo and Theng 2014). The extension services are ineffective due to weak linkages between research institutes and other stakeholders, lack of resources for extension agencies' operations, and lack of incentives for extension workers (P. Meas, unpublished FAO report prepared for MAFF, 2010).

Credit

Adding significantly to input costs and a core constraint to farmers' investment in rice production is expensive credit. There have been signs of structural change in rural credit markets as microfinance institutions have extended their reach and become increasingly active in rural areas. Nevertheless, the majority of households usually obtain credit from informal moneylenders (Kem 2012).

The reason why informal moneylenders remain prevalent sources of rural credit, despite the fact that they charge high rates of interest (5% per month), is because they are easily accessible to poor households. Informal loans are dynamic and embedded in social relationships—they can be obtained quickly if households experience shocks that deplete their financial resources, and their terms can be tailored to the complex needs of the vulnerable. Microfinance institutions, on the other hand, may be reluctant to lend to poor smallholders, where the risks are deemed too high and the profit margins are small. Many poor households also lack collateral because they are landless, or because their land-ownership rights have not been formalised. Even where households do meet requirements for a microfinance loan, interest rates are high at 2.5% per month—a major burden for smallholders.

Expensive inputs discourage farmers from accessing credit for investment, causing them to remain rooted in subsistence farming. For outcomes to be optimised, low interest rate credit should augment low-cost, high-quality farm inputs, and be supported by high-quality extension services.

Structural constraints in smallholder rice markets

Information asymmetries in Cambodia's rice markets are present from the top to the bottom of the value chain. At the local level, smallholders are highly dependent on brokers from Thailand and Vietnam to facilitate trade. These brokers are able to determine prices and demand for particular products, creating large profits for themselves in the process (Gergely et al. 2010; JICA 2012; Chhim et al. 2013). The structure of this market is highly undesirable from both an efficiency and equity perspective. Smallholder producers, who contribute to growth by creating a surplus, get below-market rates for their produce and face demand uncertainty, curtailing investment and limiting productivity. Rent-seeking traders, who extract value from the rice chain without making any contribution to rice productivity, benefit proportionately more than primary producers. Not only do they increase transaction costs in rice markets, they also create market information asymmetries (Table 1).

To redress this market imperfection, smallholders must be given adequate access to market information regarding prevailing crop prices and demand, so that they are able to get a fair market price for their products. A tangible policy step that could benefit smallholders would be the creation of a database of quality-linked product prices open to the public (JICA 2012).

Contract farming

To remedy structural constraints, new institutional arrangements are now being trialled within rice production that might help to overcome the structural bias against smallholders embedded in rice markets. An emerging mechanism attracting much attention is contract farming, which is often perceived as beneficial to smallholders because it eliminates the uncertainty associated with negotiating with rice brokers. The farmer is contracted to produce a certain amount of produce and the buyer/contractor is obliged to buy those goods at an agreed price for the duration of the contract, subject to quality-control standards being met by producers. Under contract-farming schemes, farmers receive high-quality seeds, access to modern production techniques, low interest loans and better prices for the produce than they would by negotiating directly with brokers.

Table 1. Wet-season and dry-season rice value chains in Takeo province, February 2012

Value chain actors	Wet season			Dry season		
	Buy in (US$/t)	Costs (%)	Mark up (%)	Buy in (US$/t)	Costs (%)	Mark up (%)
Village collectors	250.0[a]	1.4	3.6	192.5[a]	1.7	3.4
Village/local traders	262.5	3.0	22.0	202.5	3.9	3.8
Regional traders	325.0	4.0	16.0	217.5	5.2	5.2
Provincial rice millers	375.0	–	–	–	0.8	–
Rice exporters	–	–	–	237.5	5.4	7.5
Vietnamese traders	–	–	–	262.5	–	–

[a] Farm-gate price
Source: Chhim et al. (2013)

However, in its present form, contract farming does not go far enough in empowering smallholders. Farmers are not consulted in drafting contract terms, and have the power only to agree with them or to forgo participation in the contract. The unequal power relationships that are the root cause of rice-market inefficiencies across the sector have therefore been replicated in contract-farming arrangements. Farmers have little power to negotiate price or define what constitutes a 'high-quality product' and are frequently confused by complex terms. Consequently, many farmers have left contract schemes without seeing any benefits (Nou and Heng 2013).

Farmer organisations

The weakness in the current contract-farming arrangement stems from the fact that it is fundamentally an agreement between individual farmers and large contractors (Gergely et al. 2010, p 70). To overcome this power imbalance, civil society organisations have been pursuing frameworks that can increase the bargaining power of farmers by uniting them in the form of farmer organisations. To date, 14,000 groups have been formed nationwide, including 240 agricultural cooperatives (JICA 2012).

At present, farmer organisations tend to have limited impact because of weak organisational structure—poor leadership and weak planning skills. Activity stops when support agencies stop their services, even among successful groups. There is a lack of mutual trust within groups, which limits meaningful collective action. Organisations have focused solely on production techniques, and have not been mobilised to benefit from collective action in input markets or to influence terms of rice trade (Theng et al. 2013).

Even so, although they are still in an early stage of development, farmer organisations are showing real potential to redress the power imbalances in rice markets. To support this promising development, it is crucial that their scope is broadened and that they are integrated into other rice-market structures. Through these measures, farmer organisations could provide a solid foundation to increase the bargaining power of smallholders through frameworks like contract farming.

Penetrating the global rice market

It is important that government policies restructure Cambodia's rice sector to better represent the demands of the global market. To compete in the competitive global marketplace, high reliability is required to consistently meet buyers' quality and volume specifications. But Cambodia, despite posting a rice surplus of more than 4.8 Mt in 2013 (MAFF 2014), has been unable to provide a predictable volume of uniform-quality product for export (JICA 2012).

Supply-chain constraints in the production of milled rice that result in variable-quality products have been a barrier for Cambodian rice entering global markets. After harvesting, rice is treated inappropriately during drying and storage, causing uneven and/or high moisture content and this leads to a low rate of head rice recovery during milling (JICA 2012). Additionally, rice varieties are sometimes mixed after they have been harvested, degrading the overall quality of the product (Chhim et al. 2013).

Current production capacity for milled rice is low. Cambodia's rice mills are sufficient to process only about 21% of the surplus rice produced and mills that are equipped with the technology to produce export-quality products account for only about 7% of paddy surplus (Table 2; Gergely et al. 2010); many rice mills were built following the rice policy launched in mid 2010. Informal data indicate that current milling capacity can mill up to about 3 Mt/year; however, there are no official data available on milling capacity. Great strides in capacity are therefore required if the export target of 1 Mt of milled rice is to be met—the addition of 92 medium-size mills and 18 large-size mills. Considering that each medium-size mill costs on average US$1.224 million (Gergely et al. 2010), the expense involved in such an expansion of production capacity is considerable.

High input costs of rice milling increase the price of Cambodian products, making them less competitive in the global marketplace and diverting revenue from producers/processors. The biggest contributor to processing costs is expensive and unreliable electricity from the national grid. As a result, most mills use high-cost, inefficient diesel-run generators to meet their electricity needs and, consequently, fuel bills are millers' biggest single expense, accounting for 32% of total processing costs (Gergely et al. 2010; JICA 2012).

The other major input cost for mills is expensive credit. Mills need significant working capital to purchase paddy rice, but the high cost of credit means that acquiring this working capital constitutes a major financial burden, accounting for 28% of total processing costs. As a result, many mills do not run at full capacity because they are unable to afford the requisite quantity of paddy. To meet the target of exporting 1 Mt of milled rice by 2015, Cambodia's mills will need about US$470 million for purchasing paddy and an additional US$200 million for working capital (Gergely et al. 2010, p. 58). This would require expanding the credit mechanisms available to millers.

Once milled rice is produced, there are further constraints to getting it to market. Cambodia relies on road transport to get rice to its ports, but at US$15/t, this is expensive compared with haulage costs in neighbouring countries. Compounding these costs are complex and expensive export procedures. For instance, an array of formal and informal fees is demanded by officials, including highway tolls, customs clearance, customs inspection, CamControl inspection and certification, issuance of certificate of origin, Ministry of Commerce inspection, fumigation and phytosanitary inspections. According to official regulations, fees amount to US$10/t, but in practice, when unofficial costs are taken into account, the figure rises to US$20/t (Gergely et al. 2010).

Significant improvements in export-related bureaucratic procedures in recent years, notably the One-Window Service Office, have greatly reduced the scope for various unofficial fees and charges levied on exporters as they move rice across the country and borders. However, Cambodia still has some way to go to improve procedures for rice export. Crucially, progressive policy frameworks could falter without parallel improvements in institutional capacity. The fact that actual customs fees are double the official figure shows that there is still much to be done to reduce the aggregate costs of petty corruption among regulatory agencies. Technological barriers and institutional limitations also need to be overcome. For example, the ability to certify products to international hygiene standards, known as sanitary and phytosanitary analysis, is a requirement for rice destined for global markets. Yet exporters currently have to send rice to buyers for pre-shipment testing

Table 2. Rice milling capacity in Cambodia, 2011

Mill type	No. of mills	Capacity (t paddy/hour)	Hours per year	Output capacity (paddy, t)	Output capacity (milled rice, t)
Small	200	1.5	2,000	600,000	372,000
Medium[a]	12	5	2,000	120,000	74,400
Large[a]	8	10	2,200	176,000	109,120
Total				896,000	555,520
Export-quality product				296,000	183,520
Milling capacity (%)				21	
Milling capacity (%)[a]				7	

[a] Mills producing exportable milled rice
Note: Paddy surplus in 2011 was 4.34 Mt, with an average rice head recovery rate of 62% (MAFF 2012)
Sources: Gergely et al. (2010); MAFF (2012)

and inspection before cargoes can be despatched—another source of delay and expense.

Logistics infrastructure must be upgraded as a matter of urgency if Cambodia's rice-export ambitions are to be realised. To meet the export target of 1 Mt, the current truck fleet would have to increase by 500%. Sihanouk Ville Port is another constraint to the export of large quantities of milled rice; handling such volumes of rice would require a flow of 50,000 containers per year, or approximately 150 per day (Gergely et al. 2010), which far exceeds current logistical capability and would require massive investment in infrastructure.

Policy: present and future

This paper posits that there are a number of structural deficiencies in markets related to paddy production, including input markets, credit markets and paddy markets themselves, which limit increases in rice investment and productivity. Further up the value chain, there are deficiencies in the production for milled rice, which result in a comparatively low volume of variable-quality product available for export. If rice exports are to reach government targets, both the volume and quality have to be improved and the hard and soft infrastructure required to facilitate large increases in product flows will have to be upgraded.

To remove current constraints to increased rice production and overcome shortcomings in institutional and policy frameworks, it is suggested that the government implement the following policy options:

- *Enhance vertical integration*—increase the quality of products for export and gain higher prices for producers through the provision of good-quality seeds, fertiliser, extension services and credit.
- *Promote horizontal linkages*—farmer organisations and contract schemes can increase farmers' bargaining power, provide benefits for poor smallholders, and secure stable volume and high-quality products for export.
- *Improve coordination*—simplify administrative procedures between ministries and the agencies within their sectors through the creation of a one-stop service. This could be an incentive to encourage more investments in food processing and exporting processed products.
- *Transform informal trade to formal trade*—strengthen rice-processing industries through financial support systems, infrastructure development and an enabling business environment.

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