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1 Acknowledgments

We thank ACIAR for providing the funds to support this project, and iputs into farming systems and multi-stakeholder approaches.

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2 Executive summary

The lowlands and uplands in southern Lao PDR have considerable potential to improve rice production, and produce market surpluses in non-rice crops and livestock. In these mixed crop-livestock systems, there are opportunities to intensify and diversify the integrated crop-livestock systems, through strengthened linkages with private sector, implementation of new production and marketing practices and adaptation of relevant technologies to increase profitability of post-rice crops and livestock production systems. This project followed on from the previous larger CSE/2009/004 (SLP) project, enriching selected elements of SLP activities in Savannakhet and Champassak provinces with core members of the SLP research team and facilities. The project worked to refine selected integrated crop-livestock technologies, assessed systems approaches to crop-livestock integration and created institutional capacity within NAFRI, PAFO and DAFO for establishing local platforms for commercialization and co-learning. On-farm research and demonstration sites provided a mechanism for understanding and application of systems approaches.

The project has undertaken on-farm research at 86 trial sites over five seasons. Topics include post-rice cropping (maize, peanut), dry direct seeding and livestock management (crop residue use as a feed source, forages, duck and fish production), with an integrated focus in implementing these trials. For example, post-rice cropping trials also consider stover fresh weight as a feed source, and ducks and fish are introduced into dry direct seeded rice systems to assess weed control and productivity (biophysical and economic). Importantly analysis has included a range of biophysical and social parameters. Drilling nutrients with the seed at sowing increased early rice growth, and split dressings gave higher yields. The weed control experiment clearly demonstrated the benefits of suppressing weeds early, with ducks in particular resulting in improved rice growth and yield. Integrated management of nutrients and weeds can improve performance, profitability and reliability of dry direct seeded rice, with reduced risk. These sites have also been used as training and field day sites for integrated direct-seeded rice based systems for 401 participants, contributing to the adoption of this technology on more than 15,000 ha in 2016.

This project has a focus objective of enhancing multilateral systems thinking, using on-farm trials and familiar examples to apply different tools. Approaches used include workshops to synthesise technology materials; focus group discussions; workshops with national and international experts to explore familiar technologies using integrative enquiry to identify constraints and opportunities based on prior experience, project results, and wider scientific inputs; and multi-stakeholder workshops to communicate and contextualise project outcomes. This has been undertaken as a basis for initiating and implementing Innovation Platforms to address complex challenges. The Agricultural Innovation Systems Approach has been used to understand the dry direct seeding innovation system in Savannakhet.

Innovation Platform training has been conducted for 59 staff at national, provincial and district levels. This has been followed up with initiation of three Innovation Platforms; in Savannakhet Province to support outscaling and research for dry direct seeding, in Phin to improve cattle fattening systems, and in Phontong for improved post-rice cropping production, focusing on onions.

Six journal papers have been submitted, with one accepted and another seven in draft form, drawing together datasets from SLP and the current project. The project has also supported two Masters students (CSU, NUOL) and cooperated with other ACIAR projects (CSE/2012/077, ASEM/2014/052) and external stakeholders.

3 Background

Extensive rural poverty means that agricultural and rural development in southern Lao PDR is a national priority. Challenges within these sectors are complex and require a systems research to complement commodity and resource investigations in order to understand constraints fully and develop scalable and commercializable solutions to improve rural livelihoods and the local economy.

In this region, smallholder crop-livestock integration is a core element of agricultural and rural development, and is confronted by a problem complex of poverty, poor financial and natural resources, weak infrastructure and institutions and poor market access, for which individual disciplinary research alone is not sufficient to improve livelihoods. Clearly, increased production and sustainable development are important goals of the Lao PDR Agricultural Strategy to 2025, along with commercialization of smallholder agriculture. Additionally, the New Aide Framework of the Australian Government provides a complementary framework for research and development in Laos. The Framework not only has a specific element on Agriculture, Fisheries and Water, but also lays down ten performance metrics including prosperity, benefits to women and innovative partnerships with the private sector.

3.1.1 Lao poverty and the regionalisation of the economy

Lao PDR has a population of 6.8 million, growing rapidly at 2.3% per annum. The population density is the lowest in Asia (29 persons/sq.km) but due to mountainous terrain the majority of land is unsuitable for food crop production other than by shifting cultivation (Roder 2001), making the lowland plains of southern Lao PDR (Savannakhet and Champassak) particularly important for national food security. About 70% of the population lives in rural areas, although the rate of urbanisation is high. There is also considerable movement of population between rural districts, especially from uplands to lowlands. The rapidly growing and urbanising population implies an increased demand for food including red meat.

The economy of Lao PDR is still largely agrarian and subsistence-oriented. Agriculture accounts for about 40% of GDP and 80% of employment, and over 70% of agricultural production is non-traded. Until recently, crop and livestock production has been primarily a subsistence activity, with limited local or export trade. About 30% of the population was below the poverty line in 2005, with the greatest concentration of poverty in southern Lao PDR (Savannakhet, Saravane, Champassack, Sekong, Attapeu). Most of the poor live in the southern lowlands, although the highest rates of poverty (as a proportion of district population) occur in the uplands, especially the southern uplands.

The economy of Lao PDR is becoming increasingly commercialised and integrated into the Greater Mekong Subregion with the majority of trade occurring with Thailand, Vietnam, and China, particularly crops and cattle from the northern provinces. The emerging private sector in Lao PDR is being encouraged to take a greater role in agricultural processing and marketing, though there are still issues of ensuring adequate information flows, dealing with regulatory constraints, and enforcing fair and transparent contractual arrangements. Regional integration has involved a surge of foreign direct investment (FDI) in both small- and large-scale commodity production (notably rubber), with Chinese firms the major investors in the north and Vietnamese firms obtaining extensive land concessions in the south (Manivong 2007). In addition, Thai agribusiness firms have been contracting supplies of maize, soyabean, and other post-rice crops from Lao farmers in more accessible areas. Regionalisation of the Lao economy is set to continue as highlighted by the projected road network, with scheduled routes to be developed linking Savannakhet and Champassak provinces with Thailand and Vietnam. ASEAN Economic Community (AEC) will also facilitate this, with associated implications for trade facilitation of agricultural produce, including SPS and product quality.

Consequently, southern Lao PDR is an agricultural economy in transition, and the Government of Lao PDR has introduced policies to support inclusive and pro-poor commercialization of agriculture.

The growing regional economy has increased the demand for labour in commercial agricultural ventures, factories, and cities, both in Laos (e.g. Vientiane, Savannakhet) and Thailand. This has drawn labour out of rural areas, especially in the south, increasing the cost of farm labour in an already labour-constrained rural economy. While wage migration during the dry-season slack period has been common in the rainfed districts, the increase in outmigration from the south means that reduced labour availability and increased labour costs are becoming significant production constraints, both for post-rice crop cultivation and livestock production, and lead to increasing incentives for labour saving technologies such as conservation agriculture and agricultural mechanization.

3.1.2 Post-rice crop agronomy

Rainfed areas in southern Lao PDR frequently suffer from significant incidences of both drought and floods. Drought is a regular occurrence throughout the cultivated areas of Lao PDR especially on upper terrace fields and the uplands, and farmers in rainfed lowland consider drought their most consistent production constraint (Khotsimuang et al. 1995). The soils in this region are predominantly loams, sandy loams and sands, and are particularly drought prone (Lathvilayvong et al. 1996). Some presence of salinity problems has been reported in southern Lao PDR but the extent of this problem is unclear. Both early and late wet season droughts occur (Fukai et al. 1998). Of particular importance to post-rice crops and forages, late-season drought is common. Fertilizer application is essential to achieve and maintain higher yield levels (Linquist and Sengxua 2001). However, farmers are reluctant to invest in fertilizers because of volatile prices, unfavourable input/output price ratios, and weak market access (Pandey 2001). Therefore, farmers need knowledge and tools to adjust their crop management to site-specific bio-physical and socio-economic conditions.

Reduced labour availability and increasing labour costs are becoming significant production constraints. The consequent shift in rice from traditional transplanting to direct seeding and, potentially mechanisation, are additional considerations for the establishment and management of post-rice crops. In the uplands, reduced labour availability impacts on weed control and timely farming operations. In practice, integration of improved practices into intensification and diversification is required, and livestock husbandry is an important linked component of the system.

3.1.3 Forages and livestock

For poor households in both the lowlands and uplands livestock production provides a major source of cash income, poverty reduction and enhanced food security. However, issues of fodder and feed availability, low labour productivity and poor market chains limit market earnings. Traditionally, rice production and small livestock like chickens and ducks used to underpin home consumption, while pigs and large ruminants (cattle and buffalo) provided cash income, draught power for land preparation, and manure for soil fertility maintenance. However, with agriculture in transition, livestock sales often account for 50% or more of farm-derived household cash income and ensure households have a capital reserve in times of need. Rice bran is the single most important feed for poultry and pigs, and rice straw ensures that cattle and buffalo can survive the long dry season.

Livestock productivity in traditional management systems is low and requires high labour inputs. Women are responsible for small livestock (poultry and pigs), while men are responsible for cattle and buffalo. Managing and feeding pigs is time consuming, so women may spend 2–3 hours a day collecting and preparing feed. Introducing a forage legume can reduce this time by 50%, while doubling pig productivity as limited feed is the main reason for low livestock productivity. Farmer control of local feed is restricted to rice straw, while households compete for grazing of common land. Given the poor nutritional quality of rice straw, livestock have poor body condition and are susceptible to diseases.

With the proximity of increasingly affluent population centres in China, south Vietnam and Thailand, Lao PDR is ideally situated to benefit from increased demand and prices for meat. City markets like Ho Chi Minh City increasingly demand high quality cattle (<4 years of age, minimum weight 350kg and a body condition score of 4), which currently is beyond the capacity of smallholder farmers in southern Lao PDR. Within Lao PDR and neighbouring countries, local and regional markets may accept smaller and older cattle at reduced prices, provided they are in good body condition (a score of 4 or 5). In northern Lao PDR, farmers who fatten cattle for 2–3 months before sale using on-farm forages can obtain an additional A$50–100 for these fatter cattle from local traders. Improved production and quality of feed, its timely allocation for fattening, and improved livestock hygiene and management should improve livestock body condition and corresponding incomes for farmers.

Technical options for improving feed supply for large ruminants (such as intensively managed grass plots for stall-fed cattle) have proven successful in upland environments in northern Lao PDR and central Vietnam, and are showing promising early results in southern Lao PDR. Growing forages in lowland fields is a relatively new concept and there is limited experience with broadly adapted forage varieties in northeast Thailand and Cambodia. Similalry, there are promising early results in southern Lao PDR.

It is important to consolidate knowledge of the appropriate post-rice fodder options, including dual-purpose legumes. Tree legumes, sugarcane and cassava may buffer feed reserves during the dry season. Forage legumes may improve soil fertility, with livestock providing manure for post-rice vegetable or forage crops. Ultimately, the integration of forage ctops with the cropping systems in a context of different gender roles and decision making and overall shortage of labour is a complex systems challenge.

3.1.4 Integrating cropping and livestock systems

The above discussions highlight many critical linkages between crop and livestock production. In practice, although forage and feed production is a core linkage, labour allocation, seasonal cash flows and financing, risk sharing and differentiated gender roles are other linkages which need to be considered. The importance of adopting a crop-livestock systems research and development approach follows. There have been a variety of systems approaches which are of relevance to the southern Lao situation, including ‘One health’ and other approaches documented in the Journal of Agricultural Systems.

There are significant and varied knowledge gaps surrounding existing crop-livestock farming systems in southern Lao PDR. Not only production constraints and opportunities interact, but also the socioeconomic aspects (e.g., different labour and decision-making roles of women and men),and commercial aspects involving connections with agribusiness also need to be investigated through a systems lens – in keeping with the New Aid Framework of the Australian Government. The innovation platform is one modern approach which is being piloted in many environments with a view to integrate science, local institutions and business to foster innovation and co-learning.

The ACIAR project CSE/2009/004 (FMS) has made considerable progress on the development and testing of post-rice crop and livestock technologies (along with socioeconomic and water management) in a systems context in selected communities. The continuation and enrichment of the systems research to identify and deliver effective technologies for integrated crop livestock systems necessarily integrates the perspectives, knowledge and tools from several bio-physical and social sciences. Strengthening effective systems research in Southern Lao PDR requires substantial capacity building; and testing local (in-community) scaling out of research results requires strong engagement with both community leaders and the private sector.

4 Objectives

1. Refine selected integrated crop-livestock technologies including post rice crop diversification and forages

1.1 Robust farmer-tested management options for post-rice diversification crops including forages under rainfed and irrigation identified, and relevant promotional materials developed for commercialisation and scaling out;

1.2 Community demonstrations of post-rice diversification crops maintained and improved; field days and farmer assessments held to generate feedback on systems adaptation and adoption;

1.3 Refinement of FMS typologies of crop-livestock farm households and social and economic metrics for the ex-ante and ex-post evaluation of crop-livestock integration technologies and community tools for the participatory monitoring of adoption and adaptation; and, in consultation with other projects, a summary of best-bet crop management options and development modalities for lowland and upland mixed-farming systems in South Laos, differentiated by farm typology, and suitable for use by PAFOs/DAFOs, ACIAR projects, and other relevant stakeholders.

2. Assessment of the potential effectiveness of selected systems approaches to crop-livestock integration

2.1 Through systems workshops with local and international experts, experience with practical approaches to systems implementation will be shared across NAFRI and PAFO, including Innovation Platforms, IAR4D, integration and implementation sciences. Constraints and limitations at different levels will also be identified. Outcomes from these workshops will be communicated to DAFO and other project partners through a 'Train the Trainer' approach.

2.2 Alternate IAR4D systems approaches will be summarized, including several schools of thought around IAR4D and innovation systems including 'one health'; and alternative scenarios for South Laos with particular reference to Savannakhet and Champassak Provinces until 2020 for income, production risk, marketing risk, gender impact and food security described;

2.3 Priorities for further systems or disciplinary research by NAFRI and partners in south Laos PDR identified.

3. Create institutional capacity with NAFRI, PAFO and DAFO for establishing local platforms for commercialisation and co-learning

3.1 Functional linkages from farmer groups to agribusiness identified for strengthened input and output value chains for selected diversification options; Provincial policy adjustments identified to remove value chain bottlenecks and facilitate opportunities; and partnering with relevant NGOs including the ADB-IFAD supported SNRMPEP program;

3.2 Innovation platforms will be initiated at the three hubs to link with relevant actors in the system, including agri-business, other R&D projects and development initiatives in south Lao PDR, to share results and facilitate opportunities for wider engagement, commercial activities and outscaling.

5 Methodology

This project was designed to build on work conducted in CSE/2009/004, and followed up on selected technologies with the core team, facilities and research hubs operating in Savannakhet and Champassak Provinces. This project has used a systems approach to define integrated on-farm research activities, and built capacity in implementing Innovation Platforms to further address constraints and challenges within lowland farming systems of southern Laos. Figure 1 illustrates how the project objectives are linked. **Objective 1** comprised on-farm research into integrated crop-livestock systems. Initially, these trials were informed by work undertaken in the CSE/2009/004 project and partner priorities. Later, they formed the basis of the selected topics for the Innovation Platforms (**Objective 3**), and both informed and were modified according to work undertaken within these groups. Partner priorities, along with an assessment of systems approaches used in Laos and elsewhere (**Objective 2**), lead to the Innovation Platform approach being used to address constraints within farming systems. Work on **Objective 3** was informed by outputs from **Objective 2**, and comprised of training at national, provincial and district levels, as well as implementing three Innovation Platforms (for DDS, cattle production and vegetable production).

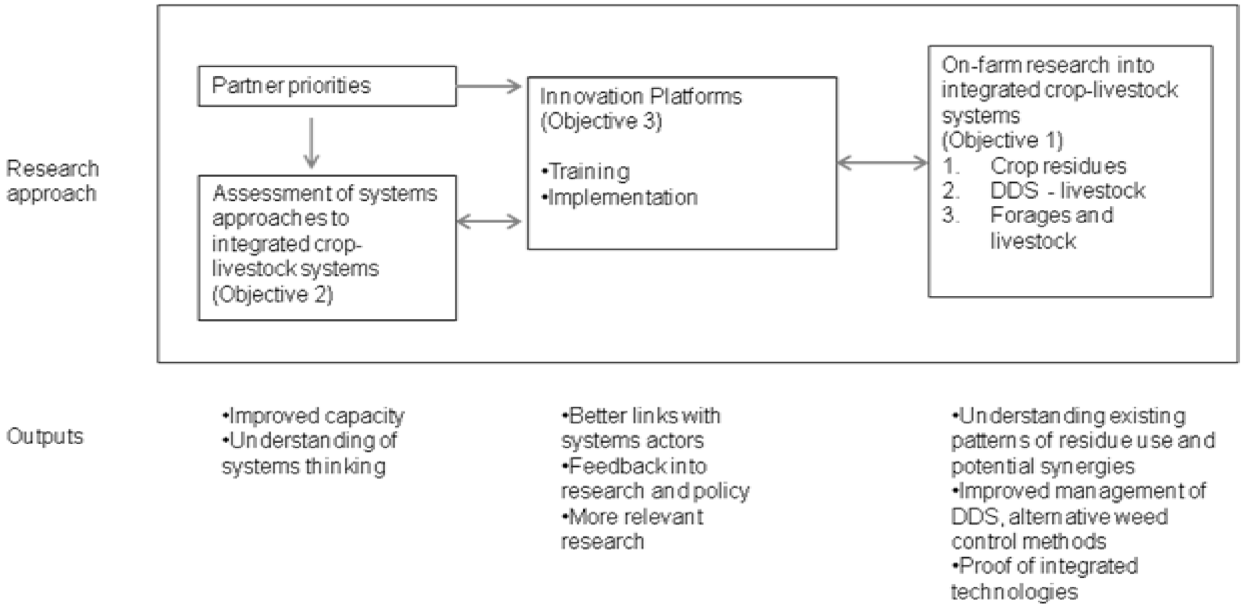

Figure 1 Research approach, showing how Objectives 1, 2 and 3 are linked.

Objective 1: On-farm research in integrated crop-livestock systems

Building on work undertaken in CSE/2009/004 and prior experiences in southern Laos, several integrated crop-livestock system options were identified at the project Inception Meeting in November 2014. Each district considered which were appropriate and achievable in their local contexts. Before implementation, these options were considered in a systems context, across enterprises, to ensure the system was considered as a whole and not as isolated components. Four integrated crop-livestock systems were identified;

1. Crop residues – Livestock (including crop residues as a feed source, urea rice-straw treatment, nutrient management)
2. Forage - Livestock

3. Livestock management – Feed regimes
4. Direct seeding integrated with small livestock management (duck, fish). This includes elements of nutrient and weed management.

Table 1 shows details of on-farm research activities, and their locations. In total, 86 activities were undertaken in fourteen villages. These villages were selected either as follow on locations from CSE/2009/004 or as places were the relevant technologies tested would be applicable within the target districts.

As the project progressed, some of the trials were modified to incorporate additional feedback from wider stakeholders through work undertaken in Objective 3 (Innovation Platforms). For example, duck-rice production was first trialed for proof of concept, farmer acceptability and productivity. When weed management concerns were raised within the DDS IP meetings as a key challenge for this technique, the focus shifted to incorporate nutrient and weed management aspects.

Table 1 On-farm research and demonstration sites by season, topic and location.

District	Village	Dry season		Wet season			
		Post-rice crop (sweetcorn, peanut); crop residue as feed source	Dry direct seeding demonstration (including nutrient management)	Dry direct seeding	Forage plantation	Duck with direct-seeded rice	Fish with direct-seeded rice
Phin	Ban Napo			1			
	Ban Phin	3		2	4	3	1
	Ban Nathongkhork			2			
Phalanxay	Ban Nongveng			1	1	2	1
	Ban Phanomxay	2		3			
	Ban Phalanneua	2					
	Ban Phalantay			1			
Champhone	Ban Phaikhong		1	5	6	3	1
	Ban Phornmuang		1	2			
	Ban Alan Wattana		2	2	2	3	1
Phonthong	Ban Nasomvang	4		2	2	2	2
	Ban Don Jod	4		2	2	2	2
	Ban Dongyang	1		1			
Xaiphouthong[1]	Ban Meuang Khai		2				
Sum		***16***	***6***	***24***	***17***	***15***	***8***
Total		***22***		***64***			

[1] *Note – this trial conducted in conjunction with Leigh Vial/Crawford Fund seeder sponsorship project. Key staff from PAFO were relocated to DAFO in Xaiphouthong, hence close management was possible.*

Objective 2: Assessment of the potential effectiveness of selected systems approaches to crop-livestock integration

Activity 2.1 relates to systems workshops with local and international experts, to identify promising opportunities and build capacity in systems thinking. The initial four months of this project were conducted in conjunction with the final stage of CSE/2009/004. This period incorporated a series of systems workshops for synthesis of technology materials, and introduced tools for exploring and understanding farming systems and linking with stakeholders. Workshop 1 focused on identification of crop and livestock technologies that were tested within the project, and that project staff felt were sufficiently ready for outscaling. Extension materials were prepared that incorporated project experiences and data, for materials that are contextually relevant for farming systems in southern Laos. Focus group discussions were held with farmers to consider their perspectives on crop and livestock integration, to look at their existing experiences and constraints, and to identify opportunities to strengthen these links. This feedback was presented in Workshop 2, and helps to incorporate the 'demand side' perspective of farmers in relation to crop-livestock links. Workshop 2 convened local and international experts to present aspects of farming systems research, and let the project team explore project technologies in the context of existing farming systems, using integrative enquiry approaches to identify constraints and opportunities based on prior experience, project results, and wider scientific inputs. This period gave project staff an opportunity to consider the potential benefits of engaging with a range of stakeholders to address farming systems constraints using an Innovation Platform approach. Workshop 3 allowed communication of project outputs to a range of provincial stakeholders, and exploration of options for working together to address system constraints for mutual benefit. These activities are reported in more detail in the CSE/2009/004 Annual Report, available at http://aciar.gov.au/publication/fr2016-04.

A literature review was conducted to summarise common systems approaches and tools for implementation that can be used for more effective research and development. These included approaches that had been previously successful both in Laos and in other regions. The outcome from this literature review was that the Agricultural Innovation Systems (AIS) approach and Innovation Platform tool (IP) (among others) was likely to be useful in Laos, as both approaches are mature enough to have amassed a wealth of knowledge and application in other places, they build on what has been done before in the Lao context, and are also inclusive and adaptable for the Lao situation.

Following the decision to focus on AIS and IP, a series of training sessions were organised at national, provincial and district levels (Figure 2).

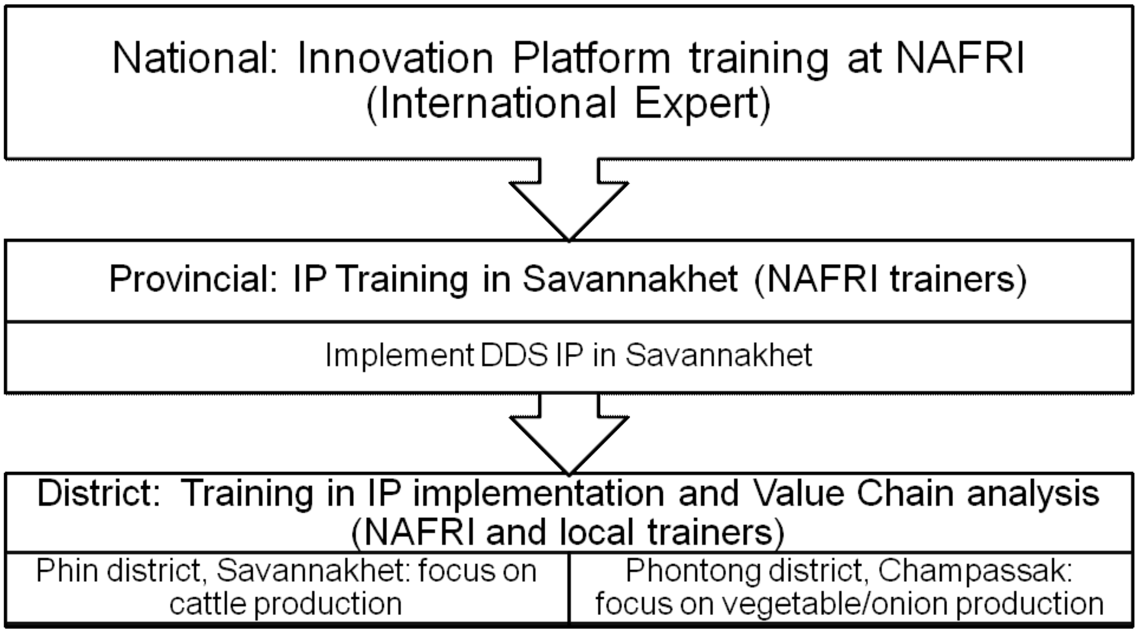

Figure 2 Training approach to build capacity for implementation of Innovation Platforms

Training on implementing Innovation Platforms was initially held in Vientiane for project staff, as an introduction and as a ‘Train the Trainer’ session. This was conducted by an international expert in implementation of IP, Dr Ranjitha Puskur. Subsequently, the training materials were modified and translated into Lao for training at the provincial and district levels. After the provincial training in Savannakhet, the project was granted a ten month extension; this meant that there was time and funds available to conduct district level training. After initial experiences, it was decided that the training needed to focus more heavily on practical skills such as analysing the value chain as a starting point for implementation of IP. The district training sessions engaged a trainer from Xieng Khoaung DAFO, Mr Viengsouk, who had previously worked on the CIAT Smallholder Agro-enterprise for Development in the Uplands (SADU) project in northern Laos, and who had excellent experience and skills in facilitation. These practical, hands-on training session were an excellent basis from which to pursue the implementation of IP in the districts. These training sessions are described in more detail in Section 7.3, as well as the project experiences with implementing the Innovation Platform process.

Priorities for further research in southern Laos will be identified in a working meeting with project partners including NAFRI, PAFO and DAFO. This brainstorming session will also incorporate feedback from various IP meetings. The outcomes from this session will be summarised and presented to senior NAFRI staff, for consideration of incorporation into the NAFRI research strategy (to be undertaken in April 2017).

Objective 3: Create institutional capacity with NAFRI, PAFO and DAFO for establishing local platforms for commercialisation and co-learning

Objective 3 focuses on developing capacity to initiate and implement Innovation Platforms in target provinces and districts, by building capacity at national, provincial and local levels. IP are a way of bringing together multi-stakeholder groups to address complex challenges in agricultural systems, and are a way of linking members of the value chain and beyond. The aim is to enhance commercialisation and co-learning in crop-livestock systems in southern Laos to achieve a range of outcomes including facilitating engagement with the wider community, sharing research results and co-learning.

Through systems workshops and training events, project members considered target locations and products that would benefit from establishing an IP. The first IP initiated was to support the rapid adoption of DDS in Savannakhet province (March 2016). The aim of the IP was to provide a space to support this technology, to link different actors within the system, to ultimately make the technology easier to access for farmers in suitable areas, and less risky for those who want to trial and adopt this technique. Implementing an IP to support DDS for rice served as a learning mechanism for project members, in terms of understanding and gaining skills in multi-stakeholder approaches. In Savannakhet province, this approach was relatively new, and there were few examples from which to learn.

In May 2016, the project was granted an extension for ten months. The project used lessons from the experience in Savannakhet to inform subsequent training and initiation of IP at the district level. Training at the district level was modified to be more hands-on, and engaged with an experienced trainer in value chain analysis. Two districts were selected to implement IP; Phin (potential for cattle marketing) and Phontong (improved vegetable production – focusing on onions). The process in these districts was to conduct training in IP and value chain studies, which gave district staff an opportunity to develop practical skills. Following the value chain studies, the results were presented at an IP meeting, to determine engagement and potential follow on activities. With additional time, this process would continue to build on and learn from these activities.

Summary of project approach

The focus of the project has been to enhance multilateral systems thinking (Objective 2), with on-farm research and demonstration sites (Objective 1) used to provide a mechanism for understanding and application of systems approaches. Objective 3 focused on developing capacity to initiate and implement Innovation Platforms in target provinces and districts, drawing together and reinforcing activities within Objectives 1 and 2. The aim is to enhance commercialisation and co-learning in crop-livestock systems in southern Laos to achieve a range of outcomes including facilitating engagement with the wider community, sharing research results and co-learning. The approach taken within the project has been flexible, adapting to opportunities as additional time and funding became available.

6 Achievements against activities and milestones

Objective 1: Refine selected integrated crop-livestock technologies including post rice crop diversification and forages

No.	Activity	Outputs/ Milestones	Completion date	Comments

1.1	Robust farmer-tested management options for post-rice diversification crops including forages under rainfed and irrigation identified, and relevant materials developed for commercialisation and scaling out	33 On-farm demonstrations established.	Mar 17	Dry season 2015 (13 sites) Wet season 2015 (58 sites) Dry season 2016 (8 sites) Wet season 2016 (5 sites) Dry season 2017 (2 sites) Total: 86 on-farm demonstration trials in 14 villages
		Support materials developed	Mar 15 & 16	Preparation of materials was undertaken in CSE/2009/004 Variance 5 (reported in http://aciar.gov.au/publication/fr2016-04). Posters (2,500), pamphlets (800), books (300) printed in 2016 and distributed through PAFO, DAFO and collaborators (e.g. machinery dealerships for DDS). Contribute to video for DDS prepared with ACIAR funds from LWR/2008/019 and in conjunction with CSE/2012/077. 15 papers in preparation for submission to international journals, based on outputs from CSE/2009/004 and this project. Progress includes: Published (2) Accepted (1) Submitted (5) Draft completed (2) Analysed data available (6) Key papers are also being prepared/translated for the Lao Journal of Agriculture and Forestry (10); the project will contribute to publication costs of one edition of LJAF.

1.2	Community demonstrations of post-rice diversification crops maintained and improved; field days and farmer assessments held to generate feedback on systems adaptation and adoption	20 Field Days. 400 Farmer participants, 200 farmer assessments. Feedback generated	Mar-Oct 15 Mar-Oct 16	In wet season 2015, these field days focused on dry direct seeding and integrated systems. Field days (5): • 2 DAFO training sessions (55 participants, 8 women) • 3 farmer field days (102 participants, 18 women) • Assessments (130 responses) In wet season 2016, field days again focused on dry direct seeding and integrated systems, as requested through the Innovation Platform. Training sessions (124) Field days (120) Summary: A total of 179 farmers attended training sessions and 222 attended field days (401).
1.3	Refinement of FMS typologies of crop-livestock farm households and social and economic metrics for the ex-ante and ex-post evaluation of crop-livestock integration technologies	Ex-ante and ex-post evaluation of ICL technology. Community tools for participatory monitoring of adoption/adaptation. Best-bet options and development modalities.	Dec 15 & March 17	ICL technologies evaluated in terms of biophysical (e.g. yield performance), economic, social (labour, household planning, gender implications) aspects, using participatory methods (integrative enquiry, systems mapping etc). This was done in systems and IP meetings for selected technologies (dry direct seeding, duck-rice integration, cattle production, onion production). The dry direct seeding adoption process was explored using an innovation systems approach, to enhance understanding and draw lessons for encouraging innovation in agricultural systems. Household typologies considered in terms of adoption and experiences.

Objective 2: Assessment of the potential effectiveness of selected systems approaches to crop-livestock integration

No.	Activity	Outputs/ Milestones	Completion date	Comments
2.1	Systems workshops with local and international experts	8 Workshops held 10 Trainers trained 50 local participants trained (DAFO, PAFO, others tbc)	Aug, Sep, Oct 15 Feb, Mar, Jul, Sep 16	This was merged with activities under Variance 5 of CSE/2009/004. Under this extension period (June – October 2015) four workshops were held, focusing on Technology Synthesis (including a second “write-shop”), Technology Integration, and Technology Synthesis and Integration Outscaling at the Provincial Level. These are reported in the final report for CSE/2009/004 (http://aciar.gov.au/publication/fr2016-04). Under CSE/2014/086 a further four workshops were held; one Innovation Platforms Training in Vientiane (February 2016 – 15 staff) and one in Savannakhet (March 2016 – 9 staff). Workshops to build practical skills in Innovation Platforms and Value Chain Analysis were held in Phin district (July 2016 – 20 staff) and Phonthong district (September 2016 – 15 staff). Eight workshops were held in total. 15 trainers trained at the NAFRI/PAFO level. 44 local participants trained (PAFO/DAFO).
2.2	Alternate IAR4D systems approaches	Alternative systems approaches summary Scenarios for Southern Laos described	June 15 Mar 17	Initial draft done in February 2015; this was finalised in June 2016. Scenarios will be described as part of the project review meeting in March 2017.

2.3	Priorities for further systems or disciplinary research by NAFRI and partners in south Laos PDR identified.	Priorities identified	Mar 17	Priorities were identified as part of the project review meeting in March 2017

Objective 3: Create institutional capacity within NAFRI, PAFO and DAFO for establishing local platforms for commercialization and co-learning

No.	Activity	Outputs/ Milestones	Completion date	Comments
3.1	Functional linkages from farmer groups to agribusiness identified for strengthened input and output value chains for selected diversification options	Input and output value chains strengthened.	Initiate in Jan 15, finalise by Dec 16	Training in IP and value chain analysis for 49 staff in total, including in gendered value chain analysis.
		Provincial policy adjustments identified	Dec 16	Investigate options at district level to establish IP, including sector specific focus (e.g. dry direct seeding, livestock exports, onion production) and potential linkages with agribusiness and other R & D initiatives.
		Partnering effective	Ongoing	Working towards effective partnering with other stakeholders at provincial and district levels, including linking with other government departments, education sector, private sector etc (see ‘Key lessons learned’ in Final Report).

3.2	Innovation platforms will be initiated	Linkage with agribusiness, other R&D initiatives Wider engagement, commercial activity and outscaling	Mar 16	IP initiated in Savannakhet to support Dry Direct Seeding (inception meeting, activity planning, field trip held for members). Link with agribusiness (machinery supplier, machinery manufacturer), other government departments, technical college to promote commercial activity and outscaling of dry direct seeding.
			Jul 16	IP initiated in Phin district for improved cattle marketing; value chain analysis done. Results communicated to stakeholders, key challenges identified. Working towards prioritising activities within IP. Need to engage with Governor's office.
			Nov 16	IP initiated in Phontong district, Champassak for improved onion production. Value chain study conducted, results communicated to stakeholders, solutions discussed and activities planned (ongoing).
		Sharing and co-learning among farmers, agribusiness and government staff	Ongoing	First outputs implemented through a series of workshops (November 2015 (reported in the Final Report for CSE/2009/004 http://aciar.gov.au/publication/fr2016-04), March – June 2016). Subsequently undertaken during preparation and implementation of IP in Savannakhet, Phin and Phontong.
		Practice notes in Lao language	Apr 17	To be developed from key lessons learned, discussed during project review day and summarised in Final Report.

7 Key results and discussion

7.1 Objective 1: Refine selected integrated crop-livestock technologies including post rice crop diversification and forages

Building on work undertaken in CSE/2009/004 and prior experiences in southern Laos, several integrated crop-livestock system options were identified at the project Inception Meeting in November 2014. Each district considered which were appropriate and achievable in their local contexts. Before implementation, these options were considered in a systems context, across enterprises, to ensure the system was considered as a whole and not as isolated components. Four integrated crop-livestock systems were identified;

1. Post-rice crop – Livestock (including crop residues as a feed source, urea rice-straw treatment, nutrient management)
2. Forage - Livestock
3. Livestock management – Feed regimes
4. Direct seeding integrated with small livestock management (duck, fish). This includes elements of nutrient and weed management.

Table 1 (Section 5) shows the on-farm trial and demonstration sites implemented during the project until March 2017. More information about the outputs from these trials is included in the following sections.

7.1.1 Post-rice crops

The effect of sweetcorn planting time on cob and fresh stover

Staggered planting of sweetcorn was tested in on-farm trials in the dry seasons of 2015 (10 farms) and 2016 (7 farms). Farmers were provided with good quality seed, and managed their plots according to their normal practice. The aim was to analyse the effect of planting time on cob production and the interaction with stover production for animal feed. A combined analysis of data was performed for five main planting times, as shown in Table 2.

Table 2 Planting times for dry season sweet corn

Planting number	Average date	Range of dates
Planting 1	8th December	4th – 12th December
Planting 2	22nd December	18th – 26th December
Planting 3	31st December	28th – 3rd January
Planting 4	7th January	5th – 8th January
Planting 5	17th January	10th – 28th January

Mean cob and stover fresh weight was highest for the first planting date in early December, and subsequently declined after that for all dates (Table 3). There was homogeneity of variances, as assessed by Levene's test for equality of variances (p = 0.5 and 0.67 for cob fresh weight and stover fresh weight respectively). The production of cob and stover fresh weight was significantly different for different planting times; for cob fresh weight, $F(4, 77) = 3.26$, $p = 0.016$, and for stover fresh weight, $F(4, 77) = 2.8$, $p = 0.032$.

Table 3 Mean cob and stover fresh weight for staggered planting dates.

		N	Mean	Std. Deviation	Significant difference		
Cob fresh weight (t/ha)	8th December	15	10.85	2.571	a**	b*	
	22nd December	22	8.10	2.902	a**		
	31st December	19	9.09	2.439			
	7th January	12	9.73	1.753			
	17th January	14	8.39	2.194		b*	
Stover fresh weight (t/ha)	8th December	15	17.07	5.139	a**	b**	c*
	22nd December	22	11.73	5.823	a**		
	31st December	19	11.79	5.834		b**	
	7th January	12	11.91	5.706			
	17th January	14	11.91	4.627			c*

Numbers with different letters indicates significant difference at $^{**}p < 0.05$ and $^{*}p < 0.1$

There was a significant decrease in cob fresh weight between the first planting date (8th December) and the second (p<0.05) and fifth (p<0.1) planting dates. Similarly for stover fresh weight, there was a significant decrease in production between the first planting and the second (p<0.05), third (p<0.05) and fifth plantings (p<0.1). This is likely due to later plantings experiencing high temperatures at crop maturity; when harvest is delayed until later in February or March, plants mature at the hottest time of the year. Water availability is also lower at the end of the dry season if farmers are using ponds or shallow groundwater (Vote et al. 2015), and farmers risk running out of water by the end of the dry season.

However, staggered planting of sweetcorn means that animal feed (stover) is available more regularly at the end of the dry season over a period of around one month, when alternative feed resources are very low. Based on general feed requirement recommendations of fresh matter equivalent to 15% of bodyweight (Nampanya et al. 2014), a 200 kg animal requires around 30 kg fresh stover per day if being exclusively fed maize stover. Based on production rates in Table 3, this requires around 18 – 26 m^2 land area per day, or 123 – 169 m^2/week, with a larger area required as the season progresses. As farmers use stover as a supplementary feed, with supplementation usually equating to around 25 – 30% of a daily diet, this land area could potentially maintain around four animals at the end of the dry season, contributing to improved animal health and body condition compared to animals without a supplementary feed source.

Dry season crop production offers farmers an additional income stream, and if managed suitably can also contribute to livestock production. Managing sweetcorn planting times by spacing planting dates by 7-14 days was found to have a significant effect on both cob and stover yield, with early December planting dates giving the highest yields. This is due to high temperatures at the end of the season when planting dates are delayed. However, this method offers a livestock feed source at the end of the dry season when other feed resources are scarce, and so farmers may benefit by maintaining animal health and condition at this critical time of the year.

Peanut productivity

Peanuts were tested on six farms in dry season 2015. Farmers planted areas of between 65 – 800 m^2. Yields in Phalanxay were much higher than in Phontong, however prices were higher in Phontong compared to Phalanxay (12,000 LAK compared to 7,000 LAK). Crop residue was measured on three farms; this correlates strongly with pod yield of peanut ($R^2 = 0.997$). Yields were lower in Phontong because there was insufficient water available at the end of the season to finish the crop. Production of peanuts has the potential to increase cash income, improve soil fertility and provide a high quality feed source for animals. However, the ability to plan for dry season water use is essential, and can have detrimental effects on yield if farmers do not have adequate water supply for the whole season.

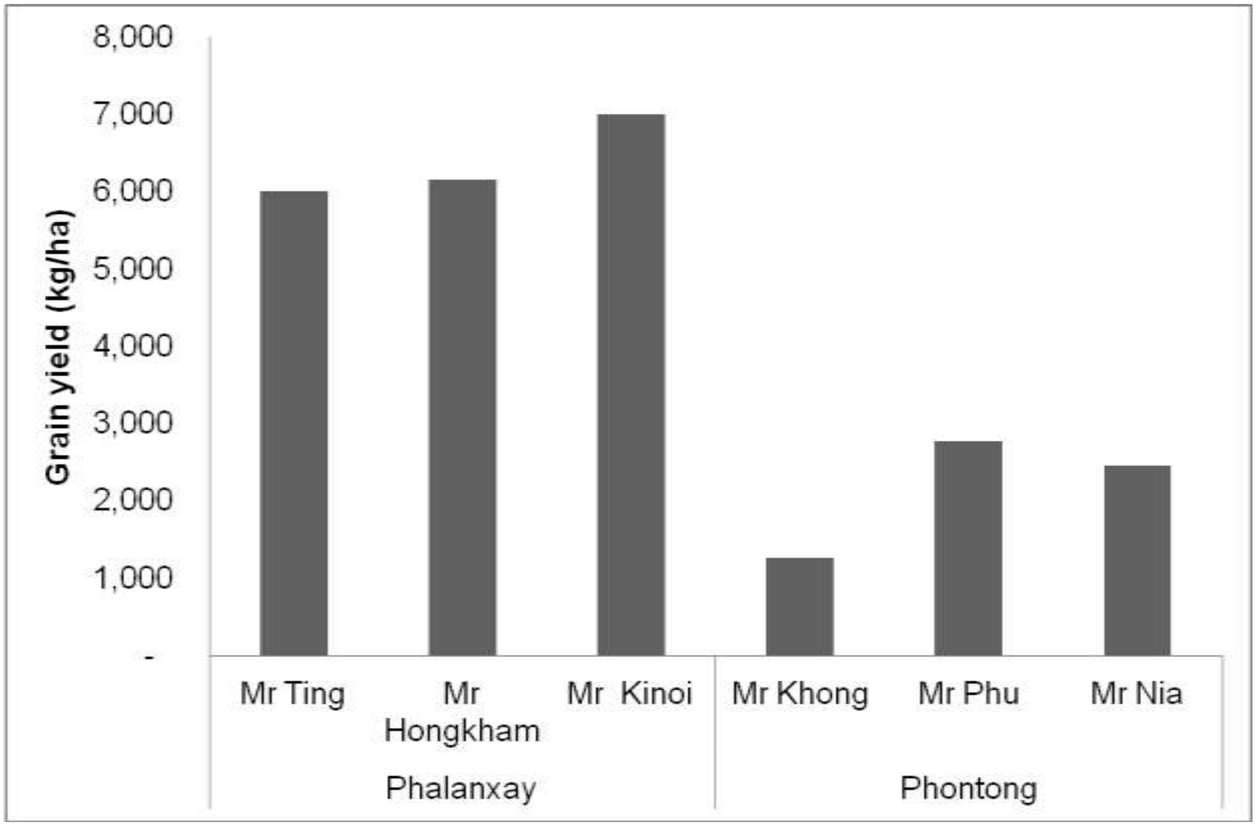

Figure 3 Peanut productivity for six farmers in dry season 2015

7.1.2 Forage and livestock management

Forage based systems

The project continued to test forages on-farm in wet season 2015 and dry season 2016. In total, 17 additional forage sites were initially established with farmers who have also implemented other project activities. The emphasis has been to work with farmers and evaluate options for including forages within their existing systems, rather than to assess biophysical performance of the forages per se. Establishment was good at all sites, in terms of land preparation, sowing and forage germination, demonstrating capacity of district staff to set up forage based systems. However, there were management problems at several of the sites, particularly in early management and utilisation of forage resources. For example, three farmers had inadequate fencing, and heavy grazing damaged plots. One farmer had planted forage in a paddy area far from his house, and subsequently returned it to rice production because fencing was difficult.

Despite this, systems change can be seen with several of the new farmers, and forages are being adapted in a way that suits their system. For example, Mr Nea in Ban Phaiykhong, Champhone district, has established a 1 ha plot of forages close to his free grazing area. He allows his cattle to graze this plot. In a separate area close to his rice paddy, he maintains two bulls with forages grown on the banks of his pond and urea treated rice straw, where he says his animals maintain weight and are also protected from theft.

Additionally, there are several farmers who were engaged with CSE/2009/004 who continue to produce and use forages, and are excellent examples of forage-based production systems in southern Laos. According to staff from the Livestock Research Centre at NAFRI, these farmers represent some of the best forage sites in southern Laos, and are comparable with early systems in the north, before more widespread adoption occurred. In the second part of the project, we will engage with several of these farmers for livestock production activities as part of local Innovation Platforms.

Ms Dok, Napokham Village, Phin district, Savannakhet

Ms Dok has an impressive area of forages, comprising around 2 ha of mixed grasses (Guinea, Ruzi, Paspalum, Napier, Mulato 2) and Stylo. She initially established her first plot in 2013 after seeing other farmers in the village testing forages as part of CSE/2009/004, and she has continued to expand her forage production area until now. Her current livestock production system includes an enclosed area for her 21 cattle and 7 buffalo. She cuts and carries forages to two separate areas for cattle and buffalo, and also feeds goats close to her house. Additionally, she utilises one large forage plot as a grazing area for selected animals that are in particularly poor condition (Figure 4). As well as forages, she has two large rice straw storage huts that store enough rice straw to last all year. Her system includes a water pump and well constructed troughs for feeding and water supplies. Her animals at the start of the wet season remain in good condition, as she has a continuous feed supply throughout the dry season. However, despite this impressive system, Ms Dok has not yet formulated a production plan per se; she says she content to accumulate more animals at this stage, and will sell only when she needs access to cash. Selling is not a problem as traders come to the village regularly to try and purchase animals. Because she has a secure feed supply and location, she is not under pressure to sell; indeed, in her own words she has “too much feed to be able to use it all”. The project will continue to work with Ms Dok as part of an Innovation Platform to support and promote cattle fattening systems in Phin district.

Figure 4 Forage based production system of Ms Dok, Napokham Village. Clockwise from top left: Forage grazing field for selected animals in poor condition; Ms Dok with her local DAFO livestock officer Ms Bangon, in her cut and carry forage field (stylo in front, guinea behind); Animals in good condition at the start of the wet season; Storage of rice straw.

Mr Su, Nakhilek Village, Outomphone district, Savannakhet

Mr Su began working with the CSE/2009/004 project in 2012. He has maintained the condition of his forages and expanded his area on his farm since then. He has a very distinct production system that is based on fattening and selling animals. At any one time, he purchases two animals for fattening; the price of these animals is between 2 - 2.5 million LAK (AUD $330 - $415). After purchase, he vaccinates and worms the animals, and then uses forages and crop residues to feed them for up to six months before selling them. He sells the animals for between

3.5 – 4 million LAK per animal (AUD $165 - $335), resulting in a profit of between 1.5 – 2 million LAK (AUD $165 - $335). He has been doing this for four years, and has invested some of the money back into his farming system, for example for enlarging his pond to allow for irrigation. He now irrigates forages and sweetcorn in the dry season, also using stover as a feed source at the recommendation of the project. This change has allowed more consistent dry season production of both crops and animals, resulting in improved household income.

Mr Khong and family, Done Jod Village, Phontong district, Champassak

Mr Khong has been working with CSE/2009/004 and CSE/2014/086 since 2011. In this time, he has tested many of the project's technologies including improved livestock production (forages, urea treated rice straw, crop residue use), post-rice production (maize, legumes, vegetables), rice varieties, Best Management Practices, dry direct seeding, and integrated duck-rice and fish-rice production. His farm is an excellent example of an integrated system, where he tests new technologies and adapts them in a way that fits within his farming system. For example, he has consistently made adjustments to forage production, changing and expanding locations (to closer to his house), planting on bunds and pond banks, and most recently converting a paddy area to a forage plantation, although this has since been returned to rice production. He is constantly modifying his farming system in response to new knowledge and techniques and market signals. Indeed, his farming system has changed so significantly that his daughter and son-in-law, who previously worked in Thailand, have now returned to work full time on the farm. His son-in-law said that previously in the dry season "there was nothing to do", but now they have diversified their system they are busy all year, and have options to generate income more often.

With regards to cattle production, the family now have two strategies; they have a herd that they maintain in a free grazing system, and they also buy and sell animals in a fattening system. They typically purchase animals and confine them for between three months and up to one year, feeding forages, crop residues, and urea-treated rice straw (Figure 5). Sale time depends on the prices offered, and they usually make a profit of between 0.5 – 2.5 million LAK (AUD $80 – $400). Before having forages, his animals were only free grazing, and they would only sell bull calves at around one year of age when they needed money. Now these animals can be fattened before selling, and the family can choose when they sell to take advantage of better prices; he makes more profit. Having a feed source has benefits in addition to higher profits; the family can target animals to fatten, such as those for sale or those pregnant or lactating, and it also helps with controlling his animals and keeping them secure.

Figure 5 Forage and livestock system belonging to Mr Khong and his family in Done Jod Village, Phontong. Clockwise from top left: Forages planted on bunds close to the house; Newly expanded forage plot; Mr Khong's son-in-law has returned from Thailand to work full time on the farm; Fattening animals with urea-treated rice straw, in addition to forages.

Urea treated rice straw

The project has trained farmers in the use of urea-treated rice straw (UTRS) to improve quality of rice straw, the most abundant feed source in the dry season. Farmers were provided with an initial bag of urea (50 kg), which is enough to treat one ton of straw, and also a cement tank to prepare the mixture. Four farmers tested UTRS in three villages. Generally UTRS is used as a feed resource in the dry season when alternative options are scarce, however some farmers in Champhone district also use UTRS in the wet season, when their grazing area is limited. Farmers use UTRS to maintain weight in the wet and dry seasons, and some have reported weight gains even in the dry season. Two farmers regularly use UTRS to fatten and sell cattle and buffalo. The farmers who have started to use this technique regularly have recognised that it does not just solve a problem (i.e. feed availability), but also improves production. Additionally, animals are reportedly easier to control as they are more willing to return to the farm from free-grazing.

The role of crop residues for fodder in crop-livestock systems in southern Lao PDR for improved resilience to climate change

Increasingly challenging climatic conditions are exacerbating existing agricultural production and management difficulties in southern Lao People's Democratic Republic. Farmers in Savannakhet and Champassak provinces have limited capital (natural resources, labour and finances) and therefore, the efficient and sustainable use of their resources is vital. Integrated crop-livestock systems comprise a multitude of components, and interact in complex and interdependent ways. There is marked complementarity in resource use, with outputs from one sector being supplied to others. Crop residues form one component of these systems, providing essential livestock fodder. Enhancing synergies between system components through optimal use of capital has many advantages for smallholder farmers. Crop residues for fodder add value to the system as a whole, and contribute to beneficial flow-on effects in the form of environmental conservation, labour efficiency and financial security. Critical analysis and discussion on the value of crop residues for fodder in integrated crop-livestock systems is explicitly justified by a strong foundation in relevant and creditable theory and examples. This gives weight to the argument of the role residues play in optimising system synergies resulting in improved climate change resilience, and therefore warranting further research on this topic.

This topic was explored within the MSc thesis of Ms Anika Molesworth, based on literature reviews and surveys of farmers and agricultural officers in southern Laos. The full thesis is available at the following link: http://laofab.org/document/view/2904.

Integrating ducks and fish into dry direct seeding

Several trials were conducted to evaluate integrating fish and ducks into direct seeded rice. Initially, this was done as a 'proof of concept' to see if this approach fitted into the farming system. Subsequently, more intensive weed and nutrient management trials were conducted (see Section 7.1.3).

In wet season 2015, eight farmers were each provided with 100 2-day-old ducklings. Ducks were purchased from Vietnam and were a cross-breed, suitable for both meat and egg production. Nets were provided to confine the ducks in one area of paddy that had been direct seeded (around 0.5 ha in total). The stocking rate was set at 200 ducks/ha. Despite varying mortality rates due to cold temperatures, animal attack and flash flooding, all farmers had at least 65% of their ducks left by the time crop flowering necessitated the removal of the ducks from the paddy. Ducks remained in the paddy on average around 60 days and after rice harvest they use duck to collect the falling grain in the field. Farmers responded enthusiastically to this trial, observing that weed control was good in paddies containing ducks (with no additional weeding required), in addition to being able to make a profit selling ducks and eggs (Table 4). Eggs were sold opportunistically, and one farmer reported getting 1,000 LAK (AU$0.17) per egg. Most farmers sold the majority of their animals but kept a core flock for breeding in the future. Profit ranged from 320,000 LAK to 3.2 million LAK (AU$53 - $567), depending on the amount of additional feed supplied during the production time. Where the natural feed availability was high (weeds, insects, snails etc), there was no need for additional feed, which increased profits. The average income was 1.8 million LAK (AU$293) after a production period of around four months. Farmers' observations were that this integration fitted into their farming system well, giving an alternative income stream while also contributing to weed control. It was important for farmers to have a suitable area for duck production, usually close to their house or field hut. One farmer reported theft of his net and could not contain his ducks. Apart from suitability of location, other potential barriers to adoption include availability of ducklings at key times in the season, up-front investment costs (around 1 million LAK (AU$166), and labour availability to manage the ducks (although this is minimal). Following positive responses to this trial from farmers in wet season 2015, in wet season 2016 these trials were repeated to quantify effect on weed control and crop productivity, reported in Section 7.1.3.

As was the case with including ducks in direct seeded rice production, fish were also successfully integrated into direct seeded rice paddies; this is common practice in some parts of Laos. Farmers were provided with around 600 fingerlings, with a recommended area of $4m^2$ per fingerling. The fish were put into direct seeded rice paddies with suitable water depth to maintain the fish during the wet season, and farmers also advised to dig a small pond in each paddy (1.5 x 2 x 0.8 m^2) to ensure fish had adequate water depth even where paddy water level dropped. Species provided included Common Carp (*Cyprinus carpio*) (around 120 fingerlings), Silver Barb (*Barbonymus gonionotus* (Pa Pak Kom)) (around 400 fingerlings), and Tilapia (around 80 fingerlings). One farmer also added a native species, Pa Khao Man (around 30 fingerlings). Fish were kept in the paddy for about 93 days, and then a sample weighed to calculate productivity. Fish weight ranged from 40 grams to 250 grams for common carp and silver barb. Pa Khao Man grew to around 1.0 kg per fish. Farmers used virtually no labour or other inputs for fish production, apart from one farmer who fed some rice bran (120,000 LAK). Potential net income ranged from 270,000 LAK to 3.1 million LAK. Aside from an income source, the other benefit of this production system lies in the contribution to household food security.

Table 4 Costs and income from raising ducks in direct seeded rice paddies for selected farmers in Savannakhet province.

Details				Costs						Income				Profit		
District	**Year**	**Farmer**	**Survival rate***	**Ducklings**	**Net (average for three years)**	**Additional feed costs**	**Labour**	**Vacc.**	**Total costs**	**Average sale weight (kg)**	**Price per kg**	**Price per duck**	**Gross income**	**Net income (LAK)**	**Income AUD per 0.5 ha**	**Income AUD per ha**
Phin	2015	Viengxay	66%	800,000	166,667	1,200,000	535,417	50,000	2,752,083	1.5	24,000	36,000	2,376,000	-376,083	-62.68	-125.3611
Phalanxay	2015	Phetsamai	95%	800,000	166,667	-	535,417	50,000	1,552,083	1.6	28,000	44,800	4,256,000	2,703,917	450.65	901.31
Champhone	2015	Nei	95%	800,000	166,667	600,000	535,417	50,000	2,152,083	2.2	15,909	35,000	3,325,000	1,172,917	195.49	390.97
Champhone	2015	Silei	75%	800,000	166,667	320,000	535,417	50,000	1,872,083	1.5	23,333	35,000	2,625,000	752,917	125.49	250.97
Champhone	2016	Silei	98%	400,000	166,667	918,000	535,417	40,000	2,060,083	2.0	18,000	36,000	2,808,000	747,917	124.65	311.63
Champhone	2016	Nei	93%	400,000	166,667	1,230,000	535,417	40,000	2,372,083	1.6	22,436	35,000	2,590,000	217,917	36.32	90.80
Champhone	2016	Sombun	94%	400,000	166,667	1,465,000	535,417	40,000	2,607,083	1.9	18,421	35,000	2,625,000	17,917	2.99	7.47
Phin	2016	Viengxay	81%	400,000	166,667	1,000,000	535,417	40,000	2,142,083	1.3	26,923	35,000	2,275,000	132,917	22.15	55.38

7.1.3 Direct seeded rice

Comparison of productivity of DDS and broadcasting rice

In dry season 2015, three farmers in Champhone district tested drilled direct seeding against hand broadcasting as their crop establishment method. Each farm had three replicates, with a total of nine replications over three farms. Results indicate that mean grain yield for DDS (4,594 kg/ha ± 114.45) was significantly higher than for broadcasting (3,491 kg/ha ± 193.80) (Figure 6), ($F(1, 16) = 24.02$, $\boldsymbol{p} < .0005$). There was homogeneity of variances, as assessed by Levene's test for equality of variances ($\boldsymbol{p} = 0.356$). The yield advantage for drill seeded crops in comparison to broadcasting has been found to be true across Asia (Kumar and Ladha 2011). Compared to hand broadcasting, drilled DDS is known to save seeds and time, facilitate easier weeding between rows, and provide better crop establishment (Kumar and Ladha 2011). All of these factors influence grain yield, particularly the ability to manage weeds. Farmers who experience labour shortages will look for alternative options for crop establishment, and should be encouraged to test mechanised dry direct seeding to maintain rice productivity.

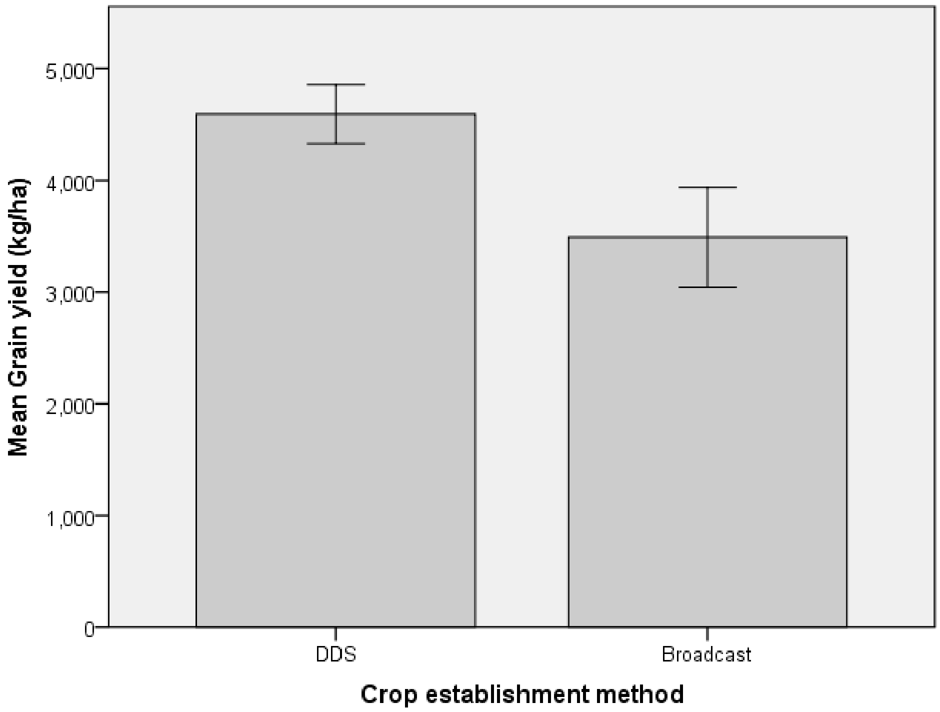

Figure 6 Mean grain yield comparison for crops established using DDS and broadcasting. Error bars represent 95% confidence intervals.

Nutrient and weed management trials

Mechanised dry direct seeding saves labour, allows earlier establishment of wet season rice crops, and also offers the option of managing fertiliser differently. Indeed, this is potentially a crucial step in farmers being able to maximise productivity and fertiliser use efficiency. In 2015-2016, two aspects of fertiliser management in DDS systems have been tested; timing of nitrogen application, and a nutrient omission trial to test the effect of omitting different macronutrients, and also different rates of basal P placed with the seed, on canopy cover and yield.

Effect of fertiliser rate and placement

Previous trials undertaken in CSE/2009/004 highlighted the importance of fertiliser management, as direct seeded rice experiences different conditions at crop establishment compared to transplanted rice. Importantly, this changes the availability of nutrients at key stages of crop development. Non-waterlogged conditions at crop establishment make Phosphorous (P) availability in particular very low (Ponnamperuma 1964; Fukai et al. 1998), all the more so given generally extremely low soil P levels in the acrisol soils of southern Lao PDR (Haefele et al. 2006). Previous trials over two seasons (dry and wet seasons 2014) used a direct seeder to place compound fertilizer (Nitrogen (N), P and Potassium (K)) with the seed to assess the effect on weed competitiveness and grain yield, as compared to broadcasting it about 14 days after seeding. In the dry season, drilling 70% of basal NPK with the seed increased ground cover at 45 days after seeding (DAS) by 73-155%, and increased grain yield by 38-73% (1.18-1.84 t/ha) compared with broadcasting basal NPK. Drilling 93% of basal P, but none of the basal K, added an additional 1.4 t/ha of grain yield, which suggested P was the nutrient most responsive to placement method. Reducing basal N, P and K rate by 30% and drilling all of it still almost doubled ground cover and increased grain yield by 38%, compared with broadcasting basal NPK at the full rate. In the following wet season, drilling 70% of basal NPK more than doubled ground cover at 35 DAS. Adding basal fertilizer with the rice seed greatly increased weed competitiveness and grain yield, and also allowed less basal fertilizer to be used whilst maintaining a higher yield than broadcasting basal fertilizer. But, by using compound fertilizers, these trials did not methodically investigate which nutrients gave the most response by placing them with the seed.

Based on these results, a subsequent nutrient omission trial was established in dry season 2015/16 to test the effect of omitting different macronutrients, and also different rates of basal P placed with the seed, on canopy cover and yield. This trial was conducted on one farm in Ban Alan Watana, Champhone district, in a mid-toposequence location. There were seven fertilizer treatments: a control of broadcast basal fertilizer, P, K and S omitted and three different rates of basal P (Table 5). There were four replicates, in a randomized complete block design. The experiment was dry season drill-seeded rice (*var TDK 8*). The field was ploughed and harrowed, then irrigated. The field was seeded with a 4-row National Seeder on a 4-wheel tractor, at a rate of 35 kg/ha, with fertilizer with the seed where required. After seeding, the field was irrigated and then drained immediately. The field was irrigated and drained again at 14 DAS (just after broadcasting the basal fertilizer), then standing water applied at 28 DAS. All plots were topdressed at 60 DAS. The aim was to quantify the effect of fertiliser placement with canopy cover after crop establishment (55 DAS), and to see if this correlated with yield and biomass at crop maturity.

Table 5 Fertiliser treatments for dry season trial, 2016

Treatment	Total basal fertilizer rate (N-P-K-S kg/ha)	Topdressed 46-0-0 @ 60 DAS	Total fertilizer application (N-P-K-S)
Control (basal fertilizer broadcast @ 14DAS)	30-30-30-11	60-0-0	90-30-30-11
P0	30-0-30-11	60-0-0	90-0-30-11
P10	30-10-30-11	60-0-0	90-10-30-11
P20	30-20-30-11	60-0-0	90-20-30-11
P30	30-30-30-11	60-0-0	90-30-30-11
K0	30-30-0-11	60-0-0	90-30-0-11
S0	30-30-30-0	60-0-0	90-30-30-0

The trial was established on 5th January, and almost immediately experienced low temperatures for approximately six weeks, including extreme low temperatures (range of 8 - 15°C) for around 5 days at 20 DAS. This delayed crop growth, although visual observations confirmed differences in crop growth patterns with fertiliser treatments (Figure 7). Canopy cover measurements were taken at 55 DAS using the Canopeo app (http://canopeoapp.com/) (Figure 7). Final yield measurements at crop maturity were planned in the initial methodology. Unfortunately due to extenuating circumstances the crop harvest yields were unable to be measured, and so no correlation between canopy cover at 55 DAS and yield was possible.

Figure 7 a) Measuring crop canopy cover at 55 DAS using the Canopeo App and b) A selection of treatments at 55 DAS, where visual observations confirm differences in canopy cover.

Canopy cover at 55 DAS (%) was significantly different under different fertiliser treatments, Welch's $F(6, 32.80) = 91.30$, $p<0.01$. P20 and K0 had the greatest canopy cover, followed by P30, then P10 and S0 (Figure 8). The canopy cover for the control and P0 treatments was lower than all other fertilizer treatments, and there was no significant difference between these treatments (Table 6). Effectively, the control and P0 have the same P availability in the first 30 days, and so it is reasonable to expect that the difference in these results is not significant. The other interactions shown in Table 6 require further exploration to determine how these may be related to practical management factors.

However, without exception, the effect of some fertilizer with the seed (even low rates such as 10 kgP/ha) sees a significant increase in canopy cover at 55 DAS. This is unsurprising, give the low nutrient content of acrisol soils in southern Lao PDR, particularly for poorly-mobile nutrients such as P that are poorly available in a non-waterlogged soil.

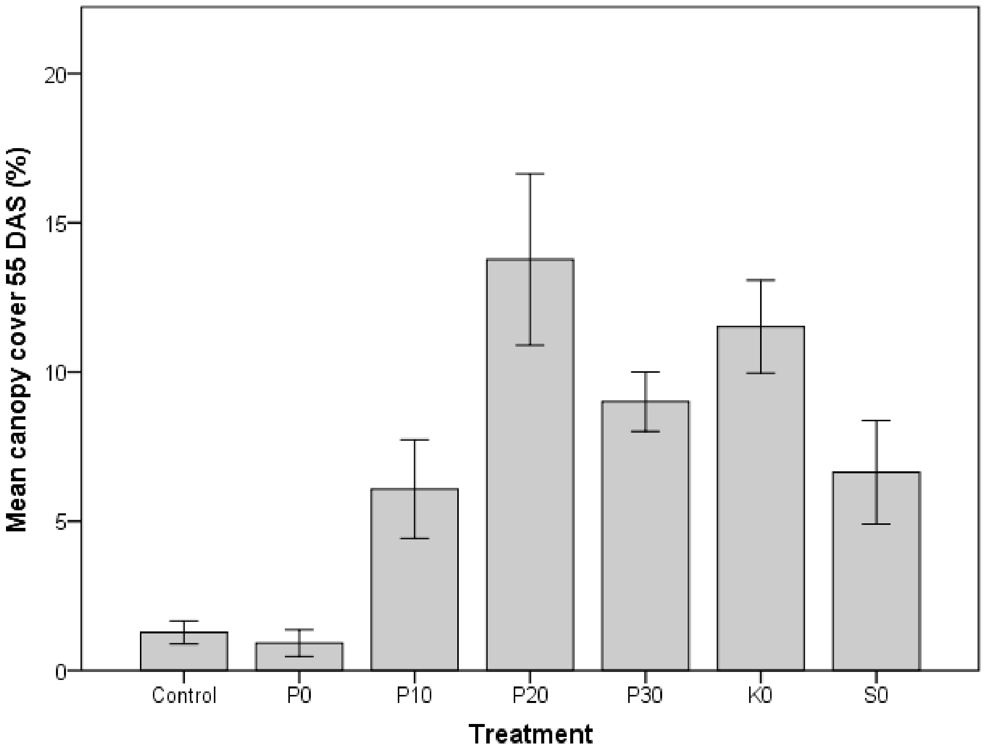

Figure 8 Mean canopy cover at 55DAS for different fertiliser treatments.

Table 6 Mean canopy cover at 55 DAS (%) for seven fertilizer treatments with four replications in Ban Alan Watana, Champhone district, Savannakhet, in dry season 2016.

Treatment	N	Mean	Std. Deviation	Non-significant range
Control	12	1.28	0.61	a
P0	12	0.92	0.70	a
P10	12	6.08	2.60	b
P20	12	13.77	4.52	c
P30	12	9.01	1.57	d e
K0	12	11.52	2.44	c d
S0	12	6.64	2.73	b e

Based on these results, it is reasonable to recommend that farmers apply fertilizer with the seed where possible — P fertilizer in particular — to increase early crop vigour and enhance weed competitiveness, and the response to even low rates seems quite large. In wet season 2016, dry direct seeding demonstration plots are being established, which will also incorporate trials of fertiliser applied with the seed compared to broadcasting. This will demonstrate the value to farmers of applying fertiliser with the seed, and also provide quantitative data for analysis. Further trials are necessary to determine optimal fertilizer rates, and to quantify the correlation between extent of early crop canopy cover and grain yield; these are planned for dry season 2017.

Weed control and fertilizer requirements for dry direct seeded rice in southern Lao PDR

In direct seeded conditions, emerging seedlings encounter greater challenges due to absence of ponded water, and its consequences for increased weed pressure and reduced nutrient availability. Consequently, two experiments were conducted on farms in Savannakhet and Champassak Provinces in southern Lao PDR to examine requirements for fertilizers, methods of weed control, and how they can enhance performance of dry direct seeded rice.

Experiment 1 comprised 5 nitrogen application treatments (N), and was conducted in 5 districts (D) in southern Lao PDR in 2015, with 5 farms per district. The districts were Champhone A, Champhone B, Phalanxay and Phin in Savannakhet Province, and Phonthong in Champassak Province (Table 1). Experiment 2 comprised 3 weed control x 3 fertilizer treatments in a factorial design, which was conducted in 4 farms in southern Lao PDR in 2016, and comprised two farms in Champhone A district, one farm in Champhone B district, and one farm in Phin district (Table 7). Characteristics of the five districts used in these dry direct seeding experiments are shown in Table 7, including soil analyses, timings of key events, and varieties sown. Each site received a broadcast basal dressing 15-15-15 N PK, before plots were direct sown.

In Experiment 1, the 5 nitrogen application treatments, which provided an additional 60 kg N ha^{-1} in treatments 2-5 over the basal application of 15 kg N ha^{-1} were: 1) Nil; 2) N applied at 20 days after emergence (DAE); 3) N applied in 2 splits at 45 and 65 DAE, 4) N applied in 3 splits at 30, 50 and 70 DAE, and 5) N applied in 3 splits at 20, 40 and 60 DAE. Plots were observed regularly and grain yields (t ha^{-1}) were obtained at maturity.

In Experiment 2, the 3 weed control treatments were 1) Unweeded, 2) Hand-weeded at 21 DAE, and 3) Ducklings introduced at 21 DAE. The 3 fertilizer treatments were: 1) farmer practice, 2) broadcast at 14 DAE; and 3) drilled with the seed at sowing.

Plant samples were cut at the soil surface at 21, 36 and 51 DAE, separated into rice and weeds, and dry mass (DM) (g m^{-2}) obtained for rice and weeds on each occasion. At maturity, a further dry mass sample of the rice only was obtained, separated into grain and straw, and harvest index was calculated. Grain yield (t ha^{-1}) was measured at maturity, and final DM of rice (t ha^{-1}) was calculated from grain yield and harvest index. Means were compared using l.s.d. with appropriate degrees of freedom for main effects and interactions ($P<0.05$).

Table 7 Characteristics of the five environments used in dry direct seeded rice experiments in southern Lao PDR in 2015 and 2016.

Province	District	Village	pH	Org. C	Total N	Avail. P	Exch. K	Toposeq.	Variety	Sowing	Flowering	Maturity
Savannakhet	Champhone A	Phaikhong	4.5	0.49	0.04	1.13	28.52	Mid	TDK8	06 Jun	19 Sep	06 Oct
Savannakhet	Champhone B	Allanvattana	4.4	0.64	0.06	5.12	39.16	High	TSN7	05 Jun	20 Sep	12 Oct
Savannakhet	Phalanxay	Phanomxay	5.1	0.50	0.12	4.79	15.03	Mid	TSN9	09 Jun	25 Sep	19 Oct
Savannakhet	Phin	Viengxay	4.1	0.16	0.05	1.28	10.97	High	TDK8	05 Jun	16 Sep	02 Oct
Champassak	Phonthong	Nasomvang	4.6	0.11	0.05	1.51	6.92	Mid	VT450-2	06 Jun	20 Sep	13 Oct

Experiment 1: All farms were direct sown in early June (Table 7). Grain yields in Phalanxay and Champhone B districts (2.30 t ha^{-1}) were much lower than in Champhone A, Phin and Phonthong districts (3.55 t ha^{-1}) (Table 8, Figure 9). On average, 2-3 split applications of N increased grain yield from 2.44 to 3.29 t ha^{-1}, while a single application of N at about 20 days increased grain yield to 2.85 t ha^{-1}, under the dry start encountered in the 2015 season. Although three splits of N increased yields significantly in Champhone B and especially in Phonthong, the response was simply to any split N application at Champhone A and Phin, while in Phalanxay district, there was no significant response to N application. The highest grain yields of 4.63 t ha^{-1} were attained in Phonthong district with split applications of N at 20, 40 and 60 days, or at 30, 50 and 70 days.

Table 8 Experiment 1: Rice grain yield (t ha-1) in 5 nitrogen treatments (N) x 5 districts (D) in southern Lao PDR in 2015. l.s.d. for D, N and DxN were 320, 305 and 715

N application	Champhone A	Champhone B	Phalanxay	Phin	Phonthong	*Mean*
Nil	2.76 c	1.72 d	2.26 d	2.93 c	2.44 d	*2.44*
At 20 days only	3.66 b	2.13 d	2.22 d	3.42 b	2.85 c	*2.85*
At 45 and 65 days	4.14 b	2.34 d	2.32 d	3.53 b	3.63 b	*3.17*
At 30, 50, 70 days	3.69 b	2.84 c	2.25 d	3.91 b	4.33 a	*3.37*
At 20, 40, 60 days	3.43 b	2.75 c	2.15 d	3.63 b	4.93 a	*3.33*
Mean	*3.53*	*2.36*	*2.24*	*3.48*	*3.64*	*3.03*

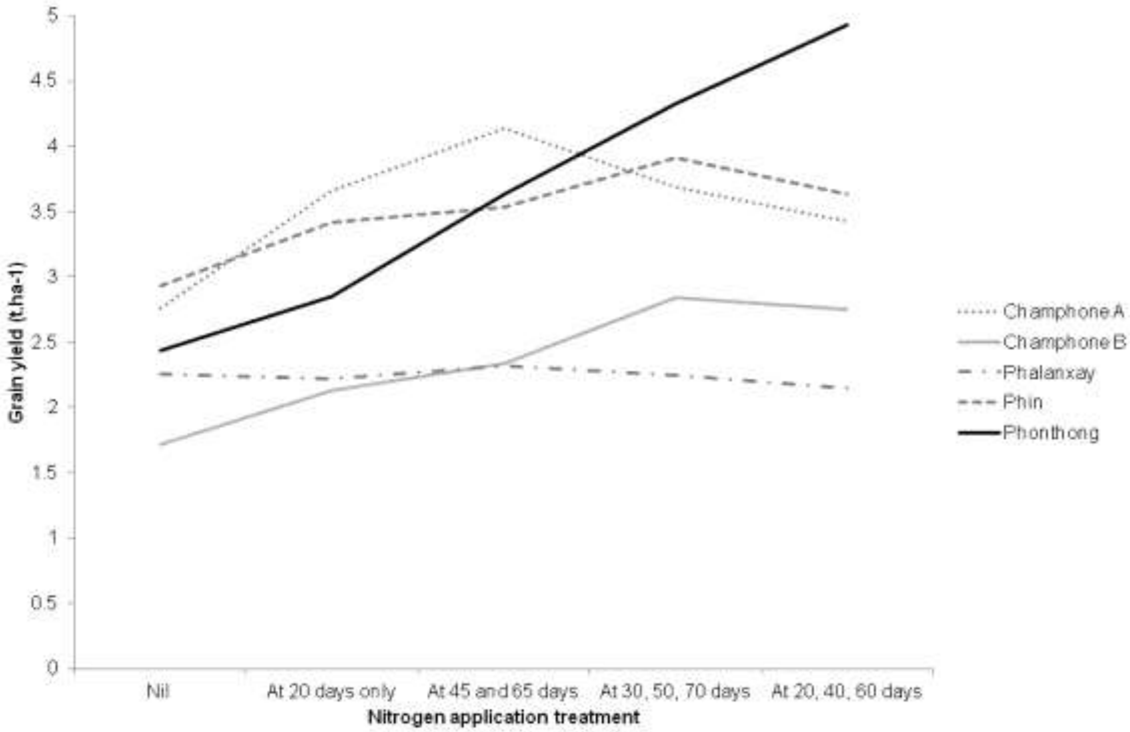

Figure 9 Grain yield (t.ha^{-1}) for different N application treatments.

Experiment 2: Weed DM in unweeded greatly exceeded hand-weeded and duck by 51 days after emergence (DAE), with the difference greater in Phin and Phaik 2 (

Table 9a, Figure 10). While on average, districts did not differ, weed DM in unweeded at 51 days was four times that in hand-weeded and duck on average. Conversely, rice DM at 51 days was approximately the inverse of patterns in weed DM at the same stage. Rice DM was high in duck and hand-weeded, and in all weed treatments in Alan, while Phin had low rice DM and was unresponsive (Table 9b). As a result, Phin had low rice DM at 51 days on average, and duck exceeded unweeded, with hand-weeded intermediate. For grain yield (Table 9c), Alan yielded more than other districts on average, and duck yielded more than unweeded, with hand-weeded intermediate. Unweeded in Phaik 1 was lowest yielding, with duck in Alan the highest yielding.

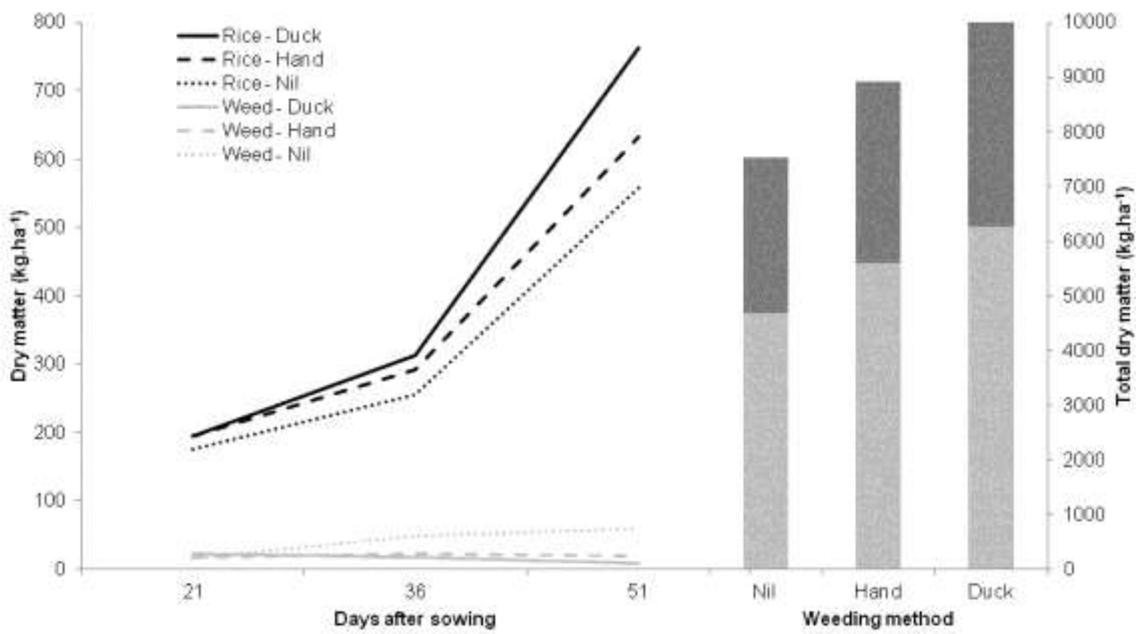

Figure 10 DM (kg.ha^{-1}) through time and at maturity for different weed control methods.

Table 9 DM of weeds and of rice at 51 days (kg ha^{-1}) and grain yield of rice at maturity, for 3 weed control treatments in 4 districts of S Laos in 2016.

a) Weed DM (kg ha^{-1}) at 51 days[a]

	Nil	Hand	Duck	Mean
Alan	43.2 bc	11.2 d	2.3 d	18.9
Phaik 1	41.3 bc	25.8 cd	19.2 cd	28.8
Phaik 2	66.9 ab	23.1 cd	9.1 d	33.0
Phin	84.2 a	17.3 cd	5.6 d	35.7
Mean	58.9	19.3	9.1	29.1

[a]l.s.d for district, weed and district x weed were 17.0, 14.7 and 29.4, respectively, at P = 0.05.

b) Rice DM (kg ha^{-1}) at 51 days[b]

	Nil	Hand	Duck	Mean
Alan	746 ab	886 a	1024 a	886
Phaik 1	545 b	698 b	996 a	746
Phaik 2	709 b	706 b	755 ab	724
Phin	230 c	239 c	272 c	247
Mean	557	632	762	651

[b]l.s.d for district, weed and district x weed were 177, 153 and 306, respectively, at P = 0.05.

c) Grain yield (t ha^{-1})[c]

	Nil	Hand	Duck	Mean
Alan	3.47 bc	3.63 ab	4.71 a	3.94
Phaik 1	2.45 c	2.80 bc	3.43 bc	2.90
Phaik 2	2.71 bc	3.47 bc	3.34 bc	3.17
Phin	2.75 bc	3.38 bc	3.63 ab	3.26
Mean	2.84	3.32	3.78	3.32

[c]l.s.d for district, weed and district x weed were 0.64, 0.55 and 1.11, respectively, at P = 0.05.

Drilling nutrients with the seed at sowing increased early rice growth, and split dressings gave higher yields. The weed control experiment clearly demonstrated the benefits of suppressing weeds early, resulting in improved rice growth and yield. Integrated management of nutrients and weeds can improve performance, profitability and reliability of dry direct seeded rice, with reduced risk.

7.1.4 Integrated scenarios

Within the project, several different techniques have been tested in on-farm trials, with the emphasis on their ability to fit with an integrated farming system. These techniques include mechanised dry direct seeded rice (DDS); ducks for weed control; improved cattle management using forages, high quality crop residues and treated rice straw; and post-rice crops (either fully or partially irrigated). Most of these options have been trialed and analysed at an individual level, or at most with an interaction between two enterprises (e.g. sweetcorn and residue use; ducks and rice productivity). This is a valid research approach for testing, refining and understanding individual activities, and to give confidence in recommending these technologies for different agro-ecological zones. However, in recognizing that smallholder farming systems are complex and usually mixed if not always well integrated, the next step is to consider the impact of these activities when applied within the same farming system. Indeed, there are several key project sites where farmers have implemented most of these options within their farming system, with corresponding benefits to their households.

Farming systems depend on access to resources, including land, water, labour and markets, and can be classified into different agro-ecological zones. The four zones identified across the project sites include the following:

1. Irrigated lowland
2. Supplementary irrigated lowland
3. Rainfed lowland
4. Transitional (households engage in both lowland and upland activities)

Table 10 shows the interaction between the options tested and their application in different agro-ecological zones. Most are suitable in all areas, with the exception of fully irrigated post-rice cropping activities.

Table 10 Potential to incorporate different integration options in different agro-ecological zones.

Integration option	**Agro-ecological zone**		
	Lowland irrigated	*Lowland rainfed*	*Transitional*
Baseline – transplanted wet season rice only	*	*	*
DDS	*	*	*
Ducks in DDS	*	*	*
Improved cattle management for	*	*	*

markets (based on forages, high quality crop residue, treated rice straw)			
Post rice (irrigated)	*		
Post rice (limited/no irrigation)	*	*	*

Baseline

In order to compare an integrated system, it is necessary to understand the baseline situation for the majority of farms within the project area. In Laos as in other developing countries, combined crop-livestock systems are the norm for the vast majority of smallholder farmers. In lowland regions of southern Laos, smallholder farmers typically focus on manual rainfed rice production in the wet season to secure household food security (Newby et al. 2013). Non-rice crops such as corn, peanuts and vegetables (e.g. cucumber, long bean, chilli, watermelon, salad vegetables) are grown in the dry season where water is available and household labour is adequate. The livestock portfolio typically consists of cattle, buffalo, pigs, chickens and ducks, and less commonly goats which are kept as capital (large livestock) and for home consumption (small livestock) or sale. Livestock production systems are mostly based on free-grazing for large portions of the year (Tiemann et al. 2014), with labour required to tend to animals as they are grazing, or to cut and carry forages to tethered animals. Thus, farming systems are complex, with farmers incorporating a diverse portfolio of on-farm, off-farm and non-farm activities within their livelihood strategy.

For the purposes of exploring integrated options, the baseline farming system is assumed to consist of manually transplanted rainfed lowland rice for household consumption, with the surplus sold for cash income. Additionally, cattle are sold throughout the year when cash is needed, and farmers have to take whatever price is offered to them; this baseline assumes the sale of one animal per year. Cattle management is based on extensive free grazing systems, using communal lands year round and rice stubble in the dry season. Home gardens and smaller livestock are assumed to be part of the system for the purposes of household food consumption, but not a major contributor to household incomes. According to Table 11, the annual cash income from this system ranges from $481 - $563/ha, assuming that 50% of rice is sold. In reality this varies with household size, yield and paddy area. In many cases farmers do not sell rice at all, or only sell if they require cash throughout the year.

Options for improving integration: scenarios

Dry direct seeded rice

Under this scenario, the wet season rice crop is established using DDS, and half of the rice is sold. DDS does not always improve yields or profitability compared to transplanting (Table 11), although survey results indicated that around 60% of farmers report either no change or increased yields for DDS in comparison to transplanting. With timely management, good seed quality and weed control, there is therefore potential to increase yields using this technique. However, it does address an increasingly important constraint within the system in terms of labour; on average, labour is reduced by almost 30%, from 58 days/ha to 43 days/hectare. Labour availability is a key constraint in southern Lao farming systems, and integrated systems can reduce and spread labour requirements throughout the year. Anecdotally, this has been a factor in attracting young people to return to the family farm within the project operating area, in terms of having farming enterprises that spread labour, risk and income distributions throughout the year. Additional benefits include being able to establish the crop using early season rainfall, as well as improved fertilizer use efficiency. Drilling nutrients with the seed at sowing increases early rice growth, and split dressings give higher yields (described in Section 7.1.3).

Dry direct seeded rice with ducks for weed management

Weeds are a serious problem in DDS systems, as farmers normally rely on standing water for weed control, and their management is thus an important factor for success. There is a general desire in southern Laos not to use chemical weed management techniques, as well as a lack of access to good quality, safe chemical options. With no other options, labour saved in crop establishment can quickly be transferred instead to hand weeding, thus losing the important labour saving benefits of the technique. On-farm trials of ducks kept in the paddy have yielded positive results in terms of duck growth rates, weed control and rice crop yield (Section 7.1.2). The weed control experiment comparing no control, hand weeding and ducks clearly demonstrated the benefits of suppressing weeds early, resulting in improved rice growth and yield. On average, ducks resulted in a 33% increase in yield compared to no weeding, and 14% more than hand weeding. Integrated management of nutrients and weeds can improve performance, profitability and reliability of dry direct seeded rice, with reduced risk.

With ducks, weeds are controlled from approximately 40 days after emergence, until seed set. Farmers reported no need for additional hand weeding in these trials. Ducks can be sold to market or consumed to improve household food security. In practice, farming households had around 0.5 ha dedicated to ducks (100 ducks) which was manageable from a labour and cash investment perspective. In comparison to hand weeding the same area, ducks saved an average of ten days of hand weeding, with a range of 2 – 21 days depending on the incidence of weeds in the plot. Hand weeding impacts mainly on women’s and children’s time availability.

Table 11 shows the profitability of ducks in the DDS system as ranging between -$35 - $325/ha (note that this only refers to the benefit of the ducks themselves, not labour savings from a reduction in weed management or increased yields). This figure is affected by many variables – i.e. survival and growth rates of the ducks, feed availability, amount of supplementary feed required, sale price etc. When managed well, a higher benefit is possible. It is worth noting that of the eight trial sites over two seasons, only one farmer had negative returns, and none of the farmers had problems with marketing their animals. Additionally, in order to compare with other enterprises, the cost of labour is included in the gross margin. In this instance, ducks fit well with the farming system in terms of time management (i.e. only 30 minutes per day once the fence and hut has been constructed), and there are additional benefits in terms of weed control (no need to hand weed), improved rice yields (fertility and pest control), and impacts on household food security and nutrition.

Forage based cattle marketing systems

Within the current and previous projects, a range of different forage species have been tested both on-station and on-farm, to explore their productivity, and their ability to fit within the farming system. On-farm trials have included a mix of *Panicum maximum* cv. Simuang, *Brachiaria spp (Mulato), Paspalum atratum* and *Stylosanthes guianensis* cv CIAT184. Local results indicate that perennial grasses can produce an average of 10 t/ha with limited or no irrigation. Based on this rate of productivity, an area of 0.4 ha is needed to fatten two animals on a continuous basis if utilising 50% fresh forage in conjunction with rice straw and other crop residues. Several farmers have large areas of these forages, and some have a proven strategy to fatten and sell cattle on a regular basis. Forages are planted on one area of the farm permanently, and used in cut and carry systems, along with treated rice straw and other high quality residues when available. Two animals are fattened and maintained for sale every six months, which allows farmers to sell four animals per year. Importantly, having a reliable feed source allows farmers to be in a stronger position when interacting with the market; they can take advantage of the ability to sell animals when they are in good condition and prices are favorable; and essentially, can refuse to sell at a low price. This allows farmers to take advantage of improved production methods while also recognizing limits to land and labour availability, as well as cash resources for capital investments (e.g. fencing).

Under baseline conditions, farmers may sell only one animal per year when cash is required and animals are usually in poor condition. The animals sold would be taken from an existing herd. Under an improved system, the conservative additional benefit in terms of price received by farmers is 1,000,000 LAK (AUD$167) per animal, and farmers have more control in terms of having options to refuse sale, and wait for a better price. Animals are also in better condition, and are in the targeted age range preferred by the market (2-3 years). In this system they purchase, fatten and sell four animals per year, so the additional benefit into the system is the higher price for one animal, plus an extra three animals sold at a higher price; this comes to an average of $1,091 per year (Table 11). Profits would be higher if the animals for fattening were taken from an existing herd, rather than purchased.

Post rice cropping systems

Fully irrigated

Under this scenario, and where full irrigation is assured for the dry season, post-rice crops such as maize are established to target the market; the first priority is cash income from cob sales, with stover for animal feed as a secondary benefit. On-farm trials showed a wide range of yields (i.e. 2 – 28 t/ha) and prices (500 – 2,000 LAK/kg) experienced in different locations and different seasons. Table 11 shows that the average return is AUD$205/ha, but variations in average yield and price experienced across project sites impacted on returns, with a potential range from -$505 - $2,437/ha. This shows the importance of good management, seed quality, an assured water supply and market prices all interacting to influence profitability. Additionally, this is a significant source of labour requirement in the dry season (73 days/ha). In reality, it is rare for farmers to plant 1 ha of maize, with area dependent on water and labour availability; but an area of around 0.5 ha is more likely and better able to be managed with available labour.

In addition to cash sales of fresh cobs, crop residue is also an important benefit from post-rice cropping, providing a source of higher quality feed in the dry season at a critical time of feed shortage. More details are found in Section 7.1.1. This residue can contribute to a cattle fattening system as described above.

Partial irrigation

In this scenario, post-rice crops are established immediately after the wet season rice crop to take advantage of residual moisture or availability of low rates of irrigation. Short duration legume crops can be targeted, which also benefit soil nutrition. Mungbeans with a maturity period of around 60 days were trialed in two locations; this fits within the existing system, depending on water and labour availability, and could even fit between an early maturing rice crop (such as sown with DDS) and a subsequent cash crop (e.g. maize), depending on labour and water availability. Yield and profitability of mungbean was shown to be adequate, ranging between 0.5 – 1.0 t/ha, and generating income of AU$1,169 - $2,539/ha. However, this relies on access to quality seed and markets if this practice were to be adopted on a wider scale.

Although potential returns and labour requirements are similar for partially and fully irrigated post-rice options, in reality these play a different role in the farming system, in terms of their time of application and market links. Selection is dependent on access to management information (i.e. awareness of short duration varieties), seed inputs, and market options; and under the current situation, there is more demand for crops such as maize in comparison to short duration legumes.

Table 11 Options for integration, including productivity, profitability and labour requirements for different parts of the farming system[2]

Agro-eco zone	Farming system	Activity	Productivity (t/ha)	Profitability (AUD $/ha or $/year)	Labour requirements (days/ha or days/year)
Lowland irrigated (e.g. Champhone, Savannakhet)	Baseline farming system	Transplanted wet season rice	2.90	$293.33	58
		Sell large livestock		$269.79	151
	Options for intensification	DDS	2.46	$282.83	43
		Ducks in DDS	0.32	$325.52	11
		Improved forages + cattle	n/a	$1,090.71	29
		Post rice (irrigated) e.g. Maize	9.232	$204.80	73
		Post rice (limited irrigation) e.g. Mungbeans	0.959	$2,539.17	55
Lowland rainfed - close to market (e.g. Champhone, Savannakhet; Phonthong, Champassak)	Baseline farming system	Transplanted wet season rice	2.90	$293.33	58
		Sell large livestock		$269.79	151
	Options for intensification	DDS	2.46	$282.83	43
		Ducks in DDS	0.32	$325.52	11
		Improved forages + cattle	n/a	$1,090.71	29
		Post rice (limited/no irrigation)	0.548	$1,169.17	55
Lowland rainfed - far from market (e.g. Phalanxai district, Savannakhet)	Baseline farming system	Transplanted wet season rice	3.10	$211.67	58
		Sell large livestock		$269.79	151
	Options for intensification	DDS	2.66	$223.17	43
		Ducks in DDS	0.30	$325.52	11
		Improved forages + cattle	n/a	$1,090.71	29
		Post rice (limited/no irrigation)	0.548	$1,169.17	55
Transitional (e.g. Phin	Baseline farming	Transplanted wet season rice	3.31	$278.17	58

[2] *Productivity and profitability calculated using outputs from on-farm trials under SLP and CLSP. Where figures differ between agro-ecological zone, this reflects different responses from the trials within those zones.*

district, Savannakhet)	system	Sell large livestock		$269.79	151
	Options for intensification	DDS	3.75	$568.33	43
		Ducks in DDS	0.19	-$34.99	11
		Improved forages + cattle	n/a	$1,090.71	29
		Post rice (limited/no irrigation)	0.548	$1,169.17	55

Integration of activities

The benefits (profit) and labour requirements for each enterprise tested as options for integration have been presented here. In Table 12, the impacts on profitability and labour requirement impacts of adopting these technologies in sequence, as part of an integrated system, are presented. This shows that profits can be improved by almost 300% while labour actually reduced by 45 - 55%. Additionally, in an integrated system, labour is spread more evenly throughout the year (Figure 11 and Figure 12). Labour requirements are reduced under the proposed integrated scenarios, because the integrated scenario reduces the amount of labour required to take care of cattle, when particularly in the wet season there is a large labour requirement for herding animals to ensure they do not damage the wet season rice crop. For post-rice crops that can be used as an animal feed source, the labour that is used to manage these crops can off-set the labour required to tether or herd animals, and find feed in the dry season, which is often far from the household.

This reduction in labour within an integrated system is because there is a large labour requirement in herding cattle in the wet season in many areas, which is often not accounted for, and with cattle kept as an asset rather than as an enterprise, profits are not maximized. This labour is also required more in the wet season, at the same time as peak labour demand for rice production. Animal care in an improved system is easier as there is a defined feed source, and labour for herding during the wet season is reduced. Only having two animals at one time means that the area required for forages is 0.4 ha. These animals can also take advantage of crop residue which is often relatively good quality in the dry season, when other feed sources are limited. Manure from these animals can contribute to crop productivity in either the wet or dry seasons. Previous trials show that 5 t/ha of manure produces a yield increase of 48% compared to no fertilizer application (Wade et al. 1999), particularly on coarse textured, free draining soils of low fertility such as are common in southern Laos. Similarly, local trials within the project sites show an 11% increase in yield of maize for the same rate.

Direct seeded rice allows crops to be established earlier, taking advantage of early season rainfall. Thus crops can also mature earlier, leaving more residual soil moisture for a short season rice crop, also potentially allowing capture of late season rainfall. This may necessitate the ability to dry rice paddy, but in areas close to larger mills this is now becoming possible. Labour requirements are also greatly reduced using DDS, particularly early in the season; this allows labour (particularly of women and children) to be used for cut and carry forage systems, or other pursuits. Weeds can be problematic in DDS rice crops, but the use of ducks as a weed control technique has been demonstrated to be profitable (on average), and has low labour requirements in terms of the ducks themselves. It also eliminates the need to hand weed. Even if ducks are only feasible on part of the crop, it would also allow more labour to be dedicated to hand weeding the remaining rice crop. Additionally, trials found that use of ducks had a positive effect on yield.

Post rice crops can have a significant benefit on household income, and make use of land and water resources in the dry season. With limited water resources, a short duration legume crop can contribute to household income, increase food security, provide a high quality animal feed, and improve soil fertility. Thus there may be additional benefits on the yield of subsequent non-rice and rice crops.

With adequate irrigation, post-rice crops allow farmers to take advantage of market demands. As an example, maize can contribute to cash income and provide a large quantity of stover at a critical time of year in terms of feed availability. With a focus on improved cattle production, this feed quality would be more important than in a non-integrated system. Additionally, there is evidence to suggest that investments in fertilizer for a non-rice crop can potentially have a significant effect on the following rice crop, increasing yields by up to 46%. This investment in the dry season (if water is available) is less risky than for a wet season rice crop, and so is a safer investment for farmers.

Table 12 Integrated options for a typical 2 ha farm. Baseline farming system assumes 2 ha transplanted wet season rice, and sale of one animal per year when cash is required. Integrated farming system assumes 1.6 ha DDS wet season rice, 0.5 ha ducks on rice, 0.4 ha forages, 0.25 ha mungbean, 0.5 ha maize and sale of four cattle in good condition.

Agro-eco zone	Farming system	Profitability (AUD$/year)	Labour requirements (days/year)
Lowland irrigated (e.g. Champhone, Savannakhet)	Baseline	$563.13	267
	Integrated	$2,216.93	152
Lowland rainfed - close to market (e.g. Champhone, Savannakhet; Phonthong, Champassak)	Baseline	$563.13	267
	Integrated	$1772. 03	122
Lowland rainfed - far from market (e.g. Phalanxai district, Savannakhet)	Baseline	$481.46	267
	Integrated	$1,724.30	122
Transitional (e.g. Phin district, Savannakhet)	Baseline	$547.96	267
	Integrated	$1,820.18	122

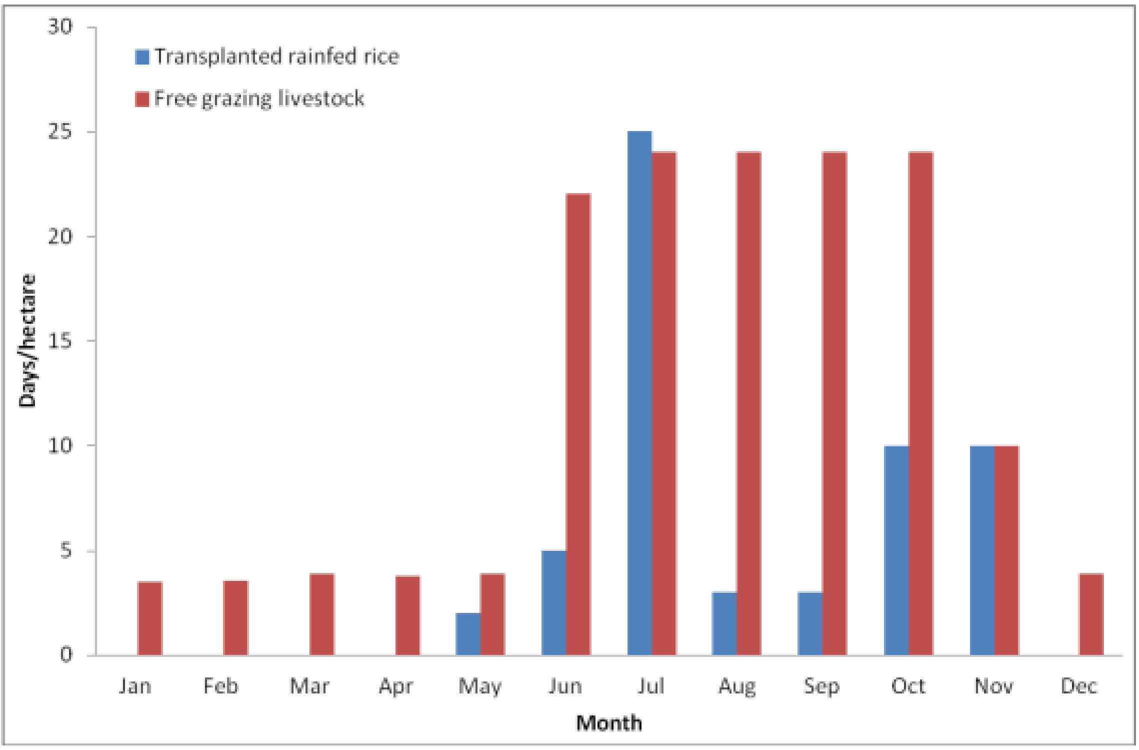

Figure 11 Baseline labour requirements across the year.

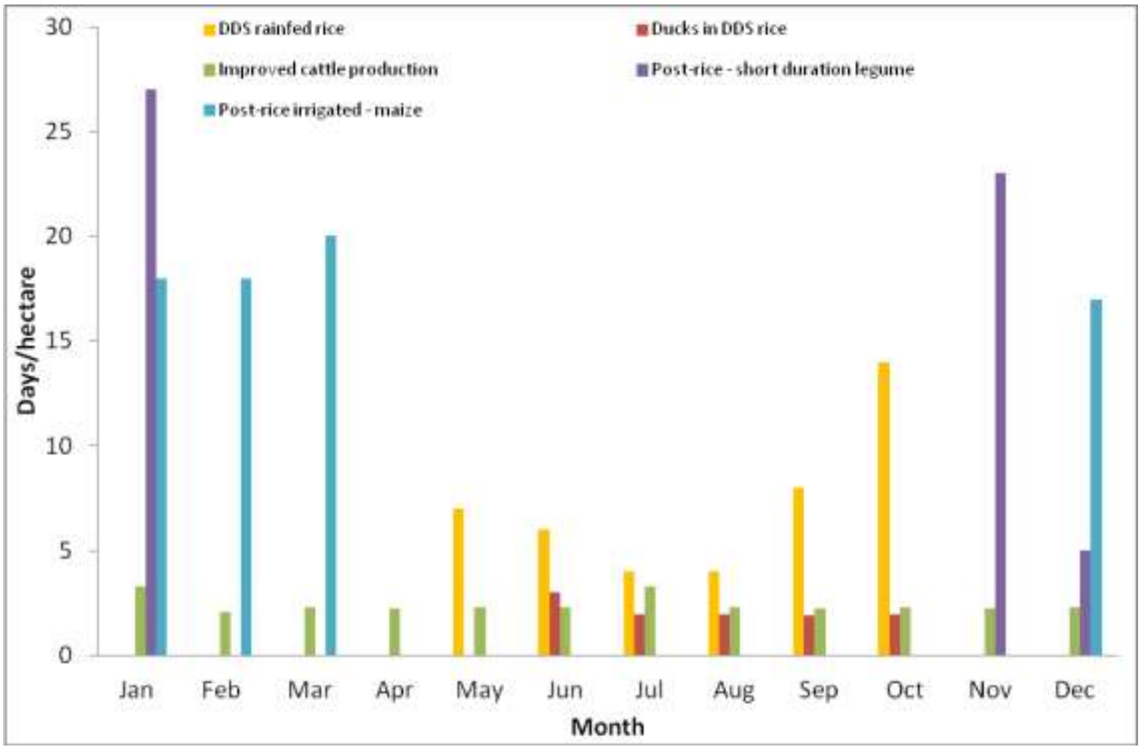

Figure 12 Labour requirements for an integrated farming system across the year.

It is clear that there are many different options available to farming households in southern Laos to intensify and integrate within their system, which have been proven at the local level and tested as integrated systems by farmers. Productivity and profitability can be increased, in some cases by up to 300%, and food security enhanced, while labour and risk are spread throughout the year. Labour can actually be reduced significantly if time intensive practices are replaced by more labour efficient options, for example mechanised dry direct seeding of rice, or cut and carry fattening systems for large livestock. In reality, farmers do not always optimize their farming systems for cash income, and each farming system will depend on available resources and household priorities. The integrated systems here provide a proven framework for improving productivity, profitability and resilience in southern Laos, and a sound base from which to build further research.

7.1.5 Summary

The on-farm research trials described in this Section have helped to refine selected integrated crop-livestock technologies relevant for southern Lao systems. These trials have been influenced by feedback from various stakeholders and systems thinking approaches undertaken in the project, which have informed research questions selected and the implementation of the trials. Additionally, the potential benefits of adopting these technologies as part of an integrated system in terms of profitability and labour requirements have been demonstrated, showing that profits can be improved by up to 250% while labour actually reduced by 30-40% and spread throughout the year. The role of these technologies within the wider agricultural system, in terms of making links and connections, is explored in greater detail in the following sections, with implications for adoption and adaptation by farming households.

7.2 Objective 2: Assessment of the potential effectiveness of selected systems approaches to crop-livestock integration

Objective two focuses on ‘Assessment of the potential effectiveness of selected systems approaches to crop-livestock integration’. The key activities include a literature review summarising alternative systems approaches to integrated agricultural research, a study to understand the adoption and adaptation of Dry Direct Seeding using an Innovation Systems approach, and capacity building for project members in using systems approaches. The remaining summary of priorities for further systems research in southern Laos will be included following group discussion prior to the final project meeting.

7.2.1 Systems workshops with local and international experts

Activity 2.1 relates to systems workshops with local and international experts, to identify promising opportunities and build capacity in systems thinking. The initial four months of this project were conducted in conjunction with the final stage of CSE/2009/004. This period incorporated a series of systems workshops for synthesis of technology materials, and introduced tools for exploring and understanding farming systems and linking with stakeholders. Workshop 1 focused on identification of crop and livestock technologies that were tested within the project, and that project staff felt were sufficiently ready for outscaling. Extension materials were prepared that incorporated project experiences and data, for materials that are contextually relevant for farming systems in southern Laos. Focus group discussions were held with farmers to consider their perspectives on crop and livestock integration, to look at their existing experiences and constraints, and to identify opportunities to strengthen these links. This feedback was presented in Workshop 2, and helps to incorporate the ‘demand side’ perspective of farmers in relation to crop-livestock links. Workshop 2 convened local and international experts to present aspects of farming systems research, and let the project team explore project technologies in the context of existing farming systems, using integrative enquiry approaches to identify constraints and opportunities based on prior experience, project results, and wider scientific inputs. This period gave project staff an opportunity to consider the potential benefits of engaging with a range of stakeholders to address farming systems constraints using an Innovation Platform approach. Workshop 3 allowed communication of project outputs to a range of provincial stakeholders, and exploration of options for working together to address system constraints for mutual benefit. These activities are reported in more detail in the CSE/2009/004 Annual Report, available at http://aciar.gov.au/publication/fr2016-04.

Training on implementing Innovation Platforms was initially held in Vientiane for project staff, as an introduction and as a ‘Train the Trainer’ session. Subsequently, the training materials were modified and translated into Lao for training at the provincial and district level. These training sessions are described in more detail in Section 7.3, as well as the project experiences with implementing the Innovation Platform process.

7.2.2 Alternate systems approaches

An overview of systems approaches to crop-livestock integration

Agricultural systems are complex in terms of their composition (biophysical, social, environmental and market components) and their involvement and effect on the population as a fundamental part of society. This complexity extends to the challenging conditions facing the agricultural sector as populations increase, the climate becomes more variable, and environmental health more vulnerable. Research and development approaches must reflect and adapt to this complexity to be able to address it. Systems approaches and frameworks for agricultural development encompass a school of thought that spans a wide range of theories and methods; many of these share a number of key elements, but differ in application and utilization. Agricultural Innovation Systems (AIS) approaches are highly applicable as they take an outcome based approach, recognizing that a broad range of actors and sectors are involved in making change happen, and that the attitudes and practices of these actors, their relationships, and the operating/enabling environment all influence these relationships.

The diverse nature of the agricultural sector is reflected by the variety of systems approaches that are commonly used, including farming systems research, innovation systems, and market systems development. Within these approaches are a range of tools for implementation, for example Innovation Platforms (IP), integrative enquiry, Public-Private Partnerships, Learning Alliances and Communities of Practice. Some of these have been used before in Laos, with success as well as recognized limitations. In reality, people involved in systems research use a range of tools and methods to understand their given system, select interventions, monitor progress, review results and communicate findings with others. Each situation is different, and so general principles are more useful than prescriptive approaches that do not cope well with diversity. This review focuses on common systems approaches and tools for implementation that can be used for more effective research and development, building on what has been previously successful both in Laos and elsewhere. It is concluded that the AIS approach and IP tools (among others) are likely to be useful in Laos, as they are mature enough to have amassed a wealth of knowledge and application in other places, build on what has been done before in the Lao context, and are also inclusive and adaptable for the Lao situation.

The full literature review is reported separately as *Systems approaches to research and development in the Lao PDR*.

7.2.3 Using the Innovation Systems approach to understand innovation in Dry Direct Seeding in Savannakhet

Study of farmer experiences and approaches with mechanised dry direct seeding in Savannakhet province - 2016

According to the literature and to prior experiences in Laos, the AIS approach seemed to fit the project's wider purpose of being able to enhance integrated crop-livestock systems research. The AIS framework was initially used to understand farmers' experiences with DDS in Savannakhet, and later to understand the wider environment, in order to draw lessons about innovation systems in Laos.

Mechanised dry direct seeding (DDS) is a crop establishment technique that reduces labour requirements, and offers flexibility in terms of earlier planting times. This technique has been tested for many years in southern Lao PDR, including more recently by several research and development projects concurrently in Savannakhet province, and there has been a trend of increasing adoption among farmers. In this province in the wet season of 2015, over 800 ha was planted using the DDS technique, in comparison to around 80 ha in the previous year. This rapid increase requires an understanding of the motivations, experiences and outcomes for farmers, in order to understand the innovation process, and to identify methods to support the uptake and outscaling of this technique.

This study focused on the experiences and perspectives of households who have either trialled or adopted DDS. These experiences are examined using an innovation systems framework, focusing on the actors within the DDS system and their relationships, their attitudes and practices, and the wider operating environment that has contributed to the uptake of DDS technology in Savannakhet.

The adoption of DDS has been driven by a combination of labour shortages and hence high labour costs, and the late onset of monsoon rains which delays traditional transplanting times. At the same time, several research and development projects have trialled and promoted the technique, and hence there is a level of experience and machinery available in some districts.

In addition to the clear triggers for adoption of the DDS technique, the survey revealed a range of actors at the village level, and very importantly, the interactions between actors in the wider farming systems, as well as in community and political systems at various levels. Activities undertaken in the districts (training and demonstration sites) provided initial interest for farmers; the importance of gender was highlighted with many women reluctant to implement the technique if they had not personally seen it. In particular, farmers who have more experience with the technique are becoming local resource persons, with their advice and services sought after by others. Contracting DDS services is a profitable business for some farmers, and allows more farmers to use the technique where access to machinery is limited. The results highlight the strong networks between farmers and within local communities, and the importance of providing farmers with opportunities to share experiences and contribute to the research agenda. Additionally, there were strong links between provincial and national organizations that were highlighted by the use of the innovation systems framework; these include DAFO and PAFO staff with close links to farms, and farmers who were also involved with organizations like the Lao National Front.

This study revealed a range of technical, social and mechanical issues that are important for further outscaling and support of this technique, and which have been raised by farmers themselves as they test and adapt the DDS technology within their lowland farming systems. Importantly, this is just one example of innovation, with lessons both for this technique and also for innovation more generally.

The full report can be found at http://www.laofab.org/document/view/2865.

Understanding innovation and adaptation of dry direct seeding using an Innovation Systems approach - 2017

Background

Dry direct seeding (DDS) is being rapidly adopted in Savannakhet province. During the past five years, the number of hectares of lowland rice planted using drill seeding has rapidly increased, along with the numbers of machines available. For example, area planted has increased from 80 hectares in 2014 to over 800 hectares in the 2015 wet season and over 15,000 ha in 2016. The ACIAR project (CSE-2014-086) has been initiated to investigate and trial systems approaches to integration and innovation in farming systems in southern Laos. This includes looking at the potential to establish innovation networks and to study existing innovation networks and processes and their effectiveness. This study is designed as part of this project, and is following the progress of drill seeding in the province.

In 2015 a qualitative innovation systems study of farmers in three districts, revealed a complex web of actors, roles and activities, attitudes and practices, interactions and enabling environmental conditions (Clarke et al. 2016). This study reinforced the importance of a complex systems approach to innovation, where there is a plethora of factors contributing to, or hindering, innovation and change. There is generally a lack of clear linear causal factors, with relationships between actors in the system (both human and non-human) being a key part of the system. In addition, each context is unique and requires continuous learning by research and development actors as well as an ongoing process of adaptation. Results clearly revealed the key drivers of this adoption to be labour shortage, a higher frequency of delayed onset of monsoon rains, and a critical mass of projects promoting the technique.

This study reinforced the need for a focus on the process of co-production of knowledge including researchers, policy makers, farmers and a range of other actors (human and non-human) for innovation in food systems, and the need for an adaptive approach for fostering and supporting an active and engaged innovation network.

There are a number of lessons here for the research and development community. Firstly, that every local system and situation is unique, physical, politically, socially and culturally. Secondly, that focusing on one set of factors is never sufficient, and thirdly, that timelines for change are long and require persistence and longer term commitment from donors. Those of us involved in development and research require humility and an adaptive, learning approach to each new context, which is supported by donor attitudes and processes. Importantly, there is a need to look beyond the single or multiple factors and to ensure that the strong networks and social interactions and relationships within and beyond farming communities are not underestimated and are fostered and supported.

Results from this initial study were presented at an Innovation Platform meeting in Savannakhet, where the group refined challenges and activities to support drill seeding. With many more farmers using the technology in the 2016 wet season, it is clear that several of the major challenges identified in the initial report and the IP are being addressed by different processes, and it is timely to investigate these to understand the patterns and impacts of innovation at the farm and wider scales. This may give clues as to why drill seeding is being adopted rapidly in Savannakhet and not other provinces, and to define appropriate policy and operational responses of relevant public and private agencies.

A follow up study was carried out in early 2017 to confirm the earlier results and to track ongoing progress with DDS implementation. The purpose of this study was to document further progress in adoption, gain further insights into the innovation process and provide ideas for possible further research and development activities to foster innovation and agricultural adaptation more generally.

These objectives subsequently frame two key research questions:

1. What kinds of challenges have been experienced, and how do these change with scale (field, household, village)? How have farmers adapted to solve these challenges?

2. What are the implications for further system change and adaptation within farming communities, and how should this shape future policy and research practices and processes.

Research approach

The analytical framework for the study was an Agricultural Innovation Systems (AIS) approach. This approach offers a way to analyse and identify options to address complex challenges in agricultural systems. Innovations (putting into practice new ways of doing something) emerge from systems or networks of actors, rather than (as often traditionally assumed) from individuals working alone (e.g. only research). The AIS approach recognizes that change comes from both technological (e.g. machines, varieties, inputs) and non-technological (organizational, institutional) approaches, occurs at different levels, and is influenced by interactions between different stakeholders (Schut et al. 2015). There are many sources of agricultural innovation; researchers, farmers, NGOs, development agencies, private companies and entrepreneurs, each of which has its own agenda(Hall et al. 2003). Thus, the experiences of farmers and other system stakeholders, and the interactions between them, are key steps towards understanding and supporting change.

The innovation systems framework offers a way of understanding and analysing any given system, focusing on the actors and their roles, the attitudes and practices of these actors, their relationships, and the operating/enabling environment that influences these relationships. The World Bank (2006) innovation systems framework considers four aspects of innovation systems, and the following are adapted from this source. More details are available in Clarke et al. (2016).

- Actors, the roles they play and the activities in which they are involved
- Attitudes and practices of the main actors
- Patterns of interaction between the main actors
- The enabling environment

This framework focuses on understanding the relationships between actors within the system, and the attitudes and practices that shape those relationships. This is useful because it allows the identification of patterns of innovation, and the elements which can support the innovation process; it is important however to note that innovation changes with location and context.

The research questions posed need several different methods to be used together to give the complete picture. In all data collection methods, the important components of Innovation Systems must be covered, i.e. who are the actors; what are their roles, attitudes and practices; how do they interact; and what are the supporting institutional norms that are enabling the innovation to occur?

Farmers (n=64) in five districts (five villages) who have used drill seeding were surveyed to understand their experiences and outcomes at the field and household level. This includes how they accessed machinery, information and capital, and who influenced them to test the technology. Additionally, a focus was on the challenges experienced, and what has been adapted to address these challenges.

Five focus group discussions were held in villages in five districts in Savannakhet. This limited sample of villages was chosen based on rapid adoption of DDS and to gain useful insights into further progress of innovation and highlight any emerging issues or developments. The focus group participants were given (but not limited to) four broad areas for discussion:

1. Descriptions of DDS adoption in the village
2. Their experiences with DDS
3. The challenges they faced in adoption
4. Any policy and/or operational issues they faced

Finally, system actors were interviewed to understand their involvement with drill seeding, where they heard about the technique, and the roles they have played in the system. System actors what happened in the previous season that was different to previous years, and investigate the ways in which these actors interact (e.g. DAFO, PAFO, machinery sellers, machinery manufacturer Champhone and Songkhone and others as emerge from the survey). For the interviews, the three overall guiding questions were

1. What was your experience with direct seeding technology?
2. What are the major challenges in supporting this technology?
3. What operational issues were encountered (e.g. payment issues, information, promotion etc)?

Results and discussion

The overall findings from this follow up study clearly indicate that the process of adoption and adaptation to DDS is continuing at a rapid rate, and to the satisfaction of farmers surveyed.

- Patterns of interaction

The focus group discussions support the finding from the previous study, that there are multiple communication pathways and channels for learning about DDS and gaining the necessary technical expertise. In particular, there is still significant knowledge exchange occurring between farmers, with farmers learning from each other and observing each others practices. Farmers also talked about attending field days and training sessions hosted by the PAFO and DAFO as a source of first introduction within all villages. Contract planting also plays a significant role.

Most farmers learned about DDS through seeing other farmers practicing in their village. This was the case for 63% of farmers surveyed. Of those who learned about the technique from external sources, the most important were projects, DAFO training sessions and PAFO. One farmer had been to Thailand to learn about the technique. The Thai connection is more important at the machinery dealer level; several machinery dealers interviewed indicated that they had learned about the machinery from a Thai company that they already had links with. Additionally, there was one local manufacturer in the districts who engaged Thai expertise, paying someone with experience to work with him in his workshop in the period that he was manufacturing machines.

Farmers were asked who the most influential person was in their decision to test the DDS technique. Not surprisingly, more than half of farmers named other farmers in their village as people who influenced their decision. The farmers themselves (25%) and their wives (16%) were also felt to have influenced decision making. More traditional sources of information like the Village Head and PAFO were ranked low in this exercise. This shows that while PAFO and/or people in authority can have an influence in raising awareness about new technology, the influences on people testing new techniques are more likely to be closer to home.

- Attitudes and practices

Labour savings are one of the main reasons given for farmers choosing to use the DDS technique. In this survey, labour savings were about 7.9 days per hectare, or about 30% compared to transplanting. Weeding time was almost double for DDS than transplanting, although it must be remembered that in 2016 weeds were a serious problem in both transplanted and direct seeded rice. Weeding methods that are less labour intensive than the widespread hand weeding can further improve labour savings, allowing household members to pursue other activities.

Most of the labour saved using DDS is for women (69%) who would otherwise be transplanting for many weeks or months at a time. Children and elder members of the household are the other people who save time (8%), often in combination with women (23%). The time women save when not transplanting is primarily devoted to housework (44%), or a combination of housework and other things such as vegetable production and livestock raising (39%). Off-farm income includes handicrafts, a shop and working in a rubber plantation. Children with more time go to school, or help with livestock raising.

In this survey, the average yield reported from DDS was 1.8 t/ha, compared to 2.04t/ha from traditional methods. The traditional method was generally transplanting, with only one farmer reporting broadcasting seed by hand. Impact on overall yield was reported to be variable, with 31% reporting no change, 28% an increase, and 42% a decrease.

In discussion groups, farmers generally said that they were happy with rice production with lower inputs and were happy to continue using the technique mainly due to the labour savings (and hence lower production costs). However, no one expressed interest in growing a bigger area of rice.

All farmers surveyed will use DDS in the following seasons. Although they reported problems with weeds and pests, and average yields were slightly lower in 2016, farmers cited labour savings (47%), timeliness of operations, improved productivity and low investment or a combination of these (44%) as the reasons to continue to use this method for crop establishment.

Weeds were the biggest problem faced by farmers in using the DDS technique, with 61% of farmers saying that they were the biggest problem, and a further 12% saying that they were a problem along with pest or disease. Pests were also found to be problematic (25%). Farmers also reported their problems with regard to transplanting; again, weeds were found to be the biggest problem (60% alone, and 20% with weeds and pests). However, 2016 was a particularly bad year for weeds due to rainfall patterns, with an extended mid-season drought. Thus, weeds were a problem in rice in general, and their incidence was less dependent on the establishment method than might normally be the case.

There was significant discussion amongst the focus group participants about management practices for DDS. The predominant topic discussed was again regarding weed control, though opinions on this were varied. Most of the farmers regarded weeds as an ongoing challenge, with or without DDS, with some giving the opinion that weeds were better or worse with DDS. They also talked about water management, though it was agreed that this was a general issue given the reliance on rainfed rice production.

Other points for discussion included:

- The possibility of larger paddies to make planting more efficient
- Managing seed planting depth
- Finding appropriate rice varieties for the toposequence
- Appropriate land preparation to optimise DDS (including dealing with issues of very dry and hard soil)
- The need for more available technical information
- Fertiliser application – for example applying basal fertiliser with the seed (though none of the planters have fertiliser boxes)
- Issues with planting into straw mulch

One of the anticipated challenges with DDS is that with earlier planting likely (as it can be planted prior to rain) there are potential issues regarding moving grazing animals off the paddy earlier in the season. Focus group participants were asked about this in each village. There did not appear to be much concern about this nor had rules regarding animal grazing appear to have changed. Two groups reported that the Nai Ban (village chief) now announces on the village PA that drill planting has started to warn villagers to keep animals away from the paddy, thereby in effect just shifting confining of animals to earlier in the season.

One representative of a miller was interviewed, but did not seem to be aware of the increase in planting using drill seeding in Savannakhet. His main concern was increasing rice supply and quality as they focus mostly on export. The mill has its own seed bank and seed production system to supply farmers with different varieties. He commented that there is very little information about the rice value chain.

Farmers are clearly innovating within the system, and had many suggestions for ways in which the DDS technology could be adapted for better performance. Ideas for adapting the machine itself revolved around being able to change the seed placement to change plant spacing (57%) or seed rate (13%). Specific comments specified that the seed placement should “look like transplanting”. Ensuring uniform application of fertilizer was also considered important (20%).

For land preparation, there was a mixture of responses; ploughing and allowing the paddy to "sun dry" for 2-3 weeks was the most common response (39%). People recommended ploughing before and after rain almost evenly. Physically transforming the paddy in terms of leveling and enlarging them was also proposed (24% in total). Land preparation should be performed in lower paddies first, with higher paddies either not sown or sown last.

For managing fertilizer, the most common response was to apply basal fertilizer with the seed, and topdress later (59%), in line with technical recommendations. Basal (17%) or placing fertilizer with the seed (14%) was also commonly mentioned.

For weed control, farmers mentioned a range of techniques; again hand weeding was most frequently reported as the option for weed control (38%), although this could be because other options are not commonly practiced at this stage. Herbicides, ducks, cutting rice and weeds together, rotary hoeing and land preparation were all mentioned at least once.

- Enabling environment

The number of machines in the villages appears to be increasing steadily, with increasing sales and distribution of DDS machinery. The survey revealed that 60% of farmers purchased their own machine, and had more than one kind of machine option available to them when they purchased the machine. Farmers indicated that having their own machine allowed them to control the time and quality of operations. A further 30% of farmers used a contractor's services. Borrowing a machine or using a group machine were less common, but are likely to be good options for farmers with less cash resources, as they make accessing the machinery cheaper. For example, hiring a contractor costs between 200,000 – 700,000 LAK per day, while hiring a machine is only around 50,000 LAK per day. From previous surveys, we know that most farmers pay for their machines with cash, as reported by farmers themselves and machinery dealers. In this survey farmers confirmed this, with only one farmer reporting selling cattle, and one borrowing money from a relative to fund the purchase.

This follow up study includes interviews with five machinery dealers which researchers were not previously aware of. This may be for a number of reasons including that they were not previously selling DDS machines, that the PAFO and DAFO staff had not previously known they were selling the machines, that the dealers did not stock many of the machines, or simply did not have them on display and that the Thai suppliers (the dominant source of machines for dealers) were not as proactive in looking for retail opportunities previously. The growth in number of dealers selling or promoting machines indicates a response to demand and a growing awareness that there is a market for these machines. Though numbers quoted by the dealers were not verified, their accounts indicate that sales of machines have significantly increased in the past two years. While one dealer expressed concern that he had lost sales previously due to lack of machines, another dealer was concerned that the demand would soon drop, once sufficient machines had been purchased.

There was discussion amongst the farmers about the relative merits of different planter designs. Some of the designs were criticised for breaking the seed (particularly in relation to whether a rolling or circular blade was used in the machine). Sellers did not necessarily have information about the different designs, nor what was available. There was agreement that the "newer" machines were better than the "older" machines, but the source and description of these machines was not recorded. Other comments included the lack of a fertiliser box, and that hole sizes varied depending on the machine and plant spacings varied.

Farmers and dealers reported that sales of machines were almost always cash. There do not appear to be sources of credit available for the purchase of machinery.

Conclusions

From very mixed beginnings (including mixed results from field trials and early adoption), the adoption of dry direct seeding is now taking on a life of its own. From the analysis of interview data and estimates of the number of hectares planted in 2015, it is clear that planting using DDS rapidly (and fairly unexpectedly) increased during the 2016 season. While this increase could not be traced back to any particular project or intervention, it is clear that the combination of factors included rising labour costs and labour shortages, continuing unpredictability of the onset of the monsoon (particularly late onset), various social and institutional factors, and the availability of machines through local (district) suppliers and the various projects which have trialed this approach over past years.

It is unclear from this study whether there is potential for increased rice production in this area, or whether this is even a relevant objective in this case. With rice prices low, farmers welcomed the opportunity to decrease input costs (in particular labour), but there was no indication that they were considering growing more rice.

Innovation processes do not happen in isolation. This innovation systems study shows that there are many interacting actors and factors influencing this process. The results from this study do not apply only to DDS, but provide some insights into ways in which development actors can foster an environment that provides innovation options and pathways for adaptation for farming systems. Creating an enabling environment for innovation is extremely important, but understanding what this means is even more urgent if these experiences are to be replicated. The adoption of DDS is just one example of farming communities innovating for their own reasons, but where the possibility has been created through external intervention. The focus of this and the earlier study is valuable as a record of learning from farmers' experiences and knowledge. Framing these studies in a systems way is important, as is the innovation concept, as a way to understand why and how people interact to create change.

7.2.4 Priorities for further systems research

Research in Laos is undertaken in a series of National Research Institutes, with line ministries hosting their own research institutes at national and provincial levels, for example the National Agriculture and Forestry Research Institute (NAFRI), the National Economic Research Institute (NERI), the National Institute of Public Health (NIOPH) and the Economic Research Institute for Trade (ERIT). Additionally, universities and topical centres or committees established within ministries also undertake research for specific purposes, for example the National Committee for Rural Development and Poverty Eradication under the Prime Minister's Office, as reported by Clarke et al. (2015). Committees in the latter category are often designed to be cross-sectoral and interdisciplinary. There is a recognition at multiple levels that the existing 'silos' between different research institutes is not conducive to achieving the impacts needed on the ground. Higher level policy makers want to see collaboration between different areas of research in Laos, and indeed there is currently a national research strategy being considered by the government that aims to achieve this collaboration through improved management and coordination among research institutes, including establishing a research network; enhanced research capacity; and better cooperation with the private sector and producers. Such a strategy illustrates that at a national level it is recognized that changes to the national research approach are needed, and that these changes must take a more collaborative approach.

NAFRI was established to consolidate agriculture and forestry research activities, and to develop a National Agriculture and Forestry Research System. It is mandated to undertake integrated agriculture, forestry and fisheries research in order to provide technical evidence to formulate strategy in accordance with government policies. Within

NAFRI there is recognition that previous internally focused approaches have not been effective, and there is a desire to look outwards to new partnerships, and to move towards a shared agenda. The Agriculture and Forestry Research Strategy 2025 (NAFRI 2015) clearly outlines a commitment to prioritize a systems-based research approach that incorporates multiple disciplines and addresses multiple and specific varieties and agricultural products. To achieve this, new ways of working with multi- stakeholder groups are needed. NAFRI's research areas are grouped into six broad strategic research programs guiding future practice-oriented interventions, of which there is an emphasis on capacity building and approaches to linking with multiple stakeholders. Indeed, NAFRI has identified work on further structural and functional re-orientation to assure effective operations with impact, efficient administrative handling and streamlining of research and development efforts as a priority focus. It has committed to initiate a deeper review of its role and mandate, responsibilities and planned achievements, and to make necessary changes and modifications in the strategy and related operational procedures to achieve its goals. These plans for future development and operation of NAFRI's role align well with the move towards a strengthened innovation system, and it is recognized that capacity building is a crucial part of achieving these goals.

At the provincial level, a new approach to agricultural development is being implemented following the update Agriculture Strategy meeting (December 2016), called “Si Huam Si Passan”, roughly translated as ‘four collaborate, four cooperate’. This brings together Departments of Agriculture and Commerce, farmers and businesses, to promote agricultural production. The focus of these groups depends on the location; in Champassak and Savannakhet, one of the focuses is rice production.

Future scenarios for southern Laos were described by the project team in a series of small group discussions. The first step was to consider things that are likely to change in southern Laos in the next 5-10 years. This included the following proposals:

- Change from smallholder to big farms, Larger farms with more mechanization
- Dry season crop change from rice to other crops due to low price for rice
- Labour shortage, therefore use machinery to replace this. Labour will go to Industrial systems
- Climate change and development of hydropower
- Change to replace local cattle with improved cattle breeds
- Richer people, consumer preference changes to GAP, organic systems

Potential farming systems included larger, more commercially oriented farms; strong farmer groups with farmers working closely; and business as usual. Along with changes in context, and considering interactions with the value chain, these farming system scenarios were considered in terms of resources (land, water, labour, cash), networks (who do people work with?) and the speed with which these systems could change.

Table 13 shows the strengths and weaknesses associated with the potential farming systems, as well as the research questions, processes and capacity that would be needed to underpin them. Many of these processes and capacity building requirements include elements of how people interact with the market and each other.

Table 13 Potential farming systems, their strengths and challenges, and the research questions, processes and capacity that would be required to support them

Farming system	Strengths	Challenges
1. Larger farms that are more commercially oriented	• Big amount of production, can use mechanization • Access to finance and markets • Can produce in an integrated way, including processing etc • Good income and welfare for householders	• Uses high investments • Needs skilled management and administration • High competition between production and marketing • Most inputs are external (and imported) • Existing infrastructure is low
Research questions, processes and capacity requirements	• Start small and learn and improve step by step to get bigger. Research to support this process (i.e. techniques that can be trialled and scaled up on-farm) • Improve and build capacity of stakeholders in production groups • Focus on quality to meet market demand • Improve/develop local industries to reduce imports • Develop infrastructure, update research activities, implement quality assurance programs	
2. Most farmers are part of strong farmer groups	• More bargaining power with traders • Better access to finance • Can produce as per production plan • Can be a model for others	• Basic education/experience in this approach is low • High interest rates – groups cannot borrow • Cannot guarantee market demand • Mechanism for establishing the group and administration to run the group is not sustainable • Relationships are not strong • People thinking individually not as a group
Research questions, processes and capacity requirements	• Capacity building for group members, particularly in establishment, partnerships and administration • Policy support for agricultural inputs (e.g. imports) • Group members join voluntarily • Evaluation processes for transparency, benefits, challenges, solutions	
3. Business as usual; subsistence smallholder systems	• Independence; people can farm as they want to • People are confident with what they have/know • Can produce and diversify production as the market requires • Resilient – able to adapt to climate change switching between rice and non-rice • Farmers can respond to the market	• Production is low, land area is small, quality often low • Chance for knowledge sharing is low • Difficult for extension agencies, market etc to reach farmers one by one • Difficult to access finance • Market; no bargaining power, often have to accept low prices • Always lose benefits compared to other value chain members • Access to market prices is difficult
Research questions, processes and capacity requirements	• Establish production groups • Integrated systems for processing and marketing • Whole systems approach • Techniques for improved production and quality • Government side – work closely with farmers for technical support • Establish and improve access to financial resources and markets • Support current market data	

7.3 Objective 3: Creating institutional capacity to implement Innovation Platforms

The agricultural sector faces challenges of unprecedented proportions, and multiple forces are interacting to create different levels of impact on the sector. There has never been more information available, or a more diverse range of stakeholders engaged in the agricultural sector. This creates conditions for change and innovation, where connections and knowledge flows between an increasingly diverse set of actors are becoming progressively more important (Spielman and Birner 2008).

Innovation Platforms (IP) are a way of bringing together different stakeholders to solve problems or address constraints within a system, and are a key method for developing effective innovation practice (Honman-Kee Tui et al. 2013). IP are effective coordinators of innovation because they bring complementary skills and competencies together through different actors (Kilelu et al., 2013). In agriculture this can be a valuable approach, given the often complex nature of constraints within systems that incorporate biophysical, social and policy aspects (Nederlof et al. 2011). The common elements of IP or networks are that they exist to bring together a diverse group of stakeholders to address a complex situation, are flexible, and have a dynamic membership (Nederlof et al. 2011). For researchers, this approach offers a way to actively engage with stakeholders to explore, design and implement solutions (Schut et al., 2011). Zelalem & Schut (2013) identify three ways in which innovation networks benefit from research. Traditional research can be undertaken to develop technologies or answer knowledge gaps proposed by the network; knowledge can be produced and managed to make it more accessible to others (both within and outside the group); and researchers can contribute to an environment that is conducive to innovation through capacity building, addressing institutional constraints, and monitoring and evaluation.

Previous research for development experiences in Laos have been strongly focused on technical approaches to solving local challenges, in a traditional transfer of technology approach; skills and capacity in this approach are relatively strong compared to other approaches. Other approaches have also worked in a transdisciplinary way by implementing learning alliances or by taking a market based approach (e.g. PPP and agro-enterprise focus). These approaches have had some success, and it is sensible to build on what has been tested previously. For this reason, the project team selected the IP approach to address challenges in farming systems, drawing on an overarching AIS and IAR4D approach. IP are one of the tools available to implement the wider framework at different levels, and with a practical focus. In addition, IP can include research approaches (i.e. on-farm and on-station research) that people are familiar with, and can be used as a learning opportunity. In reality, people involved in systems research use a range of tools and methods to understand their given system, select interventions, monitor progress, review results and communicate findings with others. Each situation is different, and so general principles are more useful than prescriptive approaches that do not cope well with diversity. The IP approach was explored, with the need for adaptation to the Lao context.

7.3.1 Approach

This project has a focus objective of enhancing multilateral systems thinking (Objective 2), with on-farm research and demonstration sites (Objective 1) used to provide a mechanism for understanding and application of systems approaches. Objective 3 focuses on developing capacity to implement Innovation Platforms in target provinces and districts, by building capacity at national, provincial and local levels. The project has focused on capacity building through training and experiential learning and reflection. The approach taken within the project has been flexible, adapting to opportunities as additional time and funding became available. Figure 2 (Section 5) shows the project approach to building capacity for implementation of Innovation Platforms. Training was first undertaken at

NAFRI with an international trainer who had a wealth of experience in implementing IP. This was followed by training at Provincial and District levels, which were more hands on, and provided practical skills for application. Finally, IP were initiated in three locations, and by the end of the project were at various stages of implementation.

7.3.2 Capacity building

Innovation Platform training at NAFRI

In early February 2016, the project team held training in IP concepts and practices in Vientiane for project team members from national and provincial agencies. The aim of the training was to equip participants with skills to commence implementation of IPs with supporting understanding of crop-livestock value chains, to identify common challenges and opportunities in using the approach, and to prepare plans for local IPs. The training focused on providing participants with practical skills, using familiar examples and building on the understanding of farming systems that are familiar to the participants.

Objectives:

- To understand key concepts and practical project applications of Integrated Agricultural Research for Development (IAR4D), value chains, innovation platforms, and their integration in the project
- To provide background and motivation in their application to project planning, implementation and, monitoring and evaluation
- To expose the participants to the necessary skills and tools to apply the concepts

The structure of the training workshop moved through concepts related to innovation (what is innovation, and why do we need new ways to support it?) and integrated agricultural research for development (IAR4D), worked on understanding the value chain and how this links with IPs, and then focused on IPs in terms of their initiation, management and monitoring.

In small groups, participants focused on three key sectors to improve understanding of value chain analysis. These included the cattle value chain in Phin district of Savannakhet, export rice from Savannakhet province to the Chinese market, and rice in Champassak province. Participants spent time analyzing the value chains, including thinking about gender aspects. Using these and other examples as a base, participants later made detailed plans for implementing IPs to link members of the value chain for specific sectors. The proposed IPs included:

1. Direct seeding support in Savannakhet province
2. Live cattle export platform in Phin district
3. Improved rice commercialisation in Phontong district, working with existing Farmers' Organisations

Participants were generally enthusiastic about both the concepts presented and the way the training was conducted, with plenty of active participation and group work. The ability to work with and present value chain studies within a group was appreciated. Importantly, people noted the importance of social skills, communication, and new methods and approaches to change the ways of doing things.

Training at the Provincial level

The Vientiane based training was condensed and translated into Lao language, for training with PAFO and DAFO staff in Savannakhet. This focused on three main themes, including an introduction to innovation, thinking about value chains, and then establishing, managing and monitoring IPs themselves.

The training started with a discussion about how the CLSP is different to previous projects, and how agricultural research in general has changed within Laos. Participants, who have almost all worked with both the SLP and CLSP projects, were able to identify key differences in this project approach. The focus on integration was highlighted, both within the project (i.e. at technical sites) and between the project and external stakeholders. This focus on integration was seen as positive, both at technical levels and as a knowledge sharing tool. Reference was made to the fact that 'knowledge and experience sharing' is much better when the project is applied in an integrated way. It helps staff to understand technical issues together, and also generates more useful results. When prompted, people stated that the usual, individual component approach is often easier to manage and implement, but that the results are less useful to a wider audience. It was stated that "**taking an integrated approach is the way that farmers work"**, in terms of managing many different enterprises, and so research and extension should support and reflect this.

The participants spent time in small groups identifying potential value chains within their districts, and interestingly selected goats in eastern districts of Savannakhet, and native chickens in western districts. Often people have tended to focus on rice itself to understand the value chain.

The group identified potential challenges in using the IP approach, in terms of how to actually effect change. For example, often when working with other stakeholders, even when the specific challenge can be identified, there is no control over other elements within the system/chain. An example was given for the livestock value chain in Phin district; the number of checkpoints for live export has been identified as a problem for traders, but the DAFO staff have no control over this element in the system. However, the participants felt clear that an approach such as IP is very appropriate for their current situation, and that in some ways there is no choice but to move in this direction; but cautioned about the time it might take to reach the objectives of these kinds of groups. This is a reminder of the importance of communication with higher levels, in terms of them understanding the nature of the approach, and the time it might take for changes to emerge.

Although the time for the training was short, participants had excellent comments to make about the process of innovation, and also demonstrated their understanding of the need for different stakeholders to work together. It seemed from comments that this integrated approach, both in technical terms and in terms of engaging with others, is appreciated by our provincial and district staff. Despite the fact that they see more traditional approaches as being easier, they recognize the benefits from working in a more coordinated fashion that do not come with working individually, both for themselves and for the farmers that they work with.

Following the training in Savannakhet, a provincial level IP was initiated to support Dry Direct Seeding technology. This is further described below.

Training at the District level

Training in Innovation Platforms and practical skills for market chain analysis was conducted in Phin district (July 2016) and Phontong district (September 2016). The aim of this training was to share experiences from northern Laos, and for local staff to gain experience and understanding in applying market chain analysis as a basis for initiating local Innovation Platforms. It is easier to build on successful previous initiatives and sensible to make use of local experiences. Part of the Innovation Platform training held in February highlighted the importance of being able to analyse and understand the value chain as a basis for Innovation Platforms.

The CIAT SADU project, which operated in northern Laos between 2003 – 2011 used an 'Agro-Enterprise for Development Process' (AEDP) to identify opportunities within local communities by analyzing the value chain. This project had success in a range of different products including cattle, maize, peanuts, rice and others. One of the SADU project members from Xieng Khouang was contacted to provide training and share experiences with working in multi-stakeholder groups. Mr Viengsouk from Pek DAFO, Xieng Khouang Province delivered training, tools and supported project PAFO and DAFO staff to analyse the local value chain.

The training started with an overview of Innovation Platforms and the CLSP project. The SADU project/AEDP process and tools used in the process were then introduced, including how these have been used practically in Xieng Khouang with different products. This approach is focused on creating new enterprises within the system. Tools used include market mapping, seasonal trading (demand and supply), trends (past and future), market specifications and trading characteristics, and SWOT analysis. There are advantages and disadvantages for both approaches. i.e. AEDP uses more resource persons, more budget etc to analyse the value chain. IP may go beyond the market chain to look at other contextual factors in the operating environment. Some of the tools and steps have already been undertaken in this project using a slightly different approach, i.e. concept mapping using integrative enquiry.

After reviewing the tools used in AEDP (market mapping, seasonal trading (demand and supply), trends (past and future), market specifications and trading characteristics, SWOT analysis, the participants applied these to the rice and cattle value chains (Phin) and onion production (Phonthong) over several days. The results were presented back to the main group and discussed.

The outputs from these training sessions were used as the basis for subsequent IP meetings in Phin (cattle production) and Phonthong (onion production), as described in subsequent sections.

7.3.3 Implementation of the Innovation Platform approach

Supporting dry direct seeding technology in Savannakhet province

In Savannakhet province, direct seeded rice is becoming a popular option for crop establishment, and in the wet season of 2015 the area planted increased dramatically from around 80 hectares to over 800 hectares. This technique is attractive due to labour shortages (lack of availability and hence high wages) and climatic conditions in which wet season rains are regularly delayed. This technique helps farmers to address these challenges, resulting in lower crop production costs, and the ability to establish crops without waiting for the onset of the main rains during the wet season. Supporting the outscaling and use of this technique thus benefits farmers by reducing production costs and providing an adaptation option for climate variability. Other beneficiaries include other actors in the system, such as input suppliers (fertilizer, chemicals and machinery manufacturers and distributors), farmers who act as contractors (giving an alternative income stream), government staff (in helping to support government policy to increase rice production), and local businesses who rely on local labour (who have a reduced staff availability during peak transplanting times).

An IP can provide a space to support this technology, linking many different actors within the system, and making the technology easier to access for farmers in suitable areas, and less risky for those who want to trial and adopt this technique. Implementing an IP to support dry direct seeded rice will also serve as a learning mechanism for project members, in terms of understanding and gaining skills in multi-stakeholder approaches. In Savannakhet province, this approach is relatively new, and there are few examples from which to learn from.

Stakeholder identification

Relevant stakeholders were identified through a range of systems workshops at national and provincial levels in 2015, using several different tools, including concept mapping, integrative enquiry (consciously thinking of the 'five ways of thinking', including physical, social, ethical, aesthetic, sympathetic) and action planning. During training in Innovation Platforms in early 2016, team members had a chance to consider aspects of the direct seeding innovation platform, including exploring lowland rice value chains, developing a schedule for the initial meeting, identifying potential challenges and discussing solutions.

A comprehensive stakeholder list was developed during these preceding workshops and training sessions; these included DAFO from relevant lowland districts, PAFO (land management, agriculture, rice seed production, extension, planning and irrigation sections), provincial government departments (Agro-meteorology, Industry and Commerce, Customs, Communications), machinery distributor (Xangpheuak), rice millers, NGOs, Education (Savannakhet University, Na-Keh Agricultural College, Technical-Vocational School), companies within the Special Economic Zone and Banks.

Members of the project team from PAFO and NAFRI then visited all of these stakeholders separately to discuss the rapid uptake of direct seeding, some of the problems being encountered by farmers and others, and to introduce the idea of a multi-stakeholder platform that might help to support and outscale the technique, for impact in lowland rice based systems. In general, there was support for the idea, and most people indicated a willingness to attend and learn more about this approach. Participants were then formally invited to the meeting by the project team members from the PAFO Land Management section.

Initial meeting

The initial meeting included stakeholders from PAFO (Agriculture, Extension, Irrigation, Planning), Provincial Office of Natural Resources and Environment, Provincial Office of Industry and Cooperation, The Lao-Thai Bridge Authority, twelve DAFO locations, World Vision, JVC, Savannakhet University, the Technical and Vocational College, the Policy Bank, the Agriculture Promotion Bank, and Lao Veun (rice traders).

The meeting began with setting the scene for IP in the GoL context, followed by focusing on the technology itself, including rates of adoption, and technical aspects such as different machinery options and management approaches. As background to the technique, four of our farmer colleagues then spoke briefly to the group, highlighting their experiences with aspects of machinery availability, contracting services, production yields, weed management, varieties and their path to adoption. Importantly, they identified that the decision to use this technique – particularly in deciding to buy the machine or not – is not just about money, but also about how the technique changes the way they work.

The aim was to set the scene for what is happening with direct seeding in Savannakhet, including from farmers' perspectives, and then to introduce the idea of an Innovation Platform, before moving onto more specific work in identifying priority challenges and actions to address these. However, some elements of the workshop went over time, and it was difficult to explain other parts to the participants, and so not all of the outcomes were addressed. Additionally, some of the invitees did not attend, including the main machinery dealer and businesses associated with the Special Economic Zone.

There was good discussion and questions from the group (DAFO staff with little experience with the technique, PAFO staff, educational facilities) to the farmers, following up on elements they had identified. As an example of the value of creating these links, the director of the local Technical-Vocational School had several questions for farmers to clarify elements of fertilizer management and machinery. He had already discussed with the Provincial Government the option of manufacturing the machines locally within his school, but has not followed up on this coordination. This is a potential activity for the IP to follow up on and support, to make sure it is done in a strategic way, and engages with the right stakeholders (i.e. decide on machinery type in conjunction with farmers, liaise with machinery distributor, check options for imports from Thailand etc). Other members of the group commented on the suitability of the Technical-Vocational school being part of the support network, as farmers and DAFO staff do not have skills in agricultural mechanization.

Following the discussion about the direct seeding technique, a ‘system map’ was presented, to highlight the range of challenges and issues, and to show why a multi-stakeholder group might work in terms of helping to address these challenges. This session seemed to create confusion among many of the stakeholders, and people focused more on individual elements of the system (i.e. being specific about which stakeholders and what their mandate is, how to capture and translate key messages in a two-way flow) than in the concept of the IP as a mechanism for coordination. In hindsight the diagram, which was supposed to convey the complexity of the system, the multiple links, and the need for different stakeholders to address challenges in different parts of the system, should probably have been simplified, and stakeholders given time to build a picture in small groups using their own experiences. Skipping this key step meant that people did not have a clear understanding of what we meant by the system, and how they could contribute. Discussion to try and address this took a significant amount of time.

Following this, the meeting facilitators decided to skip discussing the rules for engagement, which it was felt the group did not feel coherent enough to do that yet, and focus instead on agreeing on the aims and priorities of the IP. Again, this seemed to be difficult for the group as a whole, and people were slow to nominate ideas for the aim of the IP; there were ideas put forward, but people were speaking in a very general sense. Some of the ideas suggested included promoting the flow of information, reduce production costs for farmers, identifying someone to lead the process and help to implement the technique, outscaling, answering research questions, and generating higher incomes throughout the value chain/system. It seems that these aspects can be summed up as indicating a support role for the IP, and the individual ideas suggested might be activities that can help to address some of the priority challenges identified. This whole discussion took almost 1.5 hours, meaning that the meeting was far behind schedule.

Following this discussion, participants split into three groups to put forward their top priority challenges and opportunities in terms of the direct seeding technique. This was initially planned as different actors being grouped according to their role in the system, but with a different mix of stakeholders compared to those expected, the groups were modified and consisted of a mix of stakeholders. The results from these small group discussions are shown in

Table 14.

Table 14 Challenges and opportunities with direct seeding technology

Group 1 (DAFO, farmers)	Group 2 (DAFO, other Provincial departments)	Group 3 (SKU, Meteorology Dept)	Priorities – summary
Problems/challenges			
1. Machinery is too expensive 2. Farmers do not know the technique 3. Inputs are expensive (fertilizer, seed) 4. Low rice prices 5. Machinery is not accessible to farmers in the villages 6. Climate change – we season starts later 7. Rice paddies are not level	1. Cannot produce machines in Laos 2. Land is not level 3. People are used to transplanting – this is a new technique 4. Information about DDS does not get to farmers 5. Do not have government funds to support this 6. Weed problems 7. Not enough water in some areas 8. Seed – not every variety is suitable	1. Soil not suitable in all areas 2. Inputs are expensive 3. Knowledge of the technique is lacking 4. Market problems (low rice price) 5. Farmers cannot/do not access finance 6. Labour shortages	1. Machinery – access, price, quality 2. Raising awareness of the technique with farmers, provide information 3. Management of inputs 4. Level paddies 5. Weed management 6. Variety selection 7. Rice prices are low 8. Finance options
Advantages			
1. Climate change adaptation option 2. Solves labour shortages 3. Uses less inputs (seed, fertilizer, labour) 4. Can expand to a bigger area	1. PAFO have good expertise to support 2. There are several farmers with experience and success 3. Saves time and labour 4. Can use the technique in the wet and dry seasons 5. Can use this technique when rains are late and transplanting is not suitable		
Priorities			
1. Produce machines in Laos 2. Ensure access to loans – cheaper rates for farmers 3. Rice price guarantee			

Following these group discussions and presentation back to the wider group, there was not enough time to work on an activity plan for work within the IP. However, some of the ideas that had been suggested during the day were included in the summary remarks as options for methods to address the challenges identified. It is difficult in Laos to start with a ‘blank slate’, for example without having a clear idea of what an IP would specifically do. Thus having identified a list of priorities with the group, it may be easier in a subsequent, smaller meeting to develop an action plan, and to approach relevant people that could contribute. The group can still evolve as needed, but it does at least have a base from which to start.

Activity planning meeting

The aim of the second meeting (April 2016), was to prioritise and plan activities for the coming wet season. The following four objectives were set:

1. To merge lists of priority challenges discussed at Meeting 1
2. To decide on priority challenges
3. To develop a set of activities to address these challenges
4. Define a workplan with activities, people responsible and budgets

A smaller number of people attended (20), but included PAFO Land Management section, PAFO Extension section and the Savannakhet Technical College. Interactions with the machinery distributor (Xangpheuak) during the meeting also communicated outcomes to them. Over two days, the group worked to prioritise challenges and plan activities to address these challenges (Table 16 and

Table 17).

Table 15 Results of group discussion from IP meeting 2 (planning meeting).

Problems	Solution	Activity for solution	Responsible
1. Machinery			
High price, individual farmers cannot buy	Purchase by groups of farmers Study the cost of in-country products	Establish farmer groups, discuss with technical school and manufacturers	DAFO PAFO
No producer in Laos	Promote to produce	Technical school	Technical school
Low quality and no fertiliser box **High density of plants**	Improve with fertiliser box	Add fertilizer box	Technical school
Limited number of shops selling machines, and no selling information (location)	Ask company to extend their shops Advertise on radio	Advertise on TV and radio	Extension section
2. Technique			
Many farmers lack knowledge of DDS technique	Training, establish demonstration plot and conduct field visits Engage experienced farmers in these activities	Disseminate handbook, training, establish demonstration plot	Project, PAFO, DAFO, extension
3. Seed availability			
Lack of good seed and suitable varieties **High price of seed** **Could not access**	Connect with Seed Multiplication Centre (Thassano) and seed producers	Recommend farmers to use good seed	PAFO, DAFO, extension, NAFRI and seed producer group
4. Soil management			
Low fertility and clay soil, uneven paddy	Training on soil fertility improvement and levelling	Disseminate handbook on organic and inorganic fertilizer application	Project, PAFO, DAFO
5. Climate information			
Farmers could not access to climate information, drought and flood forecasts in season	Find climate information from different sources	Recommend farmer to find a good source of information (Thai TV)	PAFO, DAFO

Table 16 Work plan for improving machinery access and distribution

Activity	Details	Time
1. Form a group of farmers to buy a machine	Discuss with farmers in target villages	May
2. Improvement of machine	Discuss with machine manufacturer in Champhone and Technical School	May
3. Extension of selling shop to other districts	Discuss with Xangpheuak company	Apr
4. Advertise on TV, radio or newspaper		
5. Evaluation of machine cost in Savannakhet	Discuss with machine maker in Champhone and Technical School	May

Table 17 Work plan for improving and promoting the DDS technique

Activity	Details	Comments
1. Training	One training session per district (Champhone, Outomphone, Phin, Phalanxai). Each training session for 8 villages, 5 farmers from each village, total 40 farmers for 2 days (1 day technical, 1 day practical)	124 participants
2. Demonstration sites	General demonstration of technique: 3 villages per district, 3 farmers per village (3,200 m^2 per farmer), provide seed (20 kg/farmer).	Fertiliser and weed management trials conducted
	Demonstration of fertilizer effect with and without seed (half plot basal fertilizer applied with the seed, half plot with broadcast basal fertilizer). 3 villages per district, 1 farmer per village where feasible. Supply fertilizer (15-15-15).	
3. Field day	Twice in each district; one in August, one in late September. 40 participants per field day to monitor progress of crop development and production.	Aug Sept
4. Disseminate information	Disseminate handbooks, posters and pamphlets through DAFO, PAFO, machinery suppliers, manufacturers.	May-June
5. Video	Make new version of promotion and training video. In conjunction with Mechanisation project.	May

Phin district – improved cattle production

During the initial training session described previously, participants considered rice and livestock value chains in the local area, and prepared value chain analyses for these products. There is considerable potential in Phin district to intensify cattle production to meet local and international markets. The province is close to the Vietnamese border where there is strong demand for beef, contains extensive land that is available for forage production, and recent government policy enforcement means that alternative income generating activities will likely be sought after by many smallholders in the coming years. This aim also aligns with the current District Development Strategy.

The ACIAR funded SLP project (CSE/2009/004) has worked in the district since 2010, and has built good relationships with farmers and district agriculture staff, and as a result there is capacity to support intensified cattle production systems, using forages and crop residues as a basis. Additionally, there exist some excellent examples of forage based farming systems. However, a gap exists in terms of how to translate these systems changes into improved income for farmers, namely in linking farmers into markets, by analysing and addressing current challenges and opportunities.

Funds were donated to the project to conduct on-farm activities to demonstrate the potential of livestock fattening systems. These activities were conducted in the wet season of 2016, and included:

- Purchase scales for two villages - to show weight gains that are possible in a fattening system, and allow a more transparent exchange between farmers and traders.
- Support students from Savannakhet University to work with the fattening trial, to ensure good data collection (transport, living costs, stipend).

- Set up a revolving fund with profits reinvested from the fattening trials. This will be used to inject cash into the system in a sustainable way. Farmers will be able to borrow funds to invest in a cattle fattening system; these funds will not be available for herd expansion. So far farmers have used the funds to purchase materials (for construction of fences, shelter, storage, straw treatment etc).

The project subsequently provided funds and support to do a more detailed market chain study on livestock. This will provide a good foundation for the initial IP meeting. With this information, the group have the basis for considering problems for key stakeholders; this needs to be done as the basis for the first IP meeting, and will allow stakeholders to decide on activities that could be implemented to address these challenges.

An additional cattle production and market chain study was conducted at the end of October, and was followed by an IP meeting on the 4th November 2016. The aim of the group was to improve smallholder cattle production in Phin district. It was decided to focus on cattle production as there is market potential in the district, in the neighbouring district of Phalanxay (large cattle farm) and for export to Vietnam. Almost 17,000 cattle are raised under three different production systems, including free grazing, semi-confined and stall feeding systems. 26% of cattle are raised under free grazing system and 73% are raised under semi-confined system. Very few cattle and farmer have tested stall feeding practice with forages and agro by-product utilization, although there are good examples of these systems within the district. From different production practices, farmers meet different problems/challenges and have different potential and opportunity. 29 people from different agencies attended, including farmers, DAFO, Traders, District Tax Office, District Industry and Commerce Office, District Custom Office, NAFRI and a representative from the Nayoby bank. The District Governor appointed the head of the District Governor’s office to chair the session; unfortunately he could not come and the meeting was chaired by the deputy director of DAFO. He was very active and thinks this approach is important, but does not have good enough experience about the IP. The research team tried to present and pointed the key point need to get people to understand problems in the same way. DAFO presented the cattle production and market chain in Phin district, that they had conducted follow up work on. The presentation content was good, and very thorough.

The presentation included:

- The existing cattle production system, the advantages-disadvantage and risk from different practice; problems/challenge and potential/ opportunities for development.
- Cattle production and market chain mapping with identified stakeholder actors and action (producing, trading, processing, linking and services).
- Cattle production and market chain SWOT analysis and identified problem /challenge/option for solving or improving.

One of the key needs is to have a good chairperson who can facilitate well. The group have identified someone from the Governor’s office, as they have more power over a broad range of offices, and perform at a higher level. Although this chairperson might not ultimately be involved in the detailed planning and implementation, at least initially it was felt to be important to have approval at this level. Additionally, it was mentioned several times that the group needs a provincial level person to support the district. This group have been hesitant to make a start in defining activities within the group, although they have done a lot of the background work in understanding the value chain, and identifying potential partners. There seems to be a reluctance to step outside what is perceived to be the “normal” boundary for DAFO, where they might need to also engage in other organisations’ mandates (e.g. customs, District Department of Industry and Commerce). This explains their desire to have support from the province, and a need for the Governor’s Office to endorse the group.

Phontong district – improved vegetable production, focus on onions

During the district training in IP and value chain analysis (September 2016), participants selected onion production and cattle as a focus for value chain studies. Initial results were presented after several days of practical work using the tools presented. It was felt by project staff that the final outputs still needed work, but were quite good, and they acknowledged that this is all a learning process. The meeting ended with a discussion of how IP could be used, and what the next steps would be. It seemed from comments and discussions that participants were engaged, asking questions, and had a better understanding of what we are trying to achieve, even after the first training session. This could be because the project team have more experience and a better understanding, and therefore can communicate more clearly. Starting with the value chain study itself, with tools applied, allowed people to have something concrete to work on as a group. Following the presentations, the group selected onion production as the basis for an IP.

A subsequent IP meeting was held in November, with the aim of improving onion production in Phonthong district. It was decided to focus on onions as there is market potential in Pakse, and many farmers are already producing these, but facing some challenges. 29 people from different agencies attended, including farmers, DAFO, traders, District Agriculture and Land Management section, DOIC. The Vice-Governor chaired the meeting; he was very active and has good experience, and thinks this approach is important. His key point was the need to get people to understand problems in the same way. DAFO presented the onion value chain in Phonthong district, that they had conducted follow up work on. The presentation content was good, and very thorough.

The main problems for farmers are:

- How to compete with Thai imports, which are cheaper, although perceived to be of lower quality.
- Suitable growing techniques for the wet season when prices are higher due to low supply.
- Seed access. Seeds from Thailand are expensive. Seeds in the local market are not good quality. Can we improve the seed supply system?

A second meeting (January 2017) focused on potential solutions to the major challenges. The Vice-Governor again chaired the meeting, and communicated the local context and benefits of an IP approach. Following presentations of different potential solutions, a number of activities were proposed, as shown in Table 18.

Table 18 Proposed activities to promote improved onion production in Phonthong

System element	Activity	Potential linkages
Production	Promote standards for improved fertiliser management	ANSOFT Project (DALaM)
	Promote techniques for wet season production to take advantage of high prices	ASEM/2012/081
	Post-harvest options to preserve product quality	ASEM/2012/081
	IPDM training	Crawford Fund ASEM/2014/051 (funds with DAEC for training)
	Seed production within the district	
Marketing	Discuss potential to initiate farmer groups, to improve quantity and quality of production, and increase bargaining power	
	Understand contract farming options – e.g. regulations with local trader, fair prices, guaranteed low/medium/high prices etc	
	Household record keeping (calendar of production, i.e. to avoid oversupply)	ANSOFT Project (DALaM)
	Manage product quality, e.g. grade different qualities (price at market is linked to quality)	ASEM/2012/081
	Understand price fluctuations – collect more market information	
	Infrastructure – storage facilities	

A number of links with other projects have been discussed, which might be possible to keep this group together at the close of the project. There are potential links with other ACIAR project results, support through DAEC and existing projects operating in the same district. These will be followed up before the end of the project.

The progress in Phonthong district has been better than expected, with the group clear in their objectives, and able to engage outside the government system (i.e. with traders etc). This group has benefited from the project team having more experience in communicating theory as well as supporting with practical tools. Additionally, the endorsement from the Governor’s office has given the approach legitimacy from the start, and there has not been any hesitation in moving forward with the group meetings or activities.

7.3.4 Lessons learned

The Innovation Platforms approach has been explored through training sessions and implementation at provincial and district levels, and needs further exploration, advancement and adaptation to the Lao context. However, there are several key lessons that have emerged out of training and implementation, which can help to refine this approach in Laos.

1. Working with external stakeholders across disciplines

This kind of approach is very new for all stakeholders. The project team have all reiterated that they (e.g. DAFO, PAFO) haven't sat with the other stakeholders before, and are not used to working outside their own organizations. Working with external stakeholders means that communicating key ideas, aims and objectives is essential.

To engage with external stakeholders, we need to be able to appeal to them and show them what the clear benefits are for them. IP take time to work, and we need to show people that with time they will get benefits (maybe more so than in the immediate future). This relies on trust between members of the group. Options for developing trust include starting with small, specific tasks/activities and build relationships that are based on trust and mutual success (i.e. include field trips etc).

It is also important to identify the right sections/people in the various organisations and which is the right one to work with the group to be effective.

In Laos, it is important to have approval/support/endorsement from higher levels for this approach to be successful. The more successful group had buy-in from the District Governor's office, which meant that they had support and endorsement to work across institutions. Such district level leaders are able to navigate through local political systems, making the groups more legitimate.

IP groups require a good facilitator, and meetings to be conducted smoothly (i.e. good time keeping is important).

2. Communication in group settings

When working with stakeholders from different backgrounds, good communication is essential. This means having clear guidelines for meetings; for example ensuring that everyone can contribute/participate in meetings, and add comments. It is important to make sure that everything presented is very clear. For example, reports on market studies, systems etc need to be presented systematically, including explanations of approach, results, and potential impacts. When asking questions, open ended questions work best, as they allow people to communicate additional issues and problems, creating a context for their comments.

Creating a shared vision can help build cohesiveness within the group, as importantly, understandings differ within the group. Using systems tools to understand the broader agricultural system, and simple approaches to understand the market chain as a basis for discussion can help to create a shared understanding.

3. Tools for systems analysis

Simple tools for understanding local systems help to share information and expertise, and create a shared understanding of the challenges within the system, and the different stakeholders engaged. In this project and in the final stages of CSE/2009/004, various approaches were used with the project and wider teams to build an understanding of local systems. For example, integrative enquiry and concept mapping were used to build rich systems diagrams. These were well received and useful for assessing systems, challenges, and identifying relevant stakeholders.

4. Tools for market analysis

The market chain can be a suitable starting point within an IP group, as a framework to assess opportunities for smallholder farmers in crop and livestock markets. The project engaged with staff who had worked with the Smallholder Agro-enterprise Development in the Uplands (SADU) project in northern Laos, to utilize their experiences in market chain analysis. The tools used in this approach include market mapping, seasonal trading (demand and supply), trends (past and future), market specifications and trading characteristics, and SWOT analysis. They are clear, simple, and readily available for use at a range of levels in Laos, including at the village and district level.

When using these tools, it is important to keep in mind the ultimate outcome; think about why the data is being collected and analysed, with reference back to the IP approach. The results from each tool should be presented, and shown how they are connected to each other in terms of data and analysis. These outputs provide a good basis for engaging with external stakeholders, and identifying challenges within the system that can be addressed within the IP.

5. Partnerships

Innovation Systems focus on stakeholders within a system, and the relationships and links between them. Understanding existing links is an essential part of the approach. Additionally, creating new partnerships and links is important. Partnerships rely on trust and transparency, and are not always easily built. This is also true in Laos, where existing and historical experiences confine stakeholders within their own mandates. Building effective partnerships between and across traditional boundaries is an element of IP that needs long term commitment and strategies in the locations where we have been working.

6. Institutionalising the IP approach in Laos

There is a need to create awareness and understanding of the approach at a wider (and higher) level, including linking to the Lao Government plans for agricultural development, as outlined in the most recent Agricultural Development Strategy. The focus of the strategy includes food security, commercialization and food safety. It was generally agreed that the time is right in Laos due to alignment with government plans and the current socio-economic context.

Support is needed for application of the approach as well as recognising the time needed to achieve impact. Budget, resources, skills and capacity all need to be considered in relation to the IP approach, both in terms of existing levels and what is really needed to make this approach work. Political will is very important, in terms of securing higher level support, as well as organizational commitment to the approach and the process, and an understanding of the time that may be required to achieve impact.

Considering how this approach can help meet the Donor acceptance was seen as important, in terms of this approach aligning with what donors are willing to fund, and the kinds of projects that can fit with this approach.

It was recognized that a range of skills are needed for effective institutionalization of the approach, in addition to technical skills, and include elements of facilitation, value chain analysis, communication, action planning, problem solving research, adaptive planning, flexibility and monitoring and evaluation. This capacity can be developed in many different ways, including through training, on-the-job learning, study tours, and pursuing opportunities to implement these concepts within the higher education system.

7.4 Summary

It is clear that there are many different options available to farming households to intensify and integrate within their system. Productivity and profitability can be increased and food security enhanced, while labour and risk are spread throughout the year. Integrated systems also have implications for soil nutrition and resilience. However, there is a vast difference between demonstrating successful farming systems - both on the ground and from a research perspective – and widespread adoption of these diversified and integrated systems. On-farm management and production challenges are not the sole impediment to adoption or testing by farmers. With reference to the technologies discussed here, there are many factors that may be required for outscaling to occur; for example, technical knowledge and support are necessary; reliable irrigation sources and methods; access to inputs such as machinery, seed and fertilizer; market options and confidence in price returns; and access to credit. It is therefore necessary to link research with these other elements of the system; one way of achieving this is using Innovation Platforms or multi-stakeholder groups to connect different stakeholders to expand options for knowledge sharing. This will allow more smallholders to benefit from the improved systems described here.

The continuation and enrichment of research and development using systems approaches to identify and deliver effective technologies and practices is crucial for integrated crop-livestock systems. Reviewing different systems approaches highlights the necessity of integrating the perspectives, knowledge and tools from a range of stakeholders, to develop a rich understanding of farming systems and their wider environment. Initial training sessions highlighted the need to understand and engage with different stakeholders along the value chain if lasting changes are to be made.

The project team has noted that the current situation for agricultural development in Laos is very conducive to the IP approach, including in terms of the regional market environment and government policy. However, there are also challenges to be managed, including power and influence, institutionalisation of the approach, and expected time to impact. Communication between different levels and different stakeholders will be key if this approach is to work.

In general there has been good baseline progress made in capacity building in systems approaches including Innovation Platforms at district, provincial and national levels. At all levels there is a feeling that collaborative approaches to agricultural development are becoming a necessity in the current environment, and in line with government policy. Project participants have analysed systems and market chains, selected appropriate products for focus, interacted with relevant stakeholders and implemented agreed activities. More time is needed to fully understand the benefits and challenges of the IP approach, but valuable lessons have been learned about interacting with external stakeholders, communication, tools for systems and value chain analysis, and ways in which this approach might be institutionalized in Laos to enhance effective agricultural development.

8 Impacts

8.1 Scientific impacts – now and in 5 years

This project is the only one conducting research in Savannakhet province for improved management of dry direct seeding. Results for management of aspects of DDS including fertiliser management options and integration with ducks for weed management will contribute to best management practices in Savannakhet province, as recommendations are continually adapted to suit local conditions.

Several publications have been submitted (6) and a further nine are in preparation to report on systems approaches and disciplinary research into rice, legumes, forages, direct seeding in southern Laos; these will be a valuable resource in contributing to understanding these systems. The first papers on perennial rice performance under field conditions have been accepted (2) for international journals. This represents a new direction in rice research, which may benefit upland and marginal systems in terms of food security, soil stabilisation and crop-livestock systems. All of these papers will also be modified for publication in the Lao Journal of Agriculture and Forestry, to ensure that local colleagues can also benefit from these synthesised works. In 5 years these papers will be published and form a comprehensive basis for understanding southern Lao farming systems.

Many of the results from these publications have been converted into recommendations for farmers, which have been printed and distributed widely in Savannakhet and Champassak provinces, which can contribute to improved productivity if followed.

The project strategy in using the Innovation Platform approach to identify and address challenges for agricultural systems and commercialisation of smallholder farms in southern Laos is new and is contributing to an understanding of the patterns of successful research for development in the Lao context.

8.2 Capacity impacts – now and in 5 years

This project has contributed to building capacity in systems thinking using tools for exploring and understanding farming systems and linking with stakeholders. This capacity has been built through formal training and learning sessions, as well as on-the-job training in implementing different parts of the project (Innovation Platforms). Additionally, on-farm integrated crop-livestock research sites provide a learning site for project members and other stakeholders.

The project has built capacity to work with multi-stakeholder groups using an Innovation Platform approach, which is becoming more important in the Lao context, and is in line with national research priorities. Committees established within ministries also undertake research for specific purposes, and they are often designed to be cross-sectoral and interdisciplinary. There is a recognition at multiple levels that the existing 'silos' between different research institutes is not conducive to achieving the impacts needed on the ground. Higher level policy makers want to see collaboration between different areas of research in Laos. At the provincial level, new groups are being convened to link Agriculture, Commerce, Traders and Farmers; project staff will be well place to contribute their improved skills in these groups. A total of 59 staff at national, provincial and district levels have been trained in IP application. The first set of training materials for IP in Lao language has been developed and delivered at the provincial and district levels.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

The project has supported research to fine tune management options and the dissemination of dry direct seeding technology in Savannakhet province through the establishment of an Innovation Platform and associated activities. This technique reduces labour requirements in the crop establishment phase. Profitability of DDS ranged from $223 - $568/ha depending on yield and rice prices. Farmers can also contract their services to others, offering an alternative income stream (between $50 - $115/ha); some farmers are able to contract sow an additional 15 hectares on top of their own land. Project research into fertiliser management shows that yield gains are possible with better fertiliser management (i.e. in particular applying P with the seed), even with reduced amounts of fertiliser. Fertiliser management also contributes to weed management by making rice plants more competitive in the early stages of crop establishment.

Families who use dry direct seeding for crop establishment also free women's labour at transplanting time, when they subsequently have more time for other income generating activities (e.g. become a labourer for others, focus on animal production, tailoring, run village shop etc).

Additionally, the project has studied the integration of ducks and fish with dry direct seeded systems; this offers farmers an alternative income source, and potential additional income of around $300 (range -$35 - $326; only one farmer experienced a loss) for duck production and a range of AUD $40 - $1400 for fish over the wet season.

Farmers who have planted forages and use Urea Treated Rice Straw to fatten and sell animals report profits of AUD $80 - $400 per animal over a six month period. Estimated profit of a fattening system for two animals per six months is around $1,091 per year.

Irrigated post-rice crops such as maize have an average return of AUD$205/ha, but variations in average yield and price experienced across project sites impacted on returns, with a potential range from -$505 up to $2,437/ha. This shows the importance of good management, seed quality, an assured water supply and market prices all interacting to influence profitability.

Estimates of integrating the different elements into one system, as is practiced by several of the collaborating farmers shows that profits can be improved by almost 300% while labour actually reduced by 45 - 55%, compared to the baseline. This translates to an annual profit of $1,724 - $2,217 depending on the typology. Additionally, in an integrated system, labour is spread more evenly throughout the year, with implications for household decisions to pursue non-farm work.

8.3.2 Social impacts

The project has contributed to researching and outscaling technologies that save women's labour at key production times. Dry direct seeding allows crop establishment of one hectare of rice to be undertaken in one day (saving around 30 days of – often female – labour compared to transplanting), while still maintaining or improving yields. This also reduces drudgery.

A key feature of the project is its integrated approach that also offers additional options for diversification of existing systems, for example using ducks and fish in dry direct seeded rice paddies to control weeds and as an income generating activity. For little labour investment, farmers can generate income and increase household food security in the wet season, alongside their normal rice production system, and in turn actually save more labour by not having to hand weed.

The project works to enhance systems thinking and draw together multiple stakeholders to understand and address local problems together. This has impact at the community level, where it creates the opportunity to develop and apply more robust and sustainable 'solutions' to common problems, and with benefits that flow throughout the value chain.

8.3.3 Environmental impacts

Through the introduction of pulses and forages for animal feed it is anticipated that pressure on the fragile common grazing lands will be reduced, as reliance on this area will decrease during the dry season. The integrated crop-livestock system will benefit from the shift to a more diverse crop rotation including post-rice pulses, vegetables and forages for ground cover, and increased soil C and N levels. Improved rice establishment under direct seeding will reduce losses of rainfall to deep percolation, and its associated N losses.

8.4 Communication and dissemination activities

8.4.1 Engagement with other relevant projects and meetings

Travelling Roadshow – ACIAR Events Funding

Funding has been approved from ACIAR to host a 'travelling roadshow' to convey key messages to the broader community from a number of past and present ACIAR projects (SMCN/2012/071, CSE/2009/004, CSE/2014/086) related to non-rice crop and livestock production and mechanisation, using a combination of unconventional and conventional extension methods. The main focus of these events will be the introduction of generalised topics through a light-hearted, humoristic education program designed and developed by a team of international and local technical specialists and theatrical performers. The proposed events will be held at local schools in two or three target districts to increase the likelihood of reaching all family members and decision makers. More traditional forms of extension will be delivered concurrently with the 'travelling roadshow', including simple pamphlets/booklets detailing more specific technical solutions. These events also offer an opportunity to connect stakeholders in local agricultural systems, by inviting traders, collectors, machinery and input suppliers, finance institutions etc to attend and interact with farming households.

ASEM/2014/052 Smallholder farmer decision-making and technology adoption in southern Laos: opportunities and constraints

Building on previous research projects in southern Laos, this project aims to improve adoption rates of proven technologies by understanding factors that influence farmers' decision making. Project members have interacted with this project from its inception, including attending planning meetings and training courses. Current proposed links include working with this project to test its Research Discussion Tool as part of the Phonthong IP on onion production, with the ASEM project providing some funding for training activities.

Farmer to farmer links: Australian farmers fundraising rice seeders for southern Lao farmers

Dr Leigh Vial is leading a fundraising effort to link Australian and Lao rice farmers. Australian farmers are being called on to donate funds to purchase dry direct seeding machines, which will be supplied to Lao farmers in southern provinces. This builds on the work done by several ACIAR projects, and makes use of outputs from CSE/2014/086. The report on 'Farmers' experiences with dry direct seeding in Savannakhet' (Reported in Section 7.2.3**Error! Reference source not found.**) is given as background material to this initiative. More information, and a link to the report, is available at http://www.crawfordfund.org/news/rice-seeders-for-lao-farmers/.

World Concern

World Concern are a small NGO operating in Champassak province, including in Phonthong district. As part of their work they have been conducting 'Communication for Development' (C4D) training for young people in their villages, and used one of our farmers in Phontong as a learning site. Photo stories were recorded and subsequently shared with farmers in their villages, as an information source.

World Concern will also join in the delivery of the Events Funding, contributing to this activity by creating a video file for screening on local and national TV as well as social media.

'Food Systems and International Development Workshop: Current Australian Perspectives

This workshop was held by the Fenner School of Environment and Society at The Australian National University in November 2016. The aim of this workshop to take stock of participating Australian researchers' and practitioners' understanding of food security investments in developing countries. The workshop focused on the current state of thinking regarding issues of food systems sustainability, food security policy and practice, policy initiatives, and community development with examples from developing countries.

Dr Liz Clarke presented a summary version of the study on dry direct seeding reported in Section in Section 7.2.3, titled '*Food systems and innovation: A study of farmer experiences and approaches in mechanization in Laos'.*

Capacity Development for Agricultural Innovation Systems (CIRAD/FAO)

The main goal of this development project is making agricultural innovation systems more efficient in meeting the demands of farmers, agri-business and consumers. At a global level, the CDAIS aims to support the development of a Common Framework on Capacity Development for Agricultural Innovation Systems and related activities in the context of the Tropical Agriculture Platform (TAP).

At the country level, activities foreseen by the project include capacity development interventions for selected agricultural innovation partnerships and/or value chains (for example in commercial rice production, cattle production groups, pig production, integrated fish-rice production) and with different national institutions. This project operates in the development sphere, without a research aim in the initial stages. The project commenced in September 2015, and has undertaken a scoping study, and selected case studies on selected 'innovation niches'. More details regarding their operational approach will be available as the project evolves.

At the project's inception meeting in February, there was an opportunity to present the approach and experiences of CSE/2014/086. Project outputs were also presented at an Innovation Fair in May 2017. There is potential to link with this project's work and add value, in terms of contributing supporting research to the development processes, and a stronger and more concerted approach, which might give a better chance for some of these approaches to be institutionalised. Overlapping with this project can also provide continuity in terms of 'extending' an AIS approach to provide a longer time frame for these approaches to be embedded.

International Mechanisation Workshop, Vientiane, November 2015

In November 2015, the first International Mechanisation Workshop for Crop Establishment was held at NAFRI. The aim of the workshop was to determine advantages/disadvantages of mechanized crop establishment methods, particularly seed drill for Laos and Cambodia, and to identify significant areas of research, development and adoption of the mechanized establishment methods. Around thirty participants from Thailand, the Philippines, Australia, Cambodia and Laos attended the meeting. This was an opportunity to present work undertaken both in CSE/2009/004 and CSE/2014/086. Two papers were presented; the first on '*Fertilizer placement for drill-seeding rice in southern Lao PDR: mechanizing traditional Na Phuk',* prepared by Dr Leigh Vial, Dr Tamara Jackson and others. The second presentation focused on 'Suitable direct seeding technology for small scale rainfed lowland rice farmers in southern Laos', and was prepared by Dr Pheng Sengxua and Dr Tamara Jackson. The second paper in particular highlighted the rapid adoption rates in Savannakhet in recent seasons, and provided a good context for the importance of the work being undertaken by various projects. Both papers were well received, and the intention to initiate an Innovation Platform to support this work in Savannakhet was of interest to several participants. Additionally, experiences from other projects in Cambodia and Bangladesh that have operated at the interface of mechanisation and commercialisation were of interest to the current project team.

8.4.2 District field days

District field days were held at the end of the wet season close to harvest to communicate information and project outputs about DDS and associated integrated techniques. In 2015, the following field days and trainings were held, focused on dry direct seeding and integrated systems:

- 2 DAFO training sessions (55 participants, 8 women)
- 3 farmer field days (102 participants, 18 women)
- Assessments (130 responses)

In wet season 2016, field days again focused on dry direct seeding and integrated systems, as requested through the Innovation Platform.

- Training sessions (124)
- Field days (120)

Summary: A total of 179 farmers attended training sessions and 222 attended field days (401).

More than half of the participants did not know about DDS before the field days. Topics included machinery operations, rice growth, effect of fertilizer management, weed control, and integrated duck and rice management.

Feedback from participants regarding DDS:

- Before this field visit 58% of the participants did not know about DDS.
- In evaluating the DDS technologyEvaluate idea of DDS, score 1 (not good) , 2 is ok (17%), 3 good (40%), 4 is very good (3%)
- Farmers like this technology because it saves labour and lowers input costs.
- 94% of farmers said they can apply in their system, 6% are not sure if they can use or not because they do not have access to a machine.
- The main challenges for using transplanting to establish rice is that hiring labour and tractors is difficult, and it is a high input system. Additionally, when rain starts late, the season is delayed.
- 100% of participants think that DDS could solve the problems related to transplanting, particularly for labour.
- 97% of participants say they will use DDS. 3% will not use (mostly due to unsuitable land – toposequence).
- Requirements for new training course: 23% of respondents wanted more training for DDS.

Feedback from participants regarding integrated duck-rice production:

- 25 families in Phalanxai reported that they did not see a good effect of the ducks in the rice paddy, however on this farm the ducks were put into the field too late and did not have the optimal effect.
- 96% of the other respondents say they think this is a good technology to contain weeds, while 4% are not sure.
- 72% say they can use this technology, 28% say they need more training in management of ducks.

Feedback from participants regarding integrated fish-rice production:

- 80% of participants said this is very good technology, while 20% lack knowledge and are concerned that it is not always suitable in rainfed areas.
- 72% of respondents say they can apply this technology in their system, while 28% say it will not work in their situation.

8.4.3 Support materials

- Preparation of support materials for crop and livestock production was undertaken in CSE/2009/004 Variance 5, reported in the CSE/2009/004 Final Report (http://aciar.gov.au/publication/fr2016-04). The following materials were printed and distributed to project partners: Posters (2,500), pamphlets (800), booklets (300). These were disseminated through PAFO and DAFO in relevant areas, including supply to external partners i.e. machinery manufacturers, colleges etc.
- A video for management and implementation of Dry Direct Seeding is being prepared with additional funding from ACIAR made available by the LWR/2008/015 team. As the project had already decided to produce a similar video, rather than duplicate this work, the project team are commenting on its draft version, and have committed funds for screening the final version. This was undertaken in conjunction with CSE/2012/077 and LWR/2008/015.

9 Conclusions and recommendations

9.1 Conclusions

The agricultural and development issues prevalent in southern Laos are complex. Extensive rural poverty, limited resources, poor market access, and weak infrastructure and institutions impede farmer productivity and profitability. This project has tested suitable integrated crop-livestock systems that build on previous work. Technologies have been selected that are relevant and in demand from farmers, with a better likelihood of adoption. Real progress has been made in understanding the wider systems of cattle marketing, post-rice crop production, and the transition to mechanised rice production. This includes supporting the direct seeding technology, helping to outscale this technology on many thousands of hectares, with an estimated 8,000 households now using the technology (this conservative estimate is based on PAFO reports of area in 2016). Other provinces are also interested in this technology, and can learn from the experience in Savannakhet. Integrated management options have been tested, discussed with and refined by farmers. DAFO and PAFO staff capacity has increased in terms of technical knowledge, as well as their ability to analyse the wider system. The wider system, stakeholders and their interactions are better understood. Post-rice options that fit within this system (e.g. maize, peanuts) have continued to be tested, and show promise, particularly with changes to available residual moisture that might be available in direct seeded systems. The project has worked to better understand cattle production and marketing systems in Phin district, and has identified opportunities for improved production, with good champion farmers evident. This research into forages is different to the experience in northern Laos, and needs to be continued to keep momentum to benefit smallholders.

The context for agricultural production in Laos is experiencing rapid change with a move from subsistence into a commercially based sector. Recent major changes to the economic operating environment include Laos' admission into the World Trade Organisation in 2012, and the establishment of the Association of Southeast Asian Nations (ASEAN) Economic Community in 2015 (Castella and Bouahom 2014). There is recognition of this change at all levels, from senior government officials through to farmers, and a desire to ensure that farmers can maximise the opportunities available to them. In addition to being beneficial for farmers and local government, IP is a way to help the local commercial sector to understand and interact with the wider system, to ensure that they remain competitive in the context of an increasingly regional economy. The IP approach has been introduced at different levels, and opportunities to apply practical skills in working with multi-stakeholder groups have built capacity to work in this space. For these reasons, the IP approach can be valuable for Laos, but requires longer time frames to reveal the full benefits, in line with the priorities of the Lao Government.

In the current context, there is also an understanding that individual disciplinary research alone is not sufficient, and consequently a systems research approach is required to complement commodity and resource investigations in order to understand constraints and develop scalable and commercial solutions to improve rural livelihoods and the local economy (Lele and Norgaard 2005). Acknowledging that the surrounding context is changing is one thing; being able to respond effectively is the next step. This project has built capacity in systems thinking and multi-stakeholder approaches that have been adapted to fit within existing networks, with high relevance to local initiatives at the provincial level that can help to improve rural livelihoods.

9.2 Recommendations

Given the array of outputs from this project, there are several potential opportunities for ongoing research and development activities that would build on this base. There are key focus areas that could be delivered under an overarching systems framework that is needed to support these initiatives. These focus areas recognise that there is already a movement towards adoption, but acknowledges that there are a range of challenges for successful implementation.

1. Continued support for dry direct seeding and interactions within the system (i.e. refined weed and nutrient management approaches, water balance study to quantify residual water availability in direct seeded systems).
2. Non-rice crops that fit within the system, particularly options for modifications given changing crop establishment approaches, water availability etc.
3. Cattle production systems, including marketing, improved feed resources and management strategies that incorporate value adding, for example in fattening systems using locally available feed resources (e.g. cassava, maize).
4. Integrated crop-livestock systems as a basis for modernisation of smallholder farming systems, including useful measures of integration impacts.

The current project has demonstrated robust individual technologies, as well as estimating potential impacts at the farm level for single and integrated technologies. These technologies have a place within different agro-ecological typologies, but the resulting systems would demonstrate different adaptations in different locations, including in terms of market interactions. How these technologies interact with typology, available resources and risk has been conceptualised, but not measured in detail. In any subsequent research, these key elements should be considered and quantified for the adapted integrated systems. Such research would need continued support from various sources, including technical as well institutionally. Local colleagues have reiterated that the GoL or NAFRI should continue to support and implement the IP approach initiated in this project, including the work with the value chain, so that the approach becomes more common. They see this as an opportunity to empower smallholders within the changing context, with opportunities to encourage entrepreneurship.

Any future research should take advantage of the capacity that has been built at local, provincial and national levels; this includes young government staff who will soon return with higher degrees from internationally recognised universities, and who would benefit hugely from an opportunity to gain experience in implementing research with strong oversight and mentoring.

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Zelalem L, Schut M (2013) Guidelines for innovation platforms: Research and innovation platforms. ILRI, Nairobi

10.2 List of publications produced by project

10.2.1 Journal papers

Published

Samson B, Voradeth S, Zhang S, Tao D, Xayavong S, Khammone T, Douangboupha K, Sihathep V, Sengxua P, Phimphachanhvongsod V, Bouahom B, Jackson T, Harnpichitvitaya D, Hu F & Wade LJ (Accepted). Performance and survival of perennial rice derivatives (*Oryza sativa* L./*Oryza longistaminata*) in Lao PDR. *Experimental Agriculture.*

Zhang S, Hu J, Yang C, Liu H, Yang F, Zhou J, Samson B, Boulaphanh C, Huang L, Huang G, Zhang J, Huang W, Tao D, Harnpichitvitaya D, Wade L & Hu F (2017). Genotype by environment interactions for grain yield of perennial rice derivatives (*Oryza sativa* L./*Oryza longistaminata*)in southern China and Laos. *Field Crops Research.*

Accepted

Sengxua P, Samson B, Bounphanousay C, Xayavong S, Douangboupha K, Harnpichitvitaya D, Jackson T & Wade LJ (Accepted). Adaptation of rice (*Oryza sativa* L.) genotypes in the rainfed lowlands of Lao PDR. *Journal of Plant Production Science*.

Submitted

Jackson TM, Sengxua P, Samson B, Vial LK, Molesworth A, Vorlasan S, Simali P, Newby J, Harnpichitvitaya D & Wade LJ (Under Review). Options for intensifying lowland rice-based farming systems in water stressed environments of southern Lao PDR. Submitted to *Water Resources and Rural Development*.

Jackson TM, Sengxua P, Tiemann T, Molesworth A, Khampoumee S, Harnpitchitvitya D, Phimphachanvongsod V & Wade LJ (Under Review). Options for strengthened integration of crop-livestock enterprises in lowland farming systems of southern Lao PDR. Submitted to the *International Journal of Agricultural Sustainability*.

Sengxua P, Jackson TM, Simali P, Vial LK, Douangboupha K, Clarke E, Harnpitchitvitya D B & Wade LJ (Under Review). Integrated nutrient-weed management under mechanised dry direct-seeding (DDS) is essential for sustained smallholder adoption in rainfed lowland rice (Oryza sativa L.) (Under Review). Submitted to *Agricultural Systems*.

Clarke L, Jackson TM, Keoka K, Phimphachanvongsod V, Sengxua P, Simali P & Wade LJ (Under Review). Insights into adoption of farming practices through multiple lenses: an innovation systems approach. Submitted to *Development in Practice*.

Publications plan

Table 19 Publications plan with progress for each paper

Paper title and journal		Data set available	Outlined	Compiled	Analysed	First draft	Full draft	Submitted	Revised	Accepted	Published
1	Genotype by environment interactions for grain yield of perennial rice derivatives (Oryza sativa L./Oryza longistaminata)in southern China and Laos (Field Crops Research)										
2	Performance and survival of perennial rice derivatives (Oryza sativa L./Oryza longistaminata) in Lao PDR (Experimental Agriculture)										
3	Adaptation of rice (*Oryza sativa* L.) cultivars in the rainfed lowlands of Lao PDR (Plant Production Science)										
4	Options for intensifying lowland rice-based farming systems in water stressed environments of southern Lao PDR (Submitted to Water Resources and Rural Development)										
5	Options for strengthened integration of crop-livestock enterprises in lowland farming systems of southern Lao PDR (Submitted to International Journal of Agricultural Sustainability)										
6	Building capacity for a changing world; practical skills for addressing challenges in agricultural systems (Submitted to Asian Journal of Agriculture and Development)										
7	Integrated nutrient-weed management under mechanised dry direct-seeding (DDS) is essential for sustained smallholder adoption in rainfed lowland rice (Oryza sativa L.) (Submitted to Agricultural Systems)										
8	Insights into adoption of farming practices through multiple lenses: an innovation systems approach (Submitted to Development in Practice)										
9	Performance and water use of mungbean (*Vigna radiata* (L.) R Wilczek) genotypes in southern Lao PDR (Agricultural Water Management)										
10	Nutrient x Water x Variety interactions in rice (Field Crops Research)										
11	Intercropping										
12	Performance and water use of legumes (soybean, peanut) in southern Lao PDR (Agricultural Water Management)										
13	Forage genotype by environment interactions										
14	Forage Biomass of Selected Grasses and Legumes in the Southern Lao PDR Lowlands (Experimental Agriculture)										
15	Upland ricegenotype by environment interactions (Field Crops Research)										
16	TDK1-Sub1 genotype by environment interactions (Euphytica)										
17	Site specific nutrient management										
18	Diversification of upland systems										
19	DDS Systems Paper										
20	Bentonite										

21	Systems integration										
22	Nested analyses (methods, how to analyse)										
23	Innovation Platforms (Development in Practice)										

10.2.2 Conference papers

Clarke, E & Jackson, T.M. (2016). *Food systems and innovation: A study of farmer experiences and approaches in mechanization in Laos.* Paper presented at the Food Systems and International Development Workshop: Current Australian Perspectives; November 14, 2016; The Australian National University.

10.2.3 Theses

Molesworth, A. (2015). *The role of crop residues for fodder in crop-livestock systems in southern Lao PDR for improved resilience to climate change.* Charles Sturt University, Wagga Wagga.

10.2.4 Working reports

Clarke E, Jackson T, Keoka K, Phimphachanvongsod V (2016) Study of farmer experiences and approaches with mechanised dry direct seeding in Savannakhet province. Canberra, ACT

Jackson T, Molesworth A, Wade L, Sengxua P & Phimphachanvongsod V (2016). Systems Approaches to Research and Development in Lao PDR. Literature Review.