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

Crop-livestock systems platform for capacity building, testing practices, commercialisation and community learning

CSE/2014/086

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Executive summary

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 is designed as part of a bigger project that was initiated to investigate and trial systems approaches to integration and innovation in farming systems in southern Laos (CSE/2014/086). It focuses 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. 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.

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. These issues will be followed up as part of CSE/2014/086, using a multi-stakeholder group approach.

1 Introduction

Mechanised dry direct seeding (DDS) is a crop establishment technique that reduces labour requirements and production costs, and allows farmers flexibility in terms of earlier planting times. A number of projects have concurrently trialled DDS in Savannakhet province since 2010. During that time, the area of lowland rice planted using DDS has rapidly increased, along with the number of machines available. For example, the area planted using DDS increased from an estimated 80 hectares in 2014 to over 800 hectares in the 2015 wet season (Savannakhet Provincial Agriculture and Forestry Office, 2016) (Table 1).

Table 1 Area planted using the DDS technique in Savannakhet province in 2014-2015

District	Area (ha)	
	2014	*2015*
Champhone	53.96	583.94
Outhomphone	21.45	108.9
Kaisone Phomvihane	0.7	5.5
Atsaphangthong	0	32.4
Phalanxay	0	12
Phin	0	6.5
Xaybouly	0	3
Xayphutong	0	77.81
Sonbouly	1	3.4
Songkhon	2.7	2.38
Total	**79.81**	**835.83**

However, while adoption and trialling of DDS has increased very rapidly among farmers in some districts in Savannakhet in the last two seasons, there is currently very little documented knowledge about the process, motivations, experience or outcomes of this rapid increase among farmers, although perceptions on climate change adaptation options, including DDS, have been documented in unpublished reports (Chialue et al., 2014). In addition, there is generally a lack of information about innovation and adoption processes for farmers in southern Laos, though there are related studies in the northern uplands of Laos (Roberts, 2015; Alexander et al., 2010). This study has been initiated to provide some insights into these processes, and to complement studies from other ACIAR projects in southern Laos involved in improving farming systems (CSE/2009/004), farmer responses to climate change (LWR/2008/019), mechanization and value adding for diversification of lowland cropping systems (CSE/2012/077) and farmer decision-making (ASEM/2014/052); see Table 2 for more details.

This ACIAR project 'Crop-livestock systems platforms for capacity building, testing practices, community learning and commercialisation' (CSE/2014/086) has been initiated to investigate and trial systems approaches to integration and innovation in farming systems in southern Laos. One of the aims of the project is to study existing innovation networks and processes and their

effectiveness, and to explore the potential to establish multi-stakeholder groups to support these processes.

This study is designed as part of the project, and will look specifically and in some detail at the experiences and perspectives of households who have either trialled or adopted DDS. This is an in-depth study of a small group of households, and is intentionally designed to complement the broader, more comprehensive data gathering across the three Savannakhet districts being studied in the project. These separate activities, along with existing reports (Vial & Newby, 2014; Laing et al., 2015), provide quantification of technical elements of the DDS technique (productivity, labour use, economic returns). This study highlights farmers' experiences with using DDS, and identifies key processes and challenges in using this technique within the lowland farming system. The outcomes can be used as a base from which to understand innovation within the farming system, and to focus priorities for future research and development approaches.

1.1 Background

1.1.1 Lowland rice production and dry direct seeding

Rice is central to not only the farming systems but to the culture of Laos, and is a staple food and a core contributor to food security for most of the population. Rice production is also a priority for government policy, with the most recent Agriculture Development Strategy to 2025 and Vision to 2030 (Government of Laos, 2015), focused on improving food security, commercialisation and the application of appropriate new agricultural production techniques and Good Agricultural Practices for improved quality and productivity. However, there are a range of pressures on the rice production system that interact to influence productivity. Different techniques are required to enhance adaptation to changing physical and socio-economic conditions. Lowland rice in southern Laos is traditionally grown using hand transplanting techniques for crop establishment. Farmers usually prepare between two and four rice seedling nurseries, each sown several weeks apart. These are sown from April onwards, and are dependent on early season rainfall in most cases, where alternative water sources are not available. Typically, farmers manage production risk in part by using rice varieties with different maturation periods. This is in order to better manage labour availability particularly during the transplanting and harvesting period, and to reduce losses caused by variable climate or pest infestation. Paddy land is ploughed and harrowed, and once standing water is available after sufficient rainfall, seedlings are transplanted into the paddies. Transplanting is labour intensive, requiring between 20 and 30 person-days per hectare, and is heavily reliant on the timing of monsoonal rains. An alternative is to sow rice directly into the paddy through different 'direct seeding' techniques, for example broadcasting seed by hand directly into the paddy, sowing pre-germinated seed in rows into wet conditions with a manual machine, and 'dry' direct seeding, which is a mechanical sowing approach that places seed (and often fertilizer) in rows, directly into the paddy. This technique saves labour as it requires only one day to sow one hectare, and it is also less reliant on the onset of monsoon rains. As the name suggests, crops are established in dry conditions and can make use of the pre-monsoon showers for establishment (Mazid et al., 2002).

DDS has been demonstrated to save labour requirements for rice production by between 10 – 30% (Vial & Newby, 2014), depending on the weed management options used. Importantly, it reduces

the time taken for crop establishment (including nursery preparation and transplanting) from around 33 person-days per hectare, to just one day. In economic terms, DDS can return higher gross margins of up to 50 – 80% compared to transplanting, as long as weeds are controlled well (Laing et al., 2015). These benefits are confirmed by farmers taking part in this study, although these elements of the technique have not been quantified here.

1.1.2 Factors affecting rice production in Savannakhet

Geography and climate: The lowland plains of Savannakhet province make it the biggest producer of rice in Laos, with a 20% share of the country's total production (World Food Program, 2013). The province has extensive lowland paddy areas (>200,000 ha), as well as several irrigated areas that allow the potential for crop production in the dry season on about 30,000 ha. Rainfed rice is grown in bunded paddies, whose location is usually described in terms of the location within the toposequence, as upper, middle and lower terraces (Wade et al., 1999). Soil type and hence water holding capacity generally change with position, with upper terraces tending to have sandier soils and lower water holding capacity and lower terraces tending more to clay soils with better water holding properties (Samson et al., 2004; Schiller et al., 2006). The soils in this region are predominantly loams, sandy loams and sands, and are particularly drought prone (Lathvilayvong et al., 1996). Sandy soils and the upper and middle terrace types make up around 70% of the lowland paddy area in Savannakhet province (Lathvilayvong, personal communication). The interaction of location and soil type has important consequences for drought effects on crop production, and on the kinds of technologies (including machinery) that can be used. DDS is less suitable for clay soils with currently available machinery, but at the same time requires a level of water holding capacity greater than the very sandy soils offer.

The dependence on rainfall makes lowland rice production very risky, as rainfall is highly variable in southern Laos, and Savannakhet province suffers from early or late wet season drought almost every year (Eliste et al., 2012). The general pattern of rainfall in southern Laos is weakly bimodal, with a minor peak around May and a major peak in August - September. Early wet season drought is common from mid-May to mid-June (Schiller et al., 2006). At the same time, flood events are also common in some areas, and it is not unusual for different parts of the province to suffer drought and flood events at the same time, for example drought conditions in the central and eastern districts between June and September while floods affect districts along the major rivers of the Se Bangfai and Xe Banghiang (World Food Program, 2013). Strategies to cope with climate variability are necessary to deal with such an extreme production environment, and farmers have been adapting to this variability for many years, including by using different varieties, staggering crop establishment, using low levels of inputs and diversifying their income streams.

International markets: Savannakhet province serves as a connection between Thailand and Vietnam, and is known as the East-West Economic Corridor. For this reason, there are active economic links with both Thailand and Vietnam, and significant quantities of rice exports to these countries, although much of this is through informal means and is not captured by official statistics (Eliste et al., 2012). China is another major export destination, with a recent formal agreement between the Yunnan Provincial Government and the Lao Ministry of Agriculture setting a target of 100,000 tonnes of rice to be exported in the coming years. Savannakhet province is expected to

contribute significantly to this quota, with up to 4,000 - 5,000 tonnes per year. Several areas, particularly within Champhone and Xaybouly districts, have been designated as focal areas to improve rice productivity as part of the Agricultural Development Strategy to 2025 (Government of Laos, 2015).

Commercialisation: Several large rice mill operations exist, including new mills that have been built within the last two years. Despite the focus on commercialization of the rice sector, rainfed wet season rice continues to be the most important crop, usually produced for household subsistence. However, an increasing number of farmers (up to 71%) report the sale of some rice, and around 30% report their main goal as producing rice for sale rather than subsistence (Eliste et al., 2012).

Migration: Savannakhet's close external links, in particular to Thailand, manifest in another important social factor within the province, which is the out-migration of (usually young) family members into Thailand or domestically to work in non-farm sectors. In a study in 2011, 42% of families surveyed in Outhomphone district (close to the Thai border) were found to have at least one family member working in Thailand, with the incidence decreasing with distance from the border (Newby et al., 2013). The industry and services sector is growing in importance in the province (International Union for Conservation of Nature, 2011), and with the expansion of the Special Economic Zone in Savannakhet, opportunities for non-farm work are increasing. With a current workforce of around 5,000 people, the projected requirement is up to 20,000 people by 2020, mostly from the surrounding districts (Deputy-Director of Savan-Seno Special Economic Zone, Personal Communication). This situation is important for several reasons; first, it reduces the available workforce, and has lead to increased daily wage rates at key rice production times such as transplanting and harvesting. Second, the remittances sent back to families often form a significant part of the household's cash income. These factors make mechanized approaches to crop production attractive, since they can help to solve the labour shortage problem, and may also provide a means for households to invest in machinery.

The factors of resource availability (land, water), climate, farmers' goals, labour availability and purchasing power interact to influence rice production in Savannakhet, and different management options are required for farmers to be able to adapt to these challenges. DDS is one such technique that can help farmers adapt to climate variability and labour shortages.

1.1.3 Key projects influencing the uptake of technology

In conjunction with the Savannakhet Provincial Agriculture and Forestry Office (PAFO) Crop and Agricultural Land Management sections, several research and development projects have worked on DDS in the province for over a decade. Within Laos, direct seeding has been tested and practiced on a small scale since the 1990s, including manual broadcasting and mechanical wet and dry direct seeding (Fukai et al., 1998; Schiller et al., 2006). Previous trials included comparison of yield performance, varietal performance and seeding rates. Promising results in terms of labour savings and improved gross margins as described previously saw PAFO request all relevant projects in recent years to consider extending their support for DDS. In particular during the wet season of 2015, DDS technology started to be adopted on a wider scale; PAFO Savannakhet reports a ten-fold increase in the area planted using DDS in 2015, more than 800 ha compared to 80 ha in the

previous wet season (Savannakhet Provincial Agriculture and Forestry Office, 2016). Similar observations have been made by local machinery suppliers and commercial rice processors.

Table 2 shows details of the various research and development projects and their focus with the DDS technology. Activities have focused primarily in Champhone and Outomphone districts, with some work also undertaken more recently in Phin and Phalanxai districts. There have been a range of activities undertaken, including:

- Research into weed management
- Research into fertilizer management; placement and rates
- Livestock integration with duck and fish for weed control, improved fertility and cash income
- Project-supported demonstration sites, including provision of machines to groups of farmers through an ADB-IFAD development project
- Training in operation and management practices associated with the DDS
- Cross-site visits for farmers from other villages, districts and provinces
- Trialling the local manufacture of DDS machines in Savannakhet (two machines produced by a local machinery workshop in 2013)
- Development and dissemination of extension materials (posters, pamphlets, instructional video)

Table 2 Projects and intervention approaches for dry direct seeding in Savannakhet.

Project	**Relevant DDS activities**
ACIAR 2007 - 2012 CSE/2006/041 Increased productivity and profitability of rice-based lowland cropping systems in Lao PDR	Focused on intensification and diversification of irrigated rice-based cropping systems in the lowlands (Vientiane, Savannakhet, Champassak), including farmers' preferences of improved rice varieties, direct seeded rice performance, fertiliser placement with drill-seeded rice and drought risk assessments.
ACIAR 2009 - 2015 CSE/2009/004 Developing improved farming and marketing systems in rainfed regions of southern Lao PDR	Focused on direct seeding as a management technique for improved lowland rice production. Conducted research trials (weed and fertiliser management), demonstrations, cross-site visits, and created links with machinery manufacturers.
ADB-IFAD 2009 - 2015 Sustainable Natural Resource Management and Productivity Enhancement Program	Focused on lowland and upland community based income generation and development activities in southern Lao PDR. Conducted demonstrations and training and provided machines to groups of farmers (28 machines in four districts of Savannakhet).

ACIAR 2010 - 2014 LWR/2008/019 Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India (ACCA)	Focused on direct seeding as a tool for climate change adaptation to address high variability of early season rainfall and end of season drought. Conducted on-farm research and demonstration trials, training of farmer groups, and provided inputs for policy discussion. Additionally, used the APSIM model to simulate wet season rice production for current and future scenarios. The modeling clearly confirmed DDS as an effective strategy to minimise current climate risk, as well as being a likely effective adaptation practice for the future.
ACIAR 2013 – 2014 LWR/2012/110 Regional co-learning in simple mechanised tools for rice planting	This project built on the field work undertaken in LWR/2008/019, and conducted on-farm testing of mechanised rice establishment methods, with between 9 – 65 farmers participating. There was a focus on weed and fertilizer management. Local-language information materials on mechanised rice establishment were produced. Additionally, it facilitated links between Lao, Cambodian and Thai researchers, and supported Masters students in Lao PDR and Thailand.
ACIAR 2015 LARF 62 Comparison of fertiliser use when applied by direct seeder vs broadcast application after germination	Research trial for fertiliser management with DDS (Mr Sysavanh Vorlason, who has also worked with several ACIAR projects).
ACIAR 2015 - 2016 CSE/2014/086 Crop-livestock systems platforms for capacity building, testing practices, community learning and commercialisation	Demonstration sites, integrated crop-livestock systems (duck and fish) for weed control, improved fertility and productivity, fertiliser management trials, surveys to understand farmers' experiences and technical applications, and establishment of a multi-stakeholder group to support the development and outscaling of the DDS technique in the province.

It is important to note that there have been a range of machines tested in different projects, with different mechanisms (tynes vs discs; circular vs rolling seed dispersal mechanisms etc). There are currently six main types of machines being used by farmers:

1. A Thai seeder, available for purchase through Xangpheuak shop in Savannakhet city, Ban Lak 35, Songkhone and Xethamouak. These are both 4 and 6 row planters: they have no fertilizer box and are of low quality, but are affordable for farmers (around 2.3 million Laotian Kip (LAK[1]))

2. A Thai machine imported by PAFO. This machine has 4 rows without a fertilizer box: they are 1 million kip higher than the type sold by Xangpheuak shop (around 3 million LAK)

3. A Thai machine imported by PAFO. This machine has 4 rows, modified with a fertilizer box. This is the most popular and in-demand type at the moment, but the price is quite high and beyond the purchase power of many farmers (around 6 million LAK).

4. The Indian seeder type provided by the ADB-IFAD SNRMPEP project. This machine is seen as too heavy and many machines are not in use, but have been left in the storage houses in designated villages (e.g. Ban Thouad). According to a local stakeholder, the machine requires modification to suit the location.

5. The prototype machine manufactured in Savannakhet, supported by Dr. Leigh Vial from IRRI and in conjunction with CSE/2009/004 and LWR/2008/019. This machine is still in use, but with modifications (around 10 million LAK)

6. Home-made machine, copied from the Thai type (type 1 and 2 in this list).

With rapid use of the technique unfolding, there is a need to understand and document the processes, triggers and experiences associated with the DDS technology. Such a study can also contribute more widely to an understanding of the innovation process, in terms of how new knowledge is created and importantly, put into use. This allows 'real-time' monitoring of the early stages of adoption, and can provide practical application for local stakeholders to build skills in documenting and assessing innovation processes. This in-depth study is designed to look specifically and in some detail at the experiences and perspectives of farmers with the DDS technology; it is designed to complement existing studies and the broader data gathering across the three Savannakhet districts being studied in this project.

[1] In April 2016, USD$1 = 8,120 LAK

2 Research approach

2.1 Objectives

- To document the process of trialling and potential adoption of dry direct seeding in farming systems in Savannakhet.
- To use the example of uptake of dry direct seeding to learn lessons and inform future research questions on innovation processes, motivations and needs for farmers in southern Laos.
- To learn lessons to inform design and development of future innovation networks for southern Laos.

2.2 Research questions

1. What are the ***motivations*** for farmers to trial and/or adopt dry direct seeding in Savannakhet?
2. What were the ***key factors or triggers that assisted or hindered*** farmers to trial or adopt dry direct seeding (e.g. climate and weather conditions, labour etc)?
3. What have been the ***different experiences of farmers trialling*** dry direct seeding, including with the process of learning and adaptation?
4. What are some of the ***key problems/risks*** associated with dry direct seeding technology?
5. How does ***risk profile*** vary depending on experience, history, research and development interventions and trajectories?
6. What are the ***implications*** of these learnings ***for future innovation processes*** in Lao farming systems?

2.3 Research design

A qualitative (and to some extent ethnographic) approach was used in the study, via interviews with a relatively small sample of participants (n=17) to elucidate narratives about their experiences and perspectives. Interviews were semi-structured, using an interview protocol as a guide (see Appendix A). The interviews involved unstructured and open-ended questions that were few in number, and aimed at elucidating the views and opinions of the interviewees. Interviewees were purposively sampled to ensure that they had enough experience with the DDS technique to be able to give detailed responses about the technique, and specifically included female members of the household to ensure their opinions were recorded.

2.4 Research framework

2.4.1 Interviewees and sampling approach

Research focused on areas in Savannakhet province where DDS has been trialled or adopted by farmers and included three districts: Champone (6 farmers), Outhomphone (4 farmers, 1 DAFO staff) and Phin (4 farmers).

Interviewees included farmers, PAFO and DAFO staff involved in DDS, and a machinery distributor in Savannakhet. Purposive sampling was used to specifically include a variety of different perspectives and experiences with DDS, including different interventions in the villages (Table 2).

A total of 17 semi-structured interviews were carried out (14 households and three key actors in the system from DAFO, PAFO and machinery distributor), with details provided in Table 3.

Table 3 Farmer participants

Village	Farmer	Paddy area	Household labour	Main enterprises	Irrigation access	Off-farm income	Experience with DDS
Champhone district							
Ban Alan Watana	Mr S	4.0	3	Rice (wet and dry season), vegetables, livestock (fish, ducks)	Scheme	DDS contractor, transplanting	Attended training in 2013 in his village. Tested on-farm in 2013 (1 ha). In 2014 planted all area. Uses DDS in wet and dry season. Now local technical advisor and contractor (charges 200, 000 LAK/ha in village, 700,000 LAK/ha outside village). Will continue in 2016.
	Mr L	3.0	3	Rice (wet and dry season), vegetables, livestock (pigs, poultry)	None	DDS contractor	Attended training in 2013 in his village. Tested on-farm in 2013 (1 ha) using Dr Leigh's machine. In 2015 applied on all land. Uses DDS in wet and dry season (on rented land). Acts as contractor. Will continue in 2016.
	Mr B	5.0	5	Rice (wet and dry season), vegetables, livestock (poultry)	Scheme	Store in village	Tested on-farm in 2015 (1 ha) using a contractor. May not continue in 2016.
Ban Touat	Mr B	1.0	2	Rice (wet and dry season, seed, organic), vegetables, livestock (fish, buffalo, goats, poultry)	Scheme	None	Introduced to DDS with ACIAR project in 2012, attended trainings. Tested 0.5 ha first year. Grows wet and dry season rice (1.5 ha). Local technical advisor and learning sites for other farmers. Contractor (charges 250,000 LAK/ha). Will buy seeder.
Ban Kaengkok Thong	Mr M	2.0	1	Rice	None	Remittances from Thailand (3), government staff (DAFO), government pension, DDS contractor	Former DAFO staff member, worked with ACCA project. Purchased machine in 2013 (from PAFO) and tested on-farm (1 ha). Contractor since 2013 (charges 700,000 LAK/ha). Local technical advisor. Will continue in 2016.
Ban Phaykhong	Mr N	4.0	2	Rice, livestock (fish, ducks, cattle, buffalo)	Scheme	Weaving	Tested on-farm with CLSP in DS 2014 (1 ha). Purchased machine in 2015. Planted all land (4ha) in wet season 2015, and acted as contractor (charges 600,000 LAK/ha). Integrated fish-ducks into paddy. Will continue in 2016.

Outomphone district							
Ban Phoneyanyang	Mr T	3.0	3	Rice	None	Remittances from Nikon Factory (2), contract builder, DDS contractor	Attended training in Ban Phin Tay in 2013. Prior experience in wet DS. Purchased machine in Savannakhet (from PAFO) and tested on-farm in 2013 and 2014 (1.5 ha). DDS contractor (charges 300,000 LAK/ha) and local technical advisor. Will continue in 2016.
	Mr P	3.0	3	Rice, livestock	None	Remittances from Thailand (2)	Friend of Mr T, observed his fields as demonstration (2013 – 2014). Used contractor to plant 1.5 ha in 2015. Will continue in 2016.
	Mr K	6.0	2	Rice, vegetables, contract sugar cane, livestock (cattle, poultry)	None	Remittances from Nikon Factory (2), school teacher	Attended training in 2014 and visited Mr T's fields to observe. Used contractor to plant 2 ha in 2015. Will purchase machine in 2016.
Ban Nahongyai	Mr L	3.0	1.5	Rice, vegetables, livestock (poultry)	None	Remittances from Thailand (8)	Friend of Mr T, observed his fields as demonstration (2013 – 2014). Used Mr T as contractor to plant 1.5 ha in 2015. Will continue in 2016.
Phin District							
Ban Phin	Mr V	3.0	6	Rice, livestock (ducks, fish, goats, chicken, pigs)	Pond	DAFO staff	DAFO staff member and wife who have worked with the SLP and CLSP projects. Tested DDS on-farm in 2015 (0.4 ha), integrated duck-fish, hosted field visit/training in 2015. Will continue in 2016.
Ban Napo	Mrs S	3.8	4	Rice, dry season vegetables, livestock (cattle), handicrafts (weaving)	Pond	UXO Laos, pension/salaries	Has worked with the CLSP project. Attended training session in May 2015. Tested DDS on-farm in 2015 (0.2 ha). Will continue in 2016.
Ban Khamsa-e	Mr K	3.0	2	Rice, livestock, (cattle, buffaloes, chickens), wet season vegetables	None		Attended training in Outhomphone in 2014. Borrowed machine and tested DDS on-farm (1 ha) in 2014. In 2015 applied DDS on all land (3 ha). Will continue in 2016.
	Mr B	5.0	3	Rice, vegetables, livestock (cattle, buffalo)	None	Remittances from Thailand (2)	Attended training in Outhomphone in 2014. Purchased seeder in Thailand in 2014. Tested on-farm in 2014 and 2015 (2 ha). Will continue in 2016.

Additional interviews:

1. PAFO land management staff in Savannakhet (1)
2. DAFO staff from selected districts (1)
3. Machinery seller in Savannakhet (1)

2.4.2 Documentation

Interviews were conducted in a location convenient to the farm households, with three people present including an independent consultant (interviewer), NAFRI staff member (scribe) and PAFO staff member with experience in the DDS technique. Guiding questions are shown in Appendix A. All interviews were conducted in Lao language, with detailed notes taken in Lao language during each interview to represent the language and content of the interview as closely as possible. These notes were then later translated into English by an independent Lao consultant.

2.5 Analysis

The data were organised through narrative development, emergent themes, orienting concepts and pattern recognition (Cresswell, 2009; Jupp, 2006; Patton, 2002). Data were then coded according to key concepts, recurrent themes and the analytical framework with reference to Agricultural Innovation Systems (The World Bank, 2006). Sensitizing concepts[2] were used as a means to guide the direction of the data interpretation and analysis and to allow for these concepts to develop over the course of the analysis process.

2.5.1 Innovation systems analytical framework

The analytical framework for the study is 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 extension agents, and the interactions between them and other stakeholders, are key steps towards understanding and supporting change.

[2] A sensitizing concept in social science is a set of provisional notions or concepts that can be used for initial data analysis to allow for a more open and appreciative approach. This can also include (but is not restricted to) words and meanings that are prevalent among the people being studied (Patton, 2002).

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. A series of questions can be used to guide the analysis of an innovation system, to understand factors that promote or inhibit innovation, and to design interventions to increase innovation capacity. The World Bank (2006) innovation systems framework considers four aspects of innovation systems, and the following are adapted from this source:

- 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. Data analysis from this study has been carried out according to these four elements of innovation systems, explained in more detail below (Table 4).

Table 4 The adapted innovation systems framework and relation to the research questions posed.

Innovation systems framework	Research questions
1. Actors, roles they play and activities in which they are involved ○ Who are the various actors – private, public sector – and how do they interact? ○ How do these actors relate to the institutional and policy settings in Laos? What roles do they play, what roles could they play? What do they talk about doing?	How does risk profile vary depending on experience, history, research and development interventions and trajectories?
2. Attitudes and practices of the main actors ○ What attitudes did the informants express, and how did they see this enabling or restricting collaboration between actors? ○ What kind of behaviours were documented or observed? How were these seen to contribute to or hinder innovation? ○ What practices were relevant to DDS innovation, and how did these contribute and/or change according to the informants? ○ Do patterns of reciprocity and trust exist and are these a foundation for future collaboration? ○ Does a culture of innovation exist? E.g. is there demand for research from the private sector? Is there an emphasis on capacity building? Do organisations deal with current problems and opportunities in a reactive way? Are there collaborative arrangements for knowledge sharing and are they common? Is there an emphasis on technical learning and institutional learning (accessing and using knowledge more effectively)?	What are the motivations for farmers' to trial or adopt DDS in Savannakhet? What have been the different experiences and processes in trialling the DDS? What are some of the key problems and risks associated with the technology?

3. Patterns of interaction ○ What patterns of interaction and relevant relationships emerged from the interviews, and what was their impact? ○ What if any, participation is observed of the poorest in the innovation process?? Is there potential for them to participate, or do there need to be intermediate steps? (risk is an issue here) ○ Are there sector coordinating or other bodies present? ○ Are there stakeholder bodies (i.e. farmer, community and industry groups) and if so, what is the scope of their knowledge based activities? What about village bodies, unions, etc e.g. LWU, village authorities, and what role to they play in this process?	How do the main actors interact, how do their attitudes and practices influence these interactions, and what are the implications of these learnings to support future innovation processes in Lao farming systems?
4. Enabling environment (policies and infrastructure) ○ Are there science and technology policies to promote collaboration? (i.e. competitive grant funds for partnerships); scale up innovations or encourage private research investments? Incentives and blockages to innovation and implementation of new technology and practices?	What were the key factors that assisted or hindered farmers to trial or adopt DDS?

3 Findings

The findings have been organised to align with the innovations systems analytical framework described above.

3.1 Actors, roles and activities

This section of the findings provides an insight into who the key actors are, what their roles are, and the activities they have undertaken in relation to implementation of the DDS technology for lowland rice production. According to innovation systems theory, there needs to be a certain mix of actors and participants working collaboratively, learning by observing first, seeing the outcomes and then adopting and communicating, and forming networks to bring together needed knowledge, experience and skills.

The farmers interviewed in this study were deliberatively sampled to include those who already had experience in DDS. Many of the interviewees held prominent roles in the local community, including the Nai-Ban (village head), teachers, head of the village security unit, local party secretary, agricultural extension officers with the DAFO as well as former army personnel and representatives of mass organisations such as Lao Women's Union, and Laos Front for National Construction. Many families also relied on remittances from off-farm employment, including in the local business park in Savannakhet as well as in Thailand.

In rural development programs it is often useful to identify homogeneous clusters or 'types' of farmers to understand the diversity of farming systems and livelihoods, and the ways in which these factors relate to household goals and decision making. This helps to avoid the idea of 'one size fits all' technologies or policies, while at the same time recognising that it is not possible to tailor programs and policies for every individual (Emtage et al., 2006). A household typology for farmers in Savannakhet province was developed in an earlier project (Newby et al., 2012), and is relevant here. This typology classified households according to their dominant livelihood strategy, further refined by the agro-economic location and asset base. The following livelihood strategies were identified; A. Subsistence-oriented farmers, B. Market-oriented farmers, C. Labour- or migration-oriented households, and D. Diversified households (combining two or more strategies). The households interviewed fitted fairly comprehensively into group C (Labour and migration oriented households – employment oriented) and to some extent into group D (Diversified households). Newby et al. describe group C as comprising around 86% of the lowland households in Savannakhet who have some form of income away from the farm or through remittances. They subdivide this group into three – two of which are relevant here – those who are migration dependent (i.e. on off farm employment, either locally or in Thailand) and those who earn a living through non-farm businesses and professional activities (such as public service roles at district or provincial level). A number of the interviewees also fitted into group D. This includes those for whom farming is a commercial activity, but who also have a diversified portfolio of income deriving activities. Additionally, farmers who are acting as DDS

contractors now have another option for diversifying their income stream, charging between 200,000 LAK and 700,000 LAK per hectare for their services.

Informants indicated that income sources both on-farm and off-farm varied to include livestock, vegetable crops and contract sugar cane, with livestock options including cattle, buffalo, goats, chickens, ducks and other poultry and fish. Off farm activities included shop keeping, weaving and tailoring, off-farm employment as farm labourers, and non-farm employment (locally and in Thailand), and weaving and tailoring (and some farm labouring, such as transplanting for others).

This would suggest that adoption of DDS has been accessed largely by those who have less dependency on farming as a source of cash income and are potentially able to manage and calculate risk more effectively; that is, those farmers who are beyond the "coping" or subsistence stage.

Other informants included a machinery shop proprietor in Savannakhet, and DAFO and PAFO staff who have been involved in the DDS field-testing and machinery development. Some of these informants were also farmers (Table 2).

3.2 Attitudes and practices

This element describes the attitudes expressed by the informants as well as their actions, and how this influenced the uptake of DDS and the patterns of interaction at the village level. This section also explores the practices that were relevant to the implementation of DDS. It explores the realised and potential collaboration and culture of innovation within these communities. These findings do not explore institutional settings per se, but instead focus on the specific actors interviewed and their practices.

Triggers: There was a general consensus that the shortage and high cost of labour (including logistical challenges associated with transporting and accommodating labour from further afield), and the late onset of the monsoon rains had prompted households to try DDS. A small proportion of the farmers had used the DDS in the 2014 season, but there had been a dramatic increase in the area planted in 2015. Many farmers expressed interest in using DDS in the 2016 wet season, and indeed had either purchased machines or had booked the services of a contracting DDS supplier.

Initial experiences – technology testing: Most farmers interviewed took a cautious approach to implementing DDS in the first year, planting only a portion of their land using the mechanised technique, and continuing to transplant the remainder, as a risk management strategy. Those who trialled the technology all had at least one family member involved in DDS training delivered through the DAFO in conjunction with the different projects, or had observed neighbouring field trials. In particular, women who had not attended training were more hesitant about the implementation, but were enthusiastic once they had experienced it. This

would suggest that it is important to ensure that women as well as men farmers participate in training and demonstrations, as informants said that the decision to use DDS was a joint negotiated family decision. Although the women are not usually the ones actually using the machine (which is the main reason usually given for targeting male farmers for DDS training), they are key players in family decision making with regard to implementation.

Management practices: The farmers (both men and women) provided copious amounts of information about their views and experiences in management practices for DDS. The most frequent concern expressed was in relation to weed control. There was a diversity of opinion regarding weed control – with some farmers asserting that weed control was improved with DDS and others finding weed control a greater challenge. For many, weed competition with the emerging rice plants was the biggest concern, although the perceived impact of this varied between informants. Some farmers suggested that DDS aided weed control, either through better competition from more vigorous rice plants or because weeding was easier when the rice was planted in rows. One farmer reported seeing a new weed variety that had not grown on his farm before.

A few of the farmers recommended cultivating the land two to three times prior to planting to try to control weeds. There were also concerns about the extra cost of fuel for additional cultivations. Only one farmer expressed interest in herbicides. One farmer is using ducks and fish in the paddies to control weeds in conjunction with the CSE/2014/086 research project.

There were a range of opinions about the optimal planting time, ranging from late March, to after Pi Mai (Lao New Year, mid-April) to early- to mid-June. This is generally earlier than transplanted rice, and hence DDS rice crops were in some cases harvested up to 15 days earlier than hand planted rice; this has been confirmed in the literature as a benefit in terms of reducing vulnerability to late-season drought (Balasubramanian & Hill, 2002; Farooq et al., 2006). One farmer said that he had harvested a second (much smaller) yield from a ratoon crop, “child rice” which he used to feed to his livestock.

Informants indicated that planting into wet soil or clay soil was problematic with the current machines. Wet soil caused blockage of the seed tubes, and one farmer recommended putting seed on the surface of a furrow, however, at the risk of loss to birds and rats.

Yield response: Reports on yield varied – some farmers said the yield was higher using DDS, while some said it was lower. This is not necessarily representative, as preparation and planting techniques, subsequent management and the seasonal conditions would have had an impact on this. However, most agreed that even when yield was not higher, profitability was definitely improved, which informants agreed mattered more to them than actual yield.

Machinery options: The planting machinery itself was a key focus. The machinery shop owner described six current machinery options that were available in Savannakhet at the time of the study, as described in section 1.1.3. There was much discussion about the advantages and disadvantages of the various machinery options. Pricing was discussed as a key issue, with the

cheaper options being affordable by farmers, but not adequate to the task. Some informants had purchased planters from the dealer in Savannakhet but had returned them due to quality issues, and had their money refunded. The more expensive machines, sold through PAFO were better but too expensive for the farmers. It was not clear from the data whether there was a consistent opinion about the optimal machine design, however, there was generally agreement that a fertiliser box was a must. Weight of the machine, related to ease of use, and number of rows was also important. One of the informants also raised the question of further mechanisation, expressing an interest in purchasing a small harvester as well.

Changes in on-farm labour practices: The informants generally said that implementing DDS had freed up time and money for other activities, particularly for women, including income earning from alternative enterprises, taking care of family and, in one case additional leisure time. One informant said that the additional time would allow her to expand her weaving activities and had plans to do a tailoring course in Vientiane and open a shop locally.

A number of the farmers are providing contract DDS planting services, and these indicated that their services had been in high demand during the planting season, including some already having 'bookings' for the 2016 wet season.

Integration with livestock management: Others indicated that they would like to focus more on integrating livestock into their farming systems, such as growing forages for livestock, and integrating ducks and fish, although this is influenced heavily by participation in various research and development projects. Some informants were concerned that cattle grazing stubble in the paddies between rice crops may damage DDS crops, given DDS is planted earlier than under conventional planting regimes, and that this might mean a need to change existing informal rules relating to livestock management, including proposals to village authorities to herd animals earlier in the season.

Future research questions: The informants discussed management practices associated with DDS, and indicated that this still needs further investigation, more field trials and demonstration plots in partnership with the farmers to investigate the problems that they are experiencing. This included land preparation, weed control, soil suitability, fertiliser application and planting times (as previously discussed). There were varied opinions and approaches to each of these.

- With regard to fertiliser, some of the farmers suggested more precise application was needed at planting time, and emphasised the importance of planting time application to assist competition with weeds. These farmers reported maintained or increased yields even with reduced fertiliser application.
- There was some discussion about soil suitability. A number of farmers felt that the DDS worked well on sandy soil, but was problematic on clay soil and on upper toposequences where land was more uneven.
- Opinions about land preparation varied, but the majority felt that land preparation prior to planting played a significant role in the success of the crop.

- One farmer had experimented with priming the seed – soaking it and then drying it prior to planting to get a faster, more vigorous strike.
- Stand establishment under a wide range of field conditions

Restrictions for future use: Most informants expected to plant more of their land using DDS in the 2016 season, but some felt they may not be able to continue due to lack of availability of the machinery. In addition, there were some reservations about the use of contract planting, as people felt that in some cases high demand for the services and the limited number of contractors had meant inadequate time was available to do sufficient land preparation and planting technique.

3.3 Patterns of interaction

A key element of a functioning innovation system according to the World Bank report (2006) is the patterns of interaction, which includes the networks of relationships and partnerships, and the existence and coordination of relevant stakeholders and stakeholder bodies. The focus in this analysis is at the local level, so patterns of interaction are focused at the district and village level.

As described above, the types of farmers who seem to be adopting DDS are those who can afford to access the machine, whether through purchase, use of project supplied machines, or ability to pay a contractor; and who in any case can afford to take a risk in applying this technology. Conversely, the poorer farming households were not included in the sampling for the study as they do not appear to be adopting DDS at this point.

Attending DDS training provided by PAFO and DAFO was one of the key reasons farmers (both men and women) gave for being prepared to try DDS on their own farms. Quite a few of the farmers were current or ex-DAFO extension officers so were familiar with DDS, had been trained in its use, and were in some cases trainers themselves.

Interactions at the village/community level were also crucial. A number of the farmers who had gained experience in DDS in the 2014 season, and were continuing in the 2015 season, were acting as resource persons for other farmers in their village or area.

Many of the participants spoke about observing their neighbours' DDS efforts and following the subsequent crop through the season. The informants told us that many of the older generation (and other members of the community) were very resistant to the implementation of DDS, expressing strong views about the risk of crop loss (and family food insecurity) and the break with familiar and traditional ways of rice farming. However, over the season these people often became more open to, and supportive of, the technique. We were told that this is very important, as the leadership and opinions of the older generation are highly respected and

regarded in the villages. In addition, a concerted family approach was also important, as decision-making was shared between male and female household members. In those households where women had not physically seen DDS applied, trialling was usually delayed by at least one season, as the women had little confidence in the technique. Men used words like "convince", "explain" and "hesitant" to refer to their discussions with their wives regarding trialling the DDS technique. In contrast, women who had had an opportunity to see the technology applied were often the ones suggesting that they should test the technique.

A number of informants said that being able to observe DDS trials close to the road (where they were accessible and visible) was important as it allowed them and their neighbours to learn about the technique through the season and enable them to make decisions about adoption.

There appeared to be a gap in machinery and metal work expertise to enable further adjustment and then manufacture of suitable machinery. The only machinery vendors mentioned were the Savannakhet machinery seller, and the machines being sold by PAFO, which are sourced from manufacturers in Thailand; both have identified weaknesses in the machines and looked at options for improvement. The farmers themselves are building and modifying planters in some cases. But a number of them said that they had had difficulty in finding appropriate manufacturers and one had travelled to Thailand himself to find a suitable planter.

In addition, there were questions raised about participation of the local body responsible for setting and maintaining standards in this case for machinery quality, and the suggestion was made to somehow involve the local agricultural college as well as the recently established provincial university.

There was only one mention of membership of a farmer group, and it is unclear whether other groups exist. On the other hand, the close interaction and community engagement within and beyond villages was discussed as an important aspect of knowledge sharing and the impetus for adoption (in particular, approval by the elder generation in the village as mentioned above).

3.4 The enabling environment

In this analysis, the enabling environment summarises the factors that are conducive to innovation and change, and those that are likely to hinder. This includes policy and other settings. The key enabler discussed by the informants was the availability of DDS machines. A number of machines were available through various projects in the area (including ACIAR- and ADB-IFAD-funded projects), though these were varied (see list of machines included in section 1.1.3). In addition, the adopters had the opportunity to observe the machinery and attend training. This was combined with the shortage and high cost of labour for planting, and the continuing late onset of the monsoonal rains.

The flip side of this is that the rapid increase in uptake has meant demand for DDS planters has exceeded supply. A number of participants said that they were not sure if they would continue with DDS, as the planters were either in short supply, or the contractors were so overwhelmed with orders that the timing of planting and the quality of these plantings may not be optimal. The contractors said that they had many bookings for the next season, though many of the farmers indicated that they would prefer to purchase their own machinery in order to control timing and quality of planting.

The late start to the monsoon rains in both 2015 and 2014 seasons prompted a number of the informants to either adopt DDS or increase the area planted via DDS. By the time the rains started in June, it was too late for many farmers to produce seedlings for transplanting.

All farmers interviewed talked about labour shortage and high cost of labour as key factors influencing them to adopt or trial DDS.

The informants raised a number of issues and challenges, as described in previous sections. These can be better understood if they are contextualised within narratives relating to specific experiences (see Box 1 and Box 2, below).

Box 1 Spreading the word about DDS - Narrative 1: Mr M and Mrs C

Mr M and Mrs C were early adopters of DDS. Both work in the district government office, though Mr M is now retired. In his former role as an extension officer, he had a great deal of exposure to the DDS through training, field trips, discussions with experts, and working with other farmers who had adopted the technique.

The couple have two adult children away working in Thailand, who both send money home to their parents and the third child is studying agriculture at a local college.

Mr M and Mrs C started to use DDS to save on the cost of labour. They purchased a DDS machine from PAFO in Savannakhet in 2013, and use it to plant one hectare of their rice paddy (half of their land area). The other hectare they still use hand transplanting to maintain traditional practices and solidarity with their family who come each year to help with transplanting in return for a gift of rice from the paddy after harvest.

When he first started using the DDS technique, his neighbours laughed at Mr M – they thought he was crazy. Their opinions have changed dramatically in the past two years, as he is now regarded as a prominent figure and DDS service provider, providing planting services across six villages. His advice is sought after and his services in high demand to the point where he has now hired a young relative to assist him with the planting and transporting the seeder and hand tractor between farms and villages.

Mr M says that weeds are still the main concern for him with DDS. In his opinion, the land needs to be ploughed 2-3 times – with the first after the previous rice harvest, then the second tillage after the first rain. It was not clear when he thought the third tillage should take place.

He estimates he pays 200,000 kip per season per hectare for fuel for land preparation, and he and his wife spend around 2-3 hours a day weeding in the first 30 days of crop establishment.

He said that the rice yield for DDS application was lower than for conventional transplanting, although this was dependent on soil type and management through the season. Mr M keeps a record of rainfall and he said that the rain generally starts 1-25 June with a 3-day interval. He advised the most appropriate time to plant using DDS is 1-25 June.

He also said that he has asked a relative to make a copy of his seeder in the hope of creating a lower per unit cost machine compared to those available in the machinery shop or at PAFO.

Box 2 New income generating opportunities - Narrative 2: Mrs K

Mrs K has not always lived in Savannakhet. She comes from the north of Laos, and met her husband, Mr N when they were both working in Vientiane. When they moved back to Champhone to live with Mr N's parents on their 5-hectare farm, Mrs K found herself learning about lowland wet rice cultivation for the first time, as her family had practiced shifting cultivation in the northern mountains. She had to learn the techniques of hand transplanting and harvesting from her husband, as the only labour available in their family was her husband and herself. This meant that they spent up to three months each year transplanting rice, and could not plant all their available land area. In addition to their rice paddy they raise fish, ducks, cattle and buffalo, and grow vegetables.

Mrs K and her husband took part in a DDS trial on one hectare of their irrigated land in the 2014 dry season. Following the success of this crop, Mr N purchased a seeder from the PAFO and can now plant all of their four hectares using DDS. Because their fields are close to the road, many people saw the success of the trial plots and the area planted to DDS has rapidly spread to other villages. Mr N says that he uses less rice seed with the planter, and has greatly reduced labour costs. However, he is facing challenges with higher elevation paddy fields, uneven land surface and difficulty managing water and weeds.

With the DDS in use to plant the entire rice crop and labour requirements for rice greatly reduced, Mrs K had time to sit down at her weaving loom for the first time in eight years. The results of her weaving – learnt in the northern region of Laos as a girl – are much admired and sought after by her family and neighbours in Champhone, as they had never seen these kinds of designs before. She is now making more than four million kip per month in additional income for the family through clients' orders for her beautiful sinhs (traditional Lao skirts).

Mrs K has plans to expand her new business venture. With her husband's agreement, she will undertake a three-month tailoring course in Vientiane, and when she comes back, she will open a shop in the new village market opening up near her home. In addition, she and her husband are also looking into the possibility of purchasing a small harvesting machine.

4 Discussion

Adoption of DDS has increased rapidly in each of the three districts included in this study. The technology has been tested by a group of 'early adopters', usually in conjunction with a project and district and provincial staff, who have challenged conventional production methods and attitudes. Now, innovation is occurring within a wider group, and the findings indicate that this rapid uptake has been due to a confluence of factors. First, the trigger for this innovation is the high cost and shortage of labour for transplanting coupled with late onset of monsoon rains in consecutive seasons. Additionally, due to several projects working within similar areas, there has been increasing availability of DDS machines in several districts, as well as options for purchasing the machine in four districts of the province. The availability of contracting services also seems to be very important, since one contractor appears to plant between 15 - 30 ha in addition to their own land, and opens up more options for farm households.

Another key factor in the rapid spread of the DDS was the activities and interactions of the farmers themselves. Visibility of demonstration plots and field trials (e.g. located near roads) was frequently discussed as a key means by which awareness and information was spread around the districts. Farmers' interest in observing field trials for DDS was also reported by Chialue et al. (2014). A number of the farmers interviewed have become contractors and "go-to" local experts in DDS and have contributed significantly to the spread of the technology. Community acceptance, particularly by the older generation, emerged as a very important factor. While the early adopters of the technologies were laughed at or disapproved of, their ultimate success with the technique was noted and approved by the elder generation within the villages. It is important to emphasise the critical nature of the engagement and approval of the elder generation and the community more generally for innovation and change in a collective society such as this.

The innovation systems framework analysis in this study indicates that this confluence of factors may go some way to explaining why DDS has been readily adopted in these three districts only recently, even though DDS technology has been available and trialled in various parts of Laos since at least the early 1990s. Further investigation is needed however, to understand what the implications of this are for more widespread adoption of DDS in southern Laos.

The analysis here indicates that patterns of interaction and relationships have been crucial to the rapid adoption of DDS in these districts, and that focusing on, and supporting innovation networks for ongoing adoption will continue to be important. This should also include active farmer involvement in further investigation and refinement of management and techniques for DDS.

Freeing up time from transplanting has been one of the key benefits of adoption of DDS, and was also reported by Chialue et al. (2014) as a key motivator for trialling DDS. Many participants reported engagement in other income-earning activities (e.g. weaving and tailoring, increased livestock production, diversification into other crops, and sources of off-farm income including businesses and employment) as well as additional family and leisure time. The reported effect

on yield was variable, with some experiencing decreases and some increases. Several farmers reported maintained yields initially, but then increased yields with more experience. Importantly, profit margins from rice were reported to have improved in most cases, to the satisfaction of the farmers involved, even where yields had declined slightly. Yield increases per se did not appear to be a goal for these farmers; this has been previously reported for farming households in southern Laos (Manivong et al., 2014).

The analysis also provides insights into some of the emerging challenges of the rapid increase in DDS in these districts. The most prominently discussed issue is that of lack of availability of DDS machines (including affordable and suitably adapted machines); this was similarly reported by Chialue et al. (2014) as a barrier to wider testing and experimentation. While DDS machines are being manufactured in Thailand, there appears to be a very limited supply chain for Savannakhet. The machinery seller interviewed in this study is selling machines to local farmers, but there was some question about their quality, suitability for local conditions and their ability to meet the requirements of the farmers.

There was significant feedback and discussion about optimising management practices and dealing with challenges, including land preparation, weed control, fertiliser application, water management and livestock management. Given the diversity of accounts in this study and the range of opinions and approaches discussed by the informants, a more detailed investigation and gathering of information in partnership with the early adopters will be crucial.

Adoption of DDS is at this stage limited to higher income farmers, or those who have more scope to invest in new technology and/or take risks (i.e. they are beyond the “coping” and subsistence stages). This may be a reflection of the households selected for this survey, as they were purposively selected with experience in this technique, and had often been part of a research project. The impact of DDS and other forms of mechanisation on poorer farmers is unclear from this study, nor is it clear if or when these farmers might adopt the technology, but the benefits in terms of reduced labour and production costs are still likely to be attractive and useful for these households. However, there might need to be different options for accessing machinery to assist adoption and application.

From a policy perspective, it is not clear at this stage how provincial and national policy implementation does, and could, influence DDS and uptake of other technologies. However, it does appear likely that DDS implementation has the potential to enhance livelihoods of rice farmers in these districts.

Therefore, demonstration of the use of DDS to enhance livelihoods and rural income (a whole of government policy priority) would be very useful, and this technique also fits with the Agriculture Development Strategy to 2025 and Vision to 2030, in terms improving food security, commercialisation (commodity focused) and the application of appropriate new agricultural production techniques and Good Agricultural Practices for both improved quality and productivity. Further analysis is needed to look at alignment and potential feedback on policy directions in more detail.

5 Conclusions and recommendations

This study has revealed a range of issues and questions 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. Key issues include the following elements:

- **Technical** – weed management options, land preparation recommendations, sowing windows, soil suitability, land suitability (toposequence, paddy size).
- **Social –** income diversification options for 'freed' labour, finance options for purchase of machine or inputs, modification of informal village rules for animal management, effects on labour-dependent households (i.e. by reducing the amount of transplanting work available).
- **Machinery** – access to machines (purchase, hire contractor, rent machine), optimal machine types (fertilizer box, weight), machine quality and cost.

Given the range of questions and challenges emerging from this study, fostering and continuing to support an active and engaged innovation network will be helpful for further uptake and improvement in the application of DDS (and other potential innovations). The study has highlighted the strong networks between farmers and within the local communities, as well as with the district extension officers and other government officials, and highlights the importance of these agencies partnering with farmers for future uptake of the technique. Bringing together a multi-stakeholder group that includes farmers can also help to set research priorities to address technical challenges associated with weed management, land preparation, sowing windows and land suitability.

The study highlights the importance of providing farmers with opportunities to share experiences and compare notes, and to play a proactive role in further development of this and other innovations. With a range of development actors and institutions operating projects and activities in Savannakhet province, they are also key partners to coordinate with. Machinery suppliers and manufacturers are an additional important link, given the need for machinery improvement and a more consistent and affordable supply of machines. There are further questions to be answered about barriers and opportunities for poorer farmers to access the machines, and about how to enable broader access to the DDS machines more generally.

Access to finance is another issue that was highlighted in the study, with cost of the direct seeding planters a much discussed issue in the study, and a number of respondents indicated that they could not afford the better quality machinery in their current circumstances. Developing and maintaining machinery quality standards is another area which requires investigation.

This study has explored the actors, their attitudes, practices and relationships, and the enabling environment that has contributed to the uptake of DDS technology in Savannakhet. The study focuses primarily at the village level in understanding the experiences of farmers, with the intent to further build on this in future iterations and incorporate different levels and actors

within the innovation system. Results provide a basis for understanding innovation, and for informing multi-stakeholder groups to enhance adoption of this and other techniques.

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Appendix A: Interview protocol

The following are indicative questions or an interview protocol. These are meant as a prompt and guideline only to ensure that the interview allows the interviewee to tell their story in their own way and their own language. Interviews covered the following aspects of DDS trial and adoption:

1. **Typology and farm household/farm system characteristics**

- Description of farm household including key features such as land area, crop and livestock options, water availability, sources of income (keep this brief and general – the purpose is to gain an indication of where the farm household may fit in the household livelihoods typology).

2. **Introduction to direct seeding**

- How did you find out about it? Who influenced your decision to try it, and who did you get information from?
- Why did you decide to use it?
- When did you start using direct seeding?

3. **Experiences**

- Tell us about your experience with DDS
- Weed management, labour, yield, other problems, crop performance, inputs etc
- Influence on your families activities? Did it free up time? If so, what are you and other the family members doing instead?

4. **Perspectives, opinions and future plans**

- What will you do in the future? Will this change what you do or how you think about farming?
- Will you continue with DDS? And why?
- What kind of information do you need? And how would you like to receive it?
- What would help you to continue with DDS?