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List of acronyms

ACCA	Shorthand for the LWR/2008/019 project
ACCA-SRA	Shorthand for this project; LWR/2012/110
CARDI	Cambodian Agricultural Research and Development Institute
CCAFS	Climate Change, Agriculture and Food Security Program (CGIAR)
DAFO	District Agriculture and Forestry Office (Lao PDR)
DDS	Dry direct seeding
FBA	Farmer Business Advisor
GAP	Good Agricultural Practice
iDE	International Development Enterprises (NGO, Cambodia)
IFAD	International Fund for Agricultural Development
LADLF	Laos-Australia Development Learning Facility
NAFRI	National Agriculture and Forestry Research Institute (Lao PDR)
NUOL	National University of Laos
PAFO	Provincial Agriculture and Forestry Office (Lao PDR)
PADEE	Project for Agriculture Development and Economic Empowerment (IFAD, Cambodia)
SNRMPEP	Sustainable Natural Resource Management and Productivity Enhancement Project (IFAD, Lao PDR)
SNV	A Dutch NGO focussing on development (Lao PDR)
SRA	Small Research Activity
TP	Transplanting
PTR	Puddled transplanted rice
UNDP	United Nations Development Program
UQ	The University of Queensland

1 Executive summary

This project, *Regional co-learning in simple mechanised tools for rice planting* has met and exceeded its three objectives: 1) the facilitation of on-farm testing of mechanised rice establishment options in regions of Lao PDR and Cambodia in 2013; 2) the creation and dissemination of Lao language training materials; and 3) supporting five Masters students; two in Lao PDR and three in Thailand.

In 2013 on farm testing activities of the dry direct seeder in Savannakhet Province, Lao PDR and the drum seeder in Svay Rieng and Prey Veng Provinces in Cambodia were successfully completed, enabling 143 households (66 in Lao PDR and 77 in Cambodia) to test mechanised rice establishment methods on their farms. These on-farm demonstrations have enabled risk averse farming communities to explore, with support from research and extension communities, the potential benefits of direct rice establishment methods, in particular in terms of labour savings and ability to reduce farmers' exposure to climate risk.

In addition to the original project objectives, dry direct seeding activities in Lao PDR were extended in 2014. Following extremely positive feedback from farmers in 2013 the project received additional funding from ACIAR to conduct a second year of on-farm trials, during which options for weed control and fertiliser placement were examined. The project contributed to the development in Lao PDR of a locally manufactured dry direct seeder in which fertiliser could be placed in the soil together with seed.

Farmers are attracted to the potential labour savings of mechanised rice establishment compared to traditional transplanting practices. In Lao PDR, gross margin analyses of results show that, where weeds are well controlled, dry direct seeding can provide economic benefits of up to 22 per cent over puddled transplanted rice due to reduced labour requirements. Similarly, strong economic gains were found for drum (or wet) seeding compared to traditional transplanting practices in Cambodia. Additionally, mechanised planting tools have the potential to reduce farmers' exposure to risks associated with increased climate variability and change by avoiding early season and terminal drought stress.

Information and training materials have been produced and used in farmer field days and training and exposure events in Savannakhet, Attapeu, Saravane, Khammouane and Vientiane Provinces. The learnings from this project underpinned contributions from the research team into training manuals on dry direct seeding in Lao PDR produced and disseminated by the Sustainable Natural Resource Management and Productivity Enhancement Project which was funded by the International Fund for Agricultural Development.

The project supported five Masters students in Lao PDR and Thailand, contributing to an increase in researcher capacity and knowledge across the region. As a result of new skills gained one student received funding from the ACIAR-funded Lao Small Research Grants program to continue researching questions around dry direct seeding in Lao PDR.

The project has clearly demonstrated the technical and economic feasibility of both dry and wet direct seeding in Lao PDR and Cambodia. The outcome is ongoing high degrees of enthusiasm and interest from farmers in the direct establishment methods for wet season rain fed rice crops. In both Lao PDR and Cambodia, we recorded a rapidly expanding number of households outside case study areas using the direct seeding technologies. We conclude that the direct seeding technology has a high prospect of adoption and future impact.

2 Introduction

Lao PDR and Cambodia are among the most vulnerable countries to climate change in Asia. Their vulnerability arises out of a combination of socio-economic factors (very low institutional and community capacity to adapt) and their high exposure to climate risks (flooding in floodplain areas of the Mekong basin; increased drought frequency more generally). Another feature is their dependence on large areas of rainfed, rice-based cropping systems to provide the mainstay of food security. This is in contrast to fully irrigated rice-based cropping systems in other rice-producing countries (e.g. Vietnam, Thailand, Bangladesh), which have a much lower inherent risk of crop failure because of more certain access to irrigation water. Rice is the main staple crop in both Lao PDR and Cambodia. With a forecast increase in the variability of the frequency and of the timing of rainfall through the wet season, rainfed farming systems are challenged not only to maintain productivity in an environment of global change, but also to increase rice production to match expected population growth.

The ACIAR-funded project *Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Laos, Bangladesh and India* (LWR/2008/019; the ACCA project) was initiated to build adaptive capacity in rural communities in Lao PDR and Cambodia (and in India and Bangladesh) by demonstrating successful, locally relevant adaptation options to climate change. Under the ACCA project successful wet season field trials in 2011 and 2012 identified that the use of mechanised rice establishment tools in Lao PDR and Cambodia had potential to reduce farmers' exposure to climate risks, improve farmers' adaptive capacity and were locally appropriate and attractive interventions. These comprised wet seeding onto puddled soil using drum seeders imported from Indonesia and Vietnam in Cambodia, and dry direct seeding using a power-tiller mounted drill machine to direct seed rice into field moist, tilled soils, mainly in Lao PDR. At the conclusion of the field trial component of the ACCA project it was recognised that there was a strong in-region interest in continued testing of mechanised rice establishment practices in project provinces in Lao PDR and Cambodia. Interest in direct planting technologies from in-country stakeholders at all levels remained, and continues to remain, high.

In particular, in Lao PDR farmers, researchers from NAFRI, and extension staff from PAFO Savannakhet and DAFO Outhoumphone and Champhone were keen to investigate further the implications of using the direct seeder, including understanding 1) the potential value of direct seeders to households in the rainfed lowland rice producing regions; 2) what, if any, changes to existing crop production practices were necessary to facilitate the introduction of mechanised rice establishment; and 3) quantifying likely changes to yields and cropping system gross margins resulting from direct seeding rice. Lao-language information materials were needed to raise awareness of the direct seeder and to more widely disseminate key learnings.

In Cambodia ACCA project activities generated significant interest from farmers and other local stakeholders: a key factor in farmer interest in drum seeding was the potential to reduce labour demands for sowing and transplanting by up to 50 per cent of that required for conventionally transplanted rice. iDE Cambodia was keen to work with the ACCA-SRA to extend on-farm demonstration trials of the drum seeder into 2013 to continue farmer testing and seeder uptake.

The ACCA-SRA was developed to ensure a continuation of wet season on-farm testing of mechanised rice establishment options in Lao PDR and Cambodia and to provide opportunities to refine these methods of rice establishment in order to reduce exposure to climate risks in rainfed lowland rice producing environments. Specific planned activities included:

- Enabling the strategic extension of on-farm demonstration activities commenced opportunistically under the ACCA project in Lao PDR
- Facilitating the extension of direct seeding testing on farms in Cambodia
- Building in-country capacity by supporting five Masters degree students in Lao PDR and Thailand, as well as through training and extension activities
- Developing local language extension materials: these will be an ongoing information resource in Lao PDR after the completion of the ACCA and ACCA-SRA projects
- Continuing co-learning and research linkages across the region and with Australian organisations.

Following the successful on-farm testing in the 2013 wet season of the dry direct seeder in Lao PDR additional funds were obtained from ACIAR to extend and refine on-farm testing into the 2014 wet season.

It was originally anticipated that on-farm testing to extend and further explore mechanised establishment options would occur in equal measure in both Lao PDR and Cambodia. While scheduled milestones were achieved in Cambodia the departure of key personnel from iDE Cambodia meant it was not possible to pursue investigations into mechanised establishment as vigorously as in Lao PDR. As well, support for Masters degree study had been envisaged for one of iDE's agronomists. This agronomist left iDE early in 2013 and the funds initially allocated for this study were redirected to defray unforseen additional study costs incurred by the Lao Masters students.

3 Objectives

The ACCA-SRA aimed to extend on-farm testing of alternative rice establishment methods and disseminate these results in order to provide smallholder farmers in Lao PDR and Cambodia with a greater range of options to better manage climate risk and labour constraints, and improve their livelihoods. This was achieved through:

Objective 1 To build local capacity in the knowledge and use of direct planting methods

1.1 Enhance the skills base in Lao PDR and Cambodia in applied research to underpin the development and refinement of direct planting methods

1.2 Train farmers in Lao PDR and Cambodia in the timing and use of direct seeding and/or drum seeding, weed management and timely residue management

1.3 Up-skill extension providers in Lao PDR and Cambodia

1.4 Produce local Lao language manuals on direct planting techniques and tools for extension providers and farmers; publish research output in relevant local Lao journals

1.5 Disseminate key learnings to stakeholders in NE Thailand

Objective 2 To conduct on-farm testing of direct planting techniques in selected areas of Savannakhet Province in Lao PDR and Svay Rieng and Prey Veng Provinces in Cambodia

2.1 Establish on-farm demonstration trials testing the direct seeder in conjunction with weed management strategies in selected villages in Outhoumphone and Champhone Districts, Savannakhet Province, Lao PDR

2.2 Establish on-farm demonstration trials testing the direct seeder and drum seeder in conjunction with double cropping of rice in selected villages in Prey Veng and Svay Rieng Provinces, Cambodia

Objective 3 To increase local research and extension capacity through support for upgrading of qualifications of colleagues in Lao PDR and for currently-enrolled students from Thailand

3.1 Provide support for two provincial government officials from Lao PDR to undertake Masters degree studies within the SRA project

3.2 Provide tuition support for three employees from World Vision Thailand who commenced studies at Khon Kaen University with the support of the ACIAR SMCN/2007/215 project to enable them to complete existing Masters degree studies

4 Methodology

Lao PDR

In 2013 a Thai direct seeder was tested on 66 farms from nine villages in Outhoumphone and Champhone districts of Savannakhet Province. Dry direct seeding (DDS) had been recently introduced to these districts under the ACCA project; farmers were interested in learning more about the establishment method and they and project staff from NAFRI and PAFO were keen to continue on-farm testing. The aims of testing the DDS on farms were to:

- Expose more farmers to the DDS technology and provide an opportunity for them to test it on their own farms;
- Compare DDS to traditional crop establishment practices; and
- Identify key strengths and weaknesses of planting with the DDS; in particular to learn from farmers what they identified as key benefits and limitations of the DDS.

In 2014 learnings and feedback from the 2013 year were used to test a different seeder on nine farms in three villages in Outhoumphone and Champhone Districts. The focus was on working with a smaller cohort of farmers, concentrating on collecting high-quality data throughout the wet season, with the particular aims of:

- Understanding different weed control options in lieu of the traditional practice, i.e. ponded water, which is no longer consistently available under early-sown direct seeded rice. The NAFRI-recommended Good Agricultural Practice (GAP) weed management approach of thorough land preparation prior to sowing and early, vigorous manual weed control was compared to application of a post-emergent herbicide;
- Examining the effects of placing fertiliser in the soil with the seed (rather than broadcast after sowing) to promote crop development over weeds; and
- Comparing the results of DDS and traditional rice establishment practices in terms of yields and gross margins.

PAFO Savannakhet hosted exchange visits with key personnel from World Vision Thailand to enable project staff to learn how to use the DDS and to pass this information onto farmers. NAFRI, supported by PAFO and DAFO staff, provided training to farmers in GAP which focussed on the establishment of rice by DDS. NAFRI and PAFO developed further information materials in Lao for dissemination.

NAFRI and PAFO Savannakhet developed Lao language information materials to inform farmers about the DDS.

A discussion paper on DDS in Lao PDR was drafted; these learnings underpinned contributions to extension materials produced by the IFAD-funded Sustainable Natural Resource Management and Productivity Enhancement Project (SNRMPEP) in both Lao and English.

Two Masters degree students from PAFO were supported through their degree studies for their tuition, field trial experiments, travel and additional coursework. Support from colleagues at NAFRI, NUOL, PAFO and UQ ensured their thesis topics and field experiments remained on track and relevant to their studies. All costs associated with thesis publication and graduating have been paid.

Cambodia

In 2013 drum seeding was tested on 69 farms in Prey Veng (37 farms) and Svay Rieng (25 farms) Provinces; dry direct seeding was tested on an additional eight farms: five in Prey Veng and three in Svay Rieng. Pray Veng and Svay Rieng are regions in which farmer and other stakeholder interest, including from iDE Cambodia, in both forms of mechanised seeding was high, particularly compared to broadcasting seed. The ACCA project had previously run on-farm trials only in Svay Rieng Province.

The aims of this testing were to:

- Extend the testing of wet direct seeding form Svay Rieng to similar areas in Prey Veng Province
- Expose more famers to mechanised establishment techniques and provide an opportunity for them to test these on their own farms; and
- Compare drum and dry direct seeded rice to traditional crop establishment practices of transplanting and broadcasting rice.

Thailand

Tuition support was provided to three employees from World Vision Thailand, to enable them to complete their Masters degrees at Khon Kaen University, which had commenced under the aegis of the ACIAR funded project SMCN/2007/2015.

5 Achievement against activities and outputs/milestones

Objective 1: To build local capacity in the knowledge and use of direct planting methods

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Train farmers in Lao PDR and Cambodia in the timing and use of direct and/or drum seeding, weed management and timely residue management	Farmers trained in the timing and use of direct planting methods, weed and residue management	31 Dec 2013	**Completed.** 56 farmers from Outhoumphone and Champhone districts of Savannakhet Province, Lao PDR received training before the 2013 wet season in the use of DDS from NAFRI and PAFO staff. In Cambodia, approximately 50 farmers in Svay Rieng and Prey Vang Provinces received training in drum seeding and DDS from iDE and CARDI. In 2014 additional GAP training, including DDS, was provided to around 20 farmers in Savannakhet.
1.2	Up-skill extension providers in Lao PDR and Cambodia	Extension providers training in the timing, use and challenges of direct planting methods	31 Dec 2013	**Completed.** Farmers and extension workers in both Lao PDR and Cambodia have received training in the use and optimal timing of seeders to establish rice crops, as well as in fertiliser application and weed and residue management. A review of farmer practices in Cambodia highlighted the interest farmers have for these establishment methods; this is also borne out by the wider on-farm testing (100 trials in addition to those supported by the SRA) undertaken by our project partner, iDE Cambodia.

1.3	Produce local language materials on direct planting techniques and tools for extension providers and farmers; publish research output in relevant local journals	Local language training materials on direct planting methods produced Research results published (e.g. in relevant local journals)	31 Dec 2014	**Completed.** Training materials (two pamphlets and three posters) have been produced in Lao to introduce farmers and local extension agents to the dry direct seeder. The Lao Masters students are writing papers in Lao for the *Lao Journal of Agriculture and Forestry*; these will be published in the July-December 2015 edition. In Cambodia, crop calendars and detailed crop management recommendations were completed: these form the base for the production of Khmer extension material in Cambodia disseminated through the PADEE program.
1.4	Disseminate key learnings to colleagues and stakeholders in NE Thailand	Training materials (English and/or Lao versions) shared with Thai colleagues and stakeholders	31 Dec 2014	**Completed.** Training materials developed under the ACCA-SRA have been provided to colleagues and stakeholders in NE Thailand, including World Vision Thailand and Khon Kaen University.

Objective 2: To conduct on-farm testing of direct planting techniques in selected areas of Savannakhet Province in Lao PDR and Svay Rieng and Prey Veng provinces in Cambodia

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Establish on-farm demonstration trials testing the direct seeder in conjunction with weed management strategies in selected villages in Outhoumphone and Champhone Districts, Savannakhet Province, Lao PDR	On farm demonstration trials testing seeders with weed management strategies in Outhoumphone and Champhone Districts, Savannakhet Province, Lao PDR	31 Dec 2014	**Completed.** On-farm demonstration trials were successfully conducted in 2013 at 66 farms in Savannakhet Province, with a focus on raising farmers' awareness of the direct seeder, and providing many households with an opportunity to use one. Following the success of these trials a variation to the SRA was funded by ACIAR to enable testing to continue in 2014 on a further three farms in Outhoumphone and six in Champhone districts. These field trials examined options for weed management and the effect of placing fertiliser in the soil at sowing. Overall productivity gains/losses between PTR and DDS, in terms of yield and gross margins, were examined.
2.2	Establish on-farm demonstration trials testing the direct seeder and drum seeder in conjunction with double cropping of rice in selected villages in Prey Veng and Svay Rieng Provinces, Cambodia	On farm demonstration trials testing seeders with weed management strategies in Svay Rieng and Prey Vang Provinces, Cambodia	31 Dec 2013	**Completed.** On-farm demonstration trials were conducted in 2013 at 77 farms in Svay Rieng and Prey Vang Provinces, with a focus on providing an opportunity for farmers to compare drum seeding with PTR and broadcasting, and to pilot DDS.

Objective 3: To increase local research and extension capacity through support for upgrading of qualifications of colleagues in Lao PDR and Cambodia, and for currently enrolled students from Thailand

No.	Activity	Outputs/ Milestones	Completion date	Comments
3.1	Provide support for two provincial government officials from Lao PDR to undertake Masters degree studies	Masters coursework completed by two Lao colleagues Masters theses submitted by two Lao colleagues	31 Dec 2014	**Completed.** Both students' tuition, travel, research and graduation costs have been paid in full by the SRA. The coursework of both Lao Masters students, Mr Sysavanh Vorlasan and Mr Panya Phiovlamoun, has been completed. Mr Vorlasan and Mr Phiovlamoun expect to complete their theses, as scheduled, by July 2015.
3.2	Provide tuition support for three employees from World Vision Thailand, who commenced their studies at Khon Kaen University with under the aegis of the ACIAR SMCN/2007/215 project, to enable them to complete their Masters degrees	Funding supplied to Khon Kaen University to enable three students to pursue ongoing study Masters theses submitted by three Thai students	31 Dec 2014	**Completed.** All three students' outstanding funding has been paid in full by the SRA. Ms Chiranan Poyprakhon and Mr Sombat Phakham have successfully submitted their theses and received their Masters degrees. Mr Athinon Pungsanthia, who encountered some professional delays to his studies, continues to work on his thesis and expects to submit in 2015.

6 Key results and discussion

Results and conclusions emanating from of the field trials in Lao PDR have been synthesised into a more comprehensive report (Laing et al. 2015a) and a conference paper, Laing et al, 2015b), which are provided in Appendices A and B. Similarly, the 2013 trial results and conclusions achieved in Cambodia were incorporated into a report produced by Dalgliesh et al. 2013, as well as in a journal paper (Dalgliesh et al., 2015), produced in conjunction with the ACCA project. These are provided as part of the ACCA final report, although they had significant inputs from this project for the 2013 data. In the section below, we summarise the key results for each country.

Lao PDR

On-farm testing

In both 2013 and 2014 early wet season rains were unusually poor and farmers reported they delayed transplanting their crops to later in the season than optimal. Particularly in 2013 many farmers were concerned about terminal season drought stress resulting from late transplanting. In contrast DDS rice was established considerably earlier in the growing season, on low rainfall: during focus group discussions in July 2013 farmers highlighted that dry direct seeding was the only technique which enabled them to plant rice where otherwise lack of rain precluded timely transplanting. During on-farm testing farmers were, in general, cautiously optimistic about establishment under DDS.

Following the conclusion of the 2013 wet season it was identified that weed control practices farmers traditionally rely on, such as using standing water to suppress weed growth and relying on the comparative advantage of a rice seedling relative to a weed seed in a paddy, are not as reliable under DDS. During post-harvest discussions, farmers noted that mechanised establishment brought new challenges in terms of weed control, however they also appreciated the potential savings in labour, time and costs and were keen to continue to experiment with DDS (some farmers also noted they had not previously realised the value of GAP recommendations around weed control and had not followed them thoroughly). As well, it was noted that traditional methods of applying fertiliser into standing water in the paddy were not reliable for DDS: farmers also expressed strong interest in methods for delivering fertiliser into the soil at sowing, with seed. It was felt that this proximal fertiliser placement would also enable rice seeds to more effectively outcompete weed seeds.

In the 2014 wet season a modified seeder was used in on-farm trials on nine farms from three villages in Outhoumphone and Champhone districts to enable farmers to test placing fertiliser in the soil at sowing. Farmers also compared manual and chemical (post-emergence herbicide) weed control methods, and, in contrast to the previous wet season, were more rigorous in land preparation and (where applicable) manual weed control to ensure weeds were considerably better controlled. In 2014 trial results there was little difference in weed presence between plots where weeds were manually controlled and those in which chemical herbicide had been applied.

Yields under Good Agricultural Practices were consistently higher, regardless of establishment method, than those under traditional farmer practice (Figure 1). Average yields (Table 1) across the nine farms were 3.4t/ha for DDS with GAP and herbicide; 3.3t/ha for both DDS with GAP and PTR with GAP; 2.3t/ha for DDS with farmer management practices; and 2.0t/ha for PTR with farmer management practice (this last result is the average of three farms; from Phin Neua only).

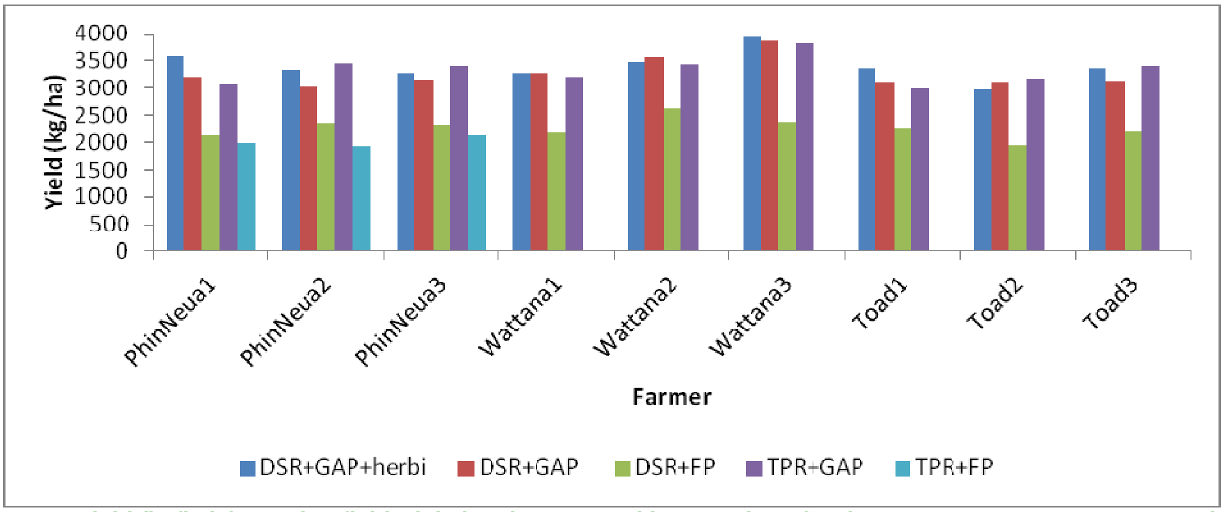

Figure 1: Yield (kg/ha) from nine field trial sites in Savannakhet Province for the 2014 wet season. GAP: good agricultural practice; FP: farmer practice. Data for the PTR+FP treatment are available for Phin Neua treatments only

Directly applying fertiliser into the soil with seed at sowing was greatly favoured by farmers over the traditional method of broadcasting fertiliser into the paddy as soon after sowing as there was sufficient water. Farmers reported that drilling the fertiliser into the soil advantaged rice seed over weeds and felt it was a more efficient application method and one where timing could be better managed.

Table 1: Average yield for treatments in the 2014 wet season field trials

Treatment	Number of farms	Average yield (kg/ha)[1]
1: DDS + GAP + herbicide	9	3330.7 (242.1)
2: DDS + GAP	9	3271.9 (272.7)
3: PTR + GAP	9	3398.0 (262.2)
4: DDS + FP	9	2271.8 (193.1)
5: PTR + FP	3	2014.9 (106.8)

[1] Standard deviations are shown in parentheses

Many farmers who began testing the DDS with the ACCA and ACCA-SRA projects continued to experiment independently with the mechanised establishment options. In 2013 PAFO Savannakhet reported that approximately 100ha was sown with DDS; much of this area was outside project field trials. In 2014 NAFRI data show that 103.87ha in Savannakhet Province were sown with a mechanical seeder: 91.03ha were sown with a dry direct seeder and the remainder were sown with a drum seeder. In this year 47 farmers used the DDS in six districts independently of the ACCA-SRA project. Additionally, DAFO staff and village heads who have been involved in DS testing with the ACCA and ACCA-SRA projects have bought their own direct seeders which they used on their own farms and which they contract out to other farmers. Many farmers were interested in accessing machines and ongoing frustration at difficulties acquiring access to a seeder in a timely manner was reported.

Farmers particularly appreciated the potential labour savings (and subsequent reduction in labour costs) gained by using the dry direct seeder, while remaining cautiously optimistic about weed control under a range of growing season conditions in the longer term.

APSIM modelling (conducted as part of the ACCA project and reported on more fully in annual and final reports for that project and in Laing et al., 2015b; Appendix B) indicates that the results observed on farms in 2014 are part of a longer term trend: over time farmers are likely to see better results (in terms of risk reduction and return on inputs, including labour, per tonne of crop) when switching from PTR to DDS. Additionally, under a 2030 climate farmers' exposure to increasing climate variability and change is reduced when rice is established with DDS rather than PTR.

Comparison of gross margins

DDS has the potential to return a higher gross margin than PTR, regardless of weed management practices (manual or chemical), as long as weeds *are* well managed. The NAFRI-recommended GAP is a useful framework for weed management.

Using data from the 2014 wet season on-farm demonstration trials (averaged across participating households) gross margins have been calculated for PTR + manual weed control, DDS + manual weed control, and DDS + herbicide (Table 2). In all cases, as in the field trials, GAP practices have been assumed.

In scenarios where weeds are managed manually DDS returns a higher gross margin than PTR due to lower labour requirements at crop establishment. This increase in gross margin is achieved despite a small reduction in average rice yield under DDS.

Table 2: Gross margins under different establishment treatments

Treatment	Gross margin (million LAK/ha)	Gross margin (AUD/ha)
PTR + manual weed control	4.6	730
DDS + manual weed control	5.6	889
DDS + chemical weed control	6.1	968

DDS where weeds are controlled by a herbicide returns a higher gross margin than DDS with manually controlled weeds because labour demand is lower, however farmers consistently report that they are not interested in chemical weed control because it increases their input costs; most farmers are not confident they know how to use herbicide safely; and they are concerned about the potential negative impacts on paddy biota (frogs, fish, snails, etc) which are important protein sources during the wet season. Application of herbicide is not supported by the Lao PDR government.

Economics under different labour and rice prices

Using the gross margins calculated in Table 2 as a baseline, scenarios have been calculated to examine changes in rice and labour prices, as these are elements of the cropping systems which are likely to vary and which directly affect gross margins (Figure 2). Variability in the rice price has been reflected by examining increases and decreases of 10 and 20 per cent; the cost of labour has been modelled at a 50 per cent increase (to 75,000 LAK/day) and at a 100 per cent increase (to 100,000 LAK/day).

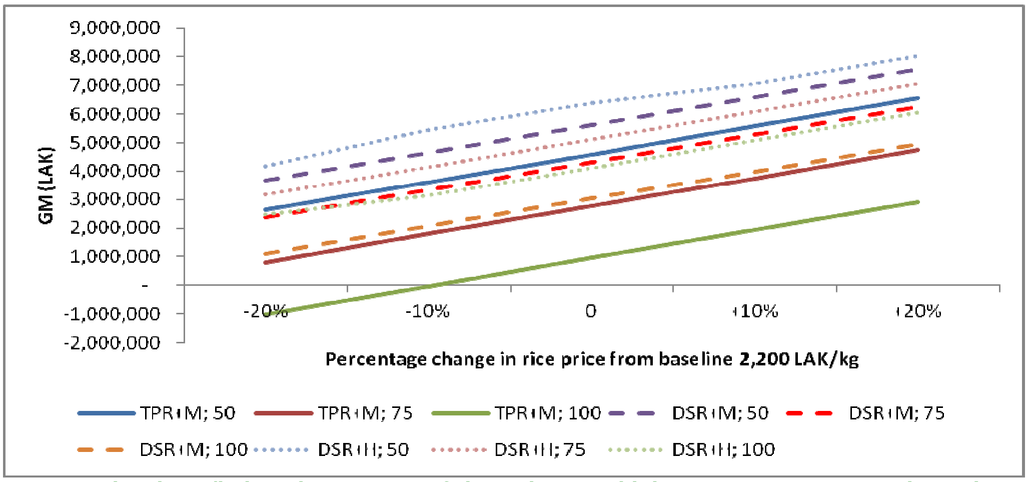

Figure 2: Gross margins (LAK/ha) under a range of rice prices and labour costs. M: manual weed control; H: herbicide weed control. The number in the description of each element represents the daily labour cost in '000 LAK

In all scenarios modelled gross margins were above 0 LAK/ha except those PTR scenarios where labour doubled (from the baseline 50,000 LAK/day to 100,000 LAK/day) and rice price decreased. Where rice price and labour cost remain at current levels changing from PTR to DDS (but maintaining manual weed control) increases average gross margin by around 22 per cent. Where PTR becomes unattractive from a gross margin perspective it may still be an attractive option for some risk averse households seeking to ensure food security, particularly under low rice prices and where uncosted labour is available.

Increasing labour costs in a PTR system, from 50,000/ LAK day to 75,000 LAK/day, reduces gross margins by around 40 per cent. This loss can be considerably offset (all but 5 per cent) by changing from PTR to DDS, for the same rice price and without introducing chemical herbicides. In general, the effect on gross margin of an increase in labour cost (e.g. from 50,000 to 75,000 or from 75,000 to 100,000 LAK/day) can be offset by moving from PTR to DDS, regardless of rice price. Where rice prices remain about the same and labour doubles farmers who change to DDS will reduce their gross margins relative to the baseline but will be significantly better off (in terms of gross margin) to those farmers who remain with PTR.

Using herbicide to control weeds – and thus reduce labour required to produce a crop – will return a higher gross margin than manually controlling weeds for all labour costs and rice prices, however the disinclination among Lao farmers to pursue this option is strong.

Development of training and awareness materials

Two brochures and two posters in Lao (Appendices D to F) were produced by PAFO Savannakhet and NAFRI and were of great interest to farmers and were distributed in Savannakhet, Attapeu, Khammouane and Vientiane provinces. Training and information sessions were facilitated: initially this training was provided to PAFO and NAFRI staff by representatives from World Vision Thailand; subsequently NAFRI and PAFO provided training to DAFO staff and farmers in Savannakhet and surrounding provinces. This training was underpinned by posters in Lao which reinforced key concepts.

An English language discussion paper on issues relating to the emergence of DDS in rainfed lowland rice production in Lao PDR has been produced: this learning has underpinned the ACCA and ACCA-SRA contributions to an IFAD report on mechanised rice establishment in Lao PDR.

Cambodia

On farm testing

In 2013 drum seeding was tested on 69 farms; 37 in Prey Veng and 25 in Svay Rieng. In both provinces a short duration variety was tested for early (17 and 12 farms respectively) and late (7 farms each) plantings; additionally a medium duration variety was tested on 13 farms in Prey Veng and 6 in Svay Rieng. Dry direct seeding was tested on 8 farms: 5 in Prey Veng and 3 in Svay Rieng. Mechanised establishment treatments were compared to yields achieved under both traditional transplanted practices and broadcast sowing.

Average drum seeder yields of 3.9t/ha in Prey Veng and 3.2t/ha in Svay Rieng were achieved, compared to yields under transplanting of 3.4t/ha in Prey Veng and 3.2t/ha in Svay Rieng, and yields from broadcasting of 4.0t/ha in Prey Veng and 2.9t/ha in Svay Rieng (Table 3, Figure 3). Due to flood damage meaningful yield data under dry direct seeding were not obtainable.

Table 3: Comparisons of average wet season rice yield under mechanised and traditional establishment practices in Pray Veng and Svay Rieng, 2013

Treatment	Prey Veng average yield (kg/ha)[1]	Svay Rieng average yield (kg/ha)[1]
Transplanting	3427.8 (664.7)	3208.4 (657.8)
Drum seeding	3892.1 (833.4)	3240.8 (639.0)
Broadcast	3967.0 (631.2)	2898.3 (753.1)

[1] Standard deviations are shown in parentheses

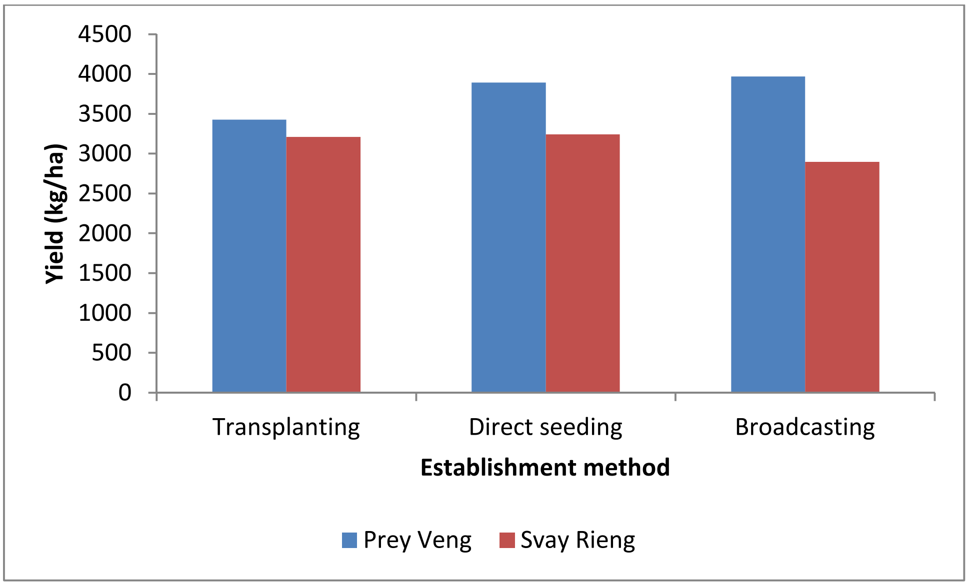

Figure 3: Average yields (kg/ha) under different establishment methods for on-farm trials in Prey Veng and Svay Rieng, 2013

Under the ACCA project, on-farm testing in previous years had experimented with mechanised planting of two short-duration crops in the wet season, rather than one medium duration variety: one facet of research had investigated the possibility of combining machine planting with shorter duration crops to increase (and possibly double) farmers' wet season yields. In 2013 farmers expressed reluctance to plant a later (or second, in the case of earlier plantings) crop due to concerns about flooding towards the end of the wet season: these concerns were well founded, particularly in Prey Veng where flood damage to crops and infrastructure was significant.

ACCA project research (Dalgliesh et al., 2013; Santoyo Rio 2013) has demonstrated that farmers are interested in alternative methods to transplanting to establish a rice crop: Dalgliesh et al. noted that of the 12 farmers they interviewed (of whom six were chosen to represent a "control" group who had not had easy access to mechanised establishment techniques) about establishment practices only 25 per cent routinely used a drum seeder while an additional 50 per cent had recently begun to establish the majority of their crop by broadcasting. Direct seeding (either drum seeding or broadcasting) reduced farmers' labour costs and the time required to establish the crop: from around 40 person days per hectare under transplanting to 2.2 hours per hectare under drum seeding. In Cambodia herbicides are regularly used to control weeds in direct seeded crops.

Economic Analysis

In both Prey Veng and Svay Rieng farmers' gross margins in 2013 were higher under mechanised establishment than farmer practice, again due to reduced labour requirements (Figure 4). Net incomes, including labour costs, in Prey Veng were USD $306/ha for drum seeding, USD $70/ha for broadcast, and a loss of USD $41/ha for traditional transplanting. In Svay Rieng net incomes including labour were USD $322/ha for drum seeding, USD $114/ha for transplanting, and USD $11/ha for broadcast seed (Table 4).

Table 4: Net income including labour costs (USD/ha) for three establishment methods in Pray Veng and Svay Rieng, 2013. Analysis conducted under the ACCA project

Establishment method	Prey Veng (USD/ha)	Svay Rieng (USD/ha)
Transplanting	-41	114
Drum seeding	306	322
Broadcast	70	11

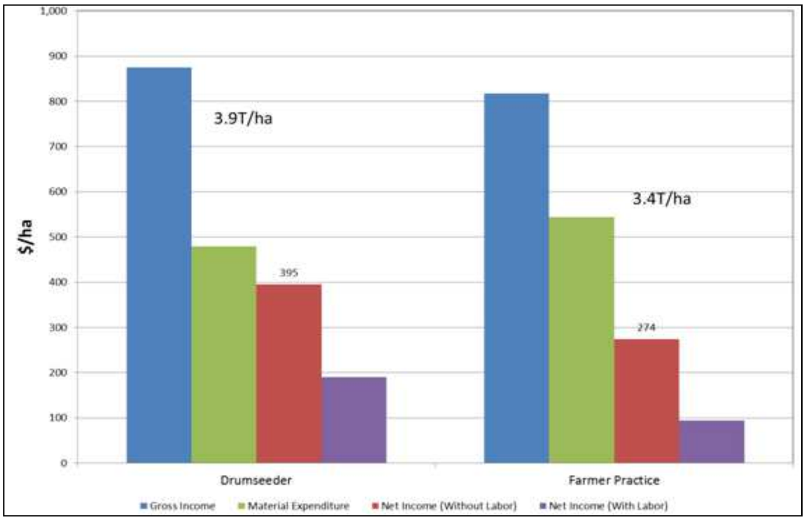

Figure 4: Analysis of gross income, variable costs and incomes with and without labour for Prey Veng, 2013 wet season; similar trends were observed in Svay Rieng. Analyses conducted under the ACCA project

Economic analyses conducted under the ACCA project, incorporating 2013 on farm trial results from the ACCA-SRA project, have demonstrated that drum seeding using modern improved varieties combined with improved agronomic management, including application of fertiliser and herbicide, will increase the productivity and economics of rainfed rice production in Cambodia (Dalgliesh, 2014).

7 Impacts

7.1 Scientific impacts

Results of this project are influencing the research being conducted by Prof Shu Fukai in the ACIAR project CSE/2012/077 (*Mechanization and value adding for diversification of lowland farming systems in Lao PDR and Cambodia*), where DDS in rain fed wet season rice is now also being tested as one of the treatments, and the mechanisation aspects of the direct seeders will be further investigated.

Results of this project have also been shared with the regional CCAFS (CGIAR Research Program on Climate Change, Agriculture and Food Security) coordinator for Southeast Asia, Dr Leo Sebastian. As a result, Dr Sebastian is planning to include DDS in the menu of climate smart agricultural practices to be further tested and propagated in Climate Smart Villages being established in Lao PDR, Cambodia and Vietnam as part of CCAFS' Southeast Asia program, potentially extending our research methodology into Vietnam and other parts of Lao PDR and Cambodia.

Journal papers (in Lao and English) under preparation by the project team and due for submission by June 2015 are likely to have a significant impact in the regional scientific community not yet exposed to DDS as a viable technology. We anticipate that these journal papers and the inclusion of DDS in the CCAFS research program will spurn additional research in support of refining and extending the DDS technology elsewhere in Southeast Asia.

7.2 Capacity impacts

Researcher capacity

The five Masters students (two in Lao PDR and three in Thailand; one of whom is female) who the project supported have, as a result of their studies, developed new skills and research abilities which they will apply throughout their professional careers. These skills include running field trials; collating and error-checking data; performing and interpreting statistical analyses of field trial data; reviewing literature; report writing; and communicating scientific outcomes to non-technical audiences.

As a result of research undertaken for his Masters degree one student has successfully received funding from the ACIAR funded Lao Small Research Grants program to assess potential methods to optimise fertiliser use in DDS established crops. The grants assessment panel noted the student's outstanding research and writing skills, which have been honed through his studies, and awarded him one of the highest scores for his proposal.

Lao PDR

The project has supported training initiatives in the use of the dry direct seeder provided by Thai experts to local researchers and extension agents. Involvement by key Lao research and extension partners in the project research activities has also led to the formation of a cohort of Lao experts in the use of the dry direct seeder as part of broader improved farm management initiatives to a wide range of farmers and extension agents in Savannakhet and nearby provinces.

Introductions performed within this SRA project have significantly increased the capacity of PAFO Savannakhet to provide information and training to farmers in DDS. In addition, associated with two projects being implemented by the NGOs ADRA in Attapeu Province and SNV in Khammouane Province respectively, this expertise has also been shared with PAFO and DAFO in other provinces and districts.

This project has also enhanced the knowledge of the technical team in the IFAD-funded Sustainable Natural Resource Management and Productivity Enhancement Project (SNRMPEP), significantly improving the content of their manual *Direct Seeding Rice*. This manual will be disseminated in the five southern rice growing provinces of Lao PDR: Champassak, Savannakhet, Attapeu, Xepon and Saravane.

Cambodia

iDE agronomists' and field technicians' skill in the use of both drum and direct seeders has been increased through training provided as part of this project in 2013. This capacity has helped iDE position itself as a primary partner in the in the IFAD-funded Project for Agriculture Development and Economic Empowerment program (PADEE), in turn greatly enhancing iDE's capacity to deploy direct seeding technologies, not just as part of this and the ACCA project, but as part of a wider package of farmer interventions being packaged and delivered through iDE's Farmer Business Advisor franchise, as well as through the PADEE program itself.

7.3 Community impacts

7.3.1 Economic impacts

In both Lao PDR and Cambodia, we recorded a rapidly expanding number of households outside case study areas using the direct seeding technologies. Both in the project provinces and as well as in other key rice growing provinces outside of Savannakhet and Svay Rieng farmers are starting to take up the technologies as a result of activities in this project. This leads us to conclude that the direct seeding has a high prospect of adoption and future impact.

Lao PDR

In addition to the on-farm trial sites conducted by the project, PAFO has facilitated the uptake of DDS in other villages in Savannakhet Province: over 100 ha was machine-seeded in both the 2013 and 2014 wet seasons, using three machines available to PAFO. In 2014 at least 10 farmers or extension agents bought their own Thai seeders for use (on their own farms and on a contract basis) that wet season.

The Provincial administration of Savannakhet is planning the acquisition of up to 1000 direct seeders to be distributed amongst farmers in Savannakhet over the next five years. From our results we conservatively estimate a direct seeder will service about 10-30 hectares. As shown in Table 2, on average farmers can expect an increase in gross margin of about 159 AUD when changing from PTR to DDS with manual weeding. Assuming each machine services 10 ha, and only 30 per cent of the machines are operational, the aggregated annual increase in gross margin of farmers in Savannakhet deploying the direct seeders would be in the order of 477,000 AUD.

Just accounting for the actual additional area sown in 2014 using DDS in 2014 (91.03 ha), we estimate an actual economic gain of 91M LAK (approximately AUD $14,500) was achieved last year.

Beyond the above significant potential impact (but likely to occur over the next couple of wet seasons), we have identified a number of additional pathways to impact likely to consolidate the above impact.

1. In conjunction with the ACCA project, the NGO SNV is extending DDS into five villages in Khammouane Province: a small trial of 1 - 5ha in each village will occur during the 2015 wet season. SNV reports interest in DDS is high and they have already received requests from farmers for more information about buying their own seeders, suggesting that potential economic impacts are likely to be higher.
2. The SNRMPEP project has incorporated learnings from this project and the ACCA project into its training manual, "Direct Seeding Rice". One thousand manuals are being printed in Lao and will shortly be distributed to research, extension and university staff throughout Lao PDR, mainly in Champassak, Saravane and Savannakhet. In addition, SNRMPEP has produced a short brochure on DDS. Five thousand copies have been printed in Lao and distributed to farmers in Savannakhet, Xepon, Saravane, Attapeu and Champassak provinces. Assuming an uptake rate of five per cent (i.e. 250 farmers) over an initially

modest area of land (0.5ha each) would lead to an initial annual economic impact of 125M LAK (19,841 AUD).

3. The CCAFS project is aware is planning to deploy DDS into its suite of climate smart agricultural practices recommended to farmers in Climate Smart Villages in Savannakhet and Vientiane provinces. An initial potential annual economic similar to that calculated in point 2 (125M LAK or AUD $19,841) is likely to be achieved through CCAFS, with greater impacts likely after more widespread experimentation with, and uptake of, DDS.
4. A key constraint to increased uptake of DDS is the lack of access to more machines. The LADLF project, funded by the Australian Aid program, is raising awareness among policymakers at both national and provincial levels about DDS, including economic, gender and environmental considerations. It is anticipated that, as a result of the LADLF project, policymakers will better facilitate the importation and/or local manufacture of local direct seeders in order to increase farmers' productivity, one of the stated goals of the Lao PDR government.

Cambodia

Outscaling of project results in Cambodia in conjunction with the ACCA project has made significant progress in the last year through the linkage of iDE with other major donor initiatives.

In Cambodia, iDE operates a hybrid agricultural input selling business that addresses the market gaps in quality, availability and advisory services. The franchise-modelled business builds the capacity of commune-based Farm Business Advisors (FBAs), to deliver inputs and advice to farmers (http://www.ide-cambodia.org/fba/). There are currently 150 FBAs throughout five provinces; on average each FBA services about 100-120 farmers, leading to a potential outreach to between 15,000 and 18,000 farmers.

Direct seeding of rice as a central component of the response farming concept developed by ACCA has been incorporated by iDE into a wider resilient cropping system incorporating a range of techniques that ultimately help farmers reduce risks and costs of production, while maintaining or increasing gross returns. The effect is an increase in net income, which can more than double from $100-200/ha to $400-$600/ha. From a sustainability point of view the new system also provides a profitable income for the entrepreneurs who service the farmers adopting new technologies with agricultural inputs and advice. Presently, these entrepreneurs are the FBAs, but as adoption of the new technology rises, it is expected to have a positive effect on a wider range of input suppliers.

Through the auspices of the PADEE program, in 2014 iDE embarked on a three province expansion (Prey Vang, Takeo and Kampong Thom) that will double the size of the FBA program in two years.

7.3.2 Social impacts

In both Lao PDR and Cambodia the SRA project has continued to demonstrate the potential for substantial labour savings for farmers who change from transplanting to mechanised rice planting. Mechanised rice establishment methods, by eliminating the need for transplanting, considerably reduce the amount of labour required to grow a rice crop: as a result the household is able to reallocate scarce labour resources. It is this aspect of mechanised rice planting which most appeals to farmers working with the project teams.

In both countries reduced on-farm labour requirements are affecting gender roles in agriculture: weeding has traditionally been primarily women's work. There are potential positive benefits for women, in terms of increased quality of life, reduced peak workloads and reduced drudgery. However, with a reduced demand for on-farm labour many women (usually young, unmarried and potentially vulnerable) are migrating on a semi-temporary basis for increased economic opportunities. Off-farm remittances form a substantial part of household income streams and, in many instances, young women are becoming the primary breadwinners in their families, resulting in changing perceptions of gender (and generational) roles.

It is important to note that the potential labour savings associated with direct seeding are only likely if weeds are well controlled. In Cambodia the use of herbicides is accepted and common, however in Lao PDR herbicides are not currently widely used. The ACCA-SRA project demonstrated in 2014 that weeds can be well controlled manually in a DDS system and that a yield penalty, relative to the application of post-emergent herbicides, is not incurred.

7.3.3 Environmental impacts

There is a potential for negative environmental impacts if herbicides are used inappropriately or without sufficient training. The project worked to ensure farmers were trained in the selection and use of appropriate herbicides, and promoted an attitude (which accords with farmers' risk reduction strategies) of 'necessary-but-no-more' application rates in the treatments where herbicide was tested.

7.4 Communication and dissemination activities

Input to ACCA project

The results of the field trials conducted and the outputs generated by this project constitute key input into the ACCA project (LWR/2008/019).

Presentations to scientific audiences

Presentations to Lao scientists at the NAFRI 15th Anniversary Symposium, 9-10 April 2014.

Engaged with CCAFS and provided relevant project documentation and reports to the CCAFS southeast Asia regional team.

Presenting a paper (Laing et al., 2015b) to the 17th Australian Society of Agronomy, September 2015.

Dissemination activities

The discussion paper on dry direct seeding produced by the project in July 2013 and revised in April 2015 (Appendix A) had a strong influence on the thinking in the IFAD-funded SNRMPEP project team. Triggered by the discussion paper, the SNRMPEP team researched the availability of suitable dry seeders to import to Lao PDR. The IFAD team also prepared a suite of crop production manuals targeted at extension personnel and leaflets and posters for farmers, including a manual for rice growing, *Direct Seeding Rice*, to which the ACCA-SRA team has made significant contributions.

ACCA-SRA and ACCA colleagues provided technical training and follow up information (through Lao language posters and brochures produced by NAFRI and PAFO) on DDS to farmers in lowland Lao PDR through PAFO Savannakhet and links with SNV and ADRA projects. PAFO Savannakhet is actively promoting dry direct seeding across Savannakhet Province beyond project sites and into key rice producing regions of nearby provinces.

As part of the PADEE program, iDE agronomists have trained Farmer Business Advisors in five Provinces in direct seeding techniques using the drum seeder.

Farmer training activities

Farmer training days were held prior to the 2013 wet season in both Lao PDR and Cambodia, and before the 2014 wet season in Lao PDR, to ensure farmers were well prepared to participate in the on-farm testing. As well, two farmer field days were held in each region in each country during the 2013 wet season to provide opportunities for farmers in neighbouring villages to learn about the on-farm testing.

Additionally, in Lao PDR the project provided an opportunity through which PAFO Savannakhet trained villagers from Attapeu and Khammouane provinces in the use of the direct seeder; these farmers, through projects sponsored by the NGOs ADRA (Attapeu) and SNV (Khammouane), have commenced testing direct seeded rice. One of the Masters students supported by the project has taken a lead role introducing farmers to the dry direct seeder and coordinating training activities. The project has also been instrumental in coordinating efforts for PAFO Savannakhet to provide training to farmers and researchers in Khammouane Province, as part of research activities supported by the Dutch NGO SNV.

Stakeholder engagement activities

Strategic stakeholder engagement continued in both countries in conjunction with the ACCA project; key interactions were recorded in trip reports. Routine briefings in the context of this project were provided to the following key stakeholders:

Lao PDR:

- Dr Monthathip Chanphengxay (Director General of the Department of Agriculture in the Ministry of Agriculture)
- Technical team of the IFAD-funded SNRMPEP
- Country manager and program officers of SNV
- Program officers of ADRA

Cambodia:

- Technical experts and Project Support Unit of the PADEE team
- Key technical staff in the Department of Rice Crop Production and the Department of Agricultural Extension
- Director of Svay Rieng Provincial Department of Agriculture
- Country manager and program officers of SNV

8 Conclusions and recommendations

8.1 Conclusions

Results achieved under this project have clearly demonstrated that direct seeding is technically feasible and is economically viable in both Lao PDR and Cambodia.

There are a number of agronomic and technical issues which will benefit from further research investment. In particular, thorough and early weed control is necessary to the success of mechanised rice establishment in both countries. This is easier to achieve in Cambodia, where herbicides are already in use, than in Lao PDR. However the ACCA-SRA project has demonstrated that weeds can be well controlled in a rainfed DDS system without herbicides, and can yield comparably to PTR with manual weed control.

Key constraints to DDS being widely taken up by farmers are poor access to machinery and lack of opportunities to improve and refine current machinery designs. To overcome this will require a policy response. Some of these issues might be addressed in Lao PDR as part of a LADLF supported project, where activities undertaken by NAFRI are aimed at facilitating policymakers' interest in, and understanding of, the value of DDS.

The dry start of both the 2013 and 2014 wet seasons showed that direct seeding can help reduce the impact of climate risk. In several locations farmers were not able to transplant rice on upper and middle terraces in a timely manner due to drought; however, in all of these sites, direct seeded rice had been established successfully and was growing well. In lowland areas, early direct seeding of rice is likely to reduce the risk of crop damage due to flooding, as the rice is already tall enough to avoid being fully submerged when heavy rainfall commences in July and August.

Farmers in Lao PDR and Cambodia have shown a very strong interest in direct seeding techniques (both those who have participated in the on-farm trials and those who have experimented independently of them) largely because of the significant potential labour savings. While direct seeding in itself is not a complex technology, its widespread uptake is likely to trigger major changes across the wider farming system (e.g. changes to whole farm systems through alterations in livestock management, timing of the cropping season and labour demands). Understanding and facilitating altering agronomic practices into whole farm and village-wide cultural and socio-economic contexts will require ongoing systems research.

8.2 Recommendations

The ACCA-SRA project identified a range of agronomic, mechanical and institutional-capacity issues which could be addressed through further research to support a wider uptake of direct seeders in rainfed lowland rice growing areas of Lao PDR and Cambodia.

Agronomic considerations include research questions around fertiliser timing and placement (this is currently being investigated by PAFO Savannakhet in a project arising out of one of the Masters students' studies, through funding from ACIAR via the Lao Small Research Grants); additional weed control measures; time of crop establishment; optimal varieties for use with a direct seeder; soil management considerations; and toposequences best suited to mechanised rice establishment.

Technical modifications to improve the ease, use and functionality of seeders are still required, as well as facilitating farmer access to machines, both through ownership and contracting arrangements.

Supply chain development considerations include potential new village-level challenges around planting decisions; avenues for sourcing, repairing and modifying machines; capacity and training requirements; and formal support mechanisms for traditionally risk averse farmers.

9 Publications produced by the project

Laing, A.M., C.H. Roth, V. Phengvichith, T. Inthavong, Sipaseuth, X. Souliyavongsa, K. Thiravong, S. Vorlasan and J. Schiller, 2015a. *Direct seeded rice in Lao PDR: Summary of learnings from the ACCA and ACCA-SRA projects*. CSIRO Agriculture Flagship unpublished report. This is Appendix A in this report.

Laing, A.M., C.H. Roth, D.S Gaydon, V. Phengvichith, Sipaseuth, K. Thiravong, S. Vorlasan and J. Schiller, 2015b. Combining field trials and crop modelling of dry direct seeded rice to reduce production risks in Lao PDR under current and future climates. Paper submitted to 17th Australian Agronomy, Hobart, 20 to 24 September 2015.

Laing, A.M., D.S. Gaydon, V. Phengvichith, T. Inthavong, P.L. Poulton, C.H. Roth, K. Thiravong, G. Lacombe, Sipaseuth. Direct seeding of rain fed rice in lowland Lao PDR reduces farmers' exposure to climate risks and ameliorates gross margins in poor years. For submission to *Experimental Agriculture* or *Climate and Development* in June 2015.

Vorlasan, S., V. Phengvichith, J. Schiller. Dry direct seeding in Savannakhet Province. For submission to *Lao Journal of Agriculture and Forestry* in June 2015.

Pamphlets and posters on using the dry direct seeder in rain fed lowland Lao PDR have been produced by both PAFO Savannakhet and NAFRI in the Lao language and circulated to farmers, extension agents and other stakeholders in Lao PDR and Thailand. These are Appendices C to E in this report.

10 References

Dalgliesh N.P., Charlesworth, P., LeNon, L. and Poulton, P.L., 2015 Cultivating resilience in Cambodian lowland ecosystems-farming system research to support flexible climate response strategies for smallholder farmers. Submitted to *Experimental Agriculture Journal*

Dalgliesh, N.P., 2014 *Increasing flexibility in Cambodian monsoonal rice cropping systems* CSIRO Agriculture Flagship, Australia. Unpublished report for the ACCA project

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Santoyo Rio, E., 2013 *Farmer views on new cropping practices piloted under the ACCA project in Svay Rieng Province* CSIRO Sustainable Ecosystems, Australia. Unpublished report for the ACCA project

11 Appendices

11.1 Appendix A: Technical report on dry direct seeding in Lao PDR prepared by CSIRO, NAFRI, PAFO Savannakhet and UQ

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Direct seeded rice in Lao PDR

Summary of learnings from the ACCA and ACCA-SRA projects

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April 2015

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We are grateful to Mr Sombat Phakham and his colleagues at World Vision Thailand for their ongoing support and knowledge-sharing in relation to using the direct seeder, and to their assistance sourcing additional project machines.

Abbreviations

ACCA	Shorthand for the LWR-2008-019 project, *Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India*
ACCA-SRA	Shorthand for the LWR-2012-110 project, *Regional co-learning in simple mechanised tools for rice planting*
DAFO	District Agriculture and Forestry Office
DAEC	Department of Agricultural Education and Cooperatives
DSR	Direct seeded rice
FP	Farmer practice
GAP	Good agricultural practice; a system of crop management developed and recommended by NAFRI
GM	Gross margin
IFAD	International Fund for Agricultural Development
NAFRI	National Agriculture and Forestry Research Institute
NUOL	National University of Laos
PAFO	Provincial Agriculture and Forestry Office
PTR	Puddled transplanted rice (traditional rice establishment practice)

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Contents

Executive summary

Mechanised dry direct seeding was tested on farms in Savannakhet Province, Lao PDR as part of activities conducted under the ACIAR-funded ACCA (LWR/2008/019: *Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India*) and ACCA-SRA (LWR/2012/110: *Regional co-learning in simple mechanised tools for rice planting*) projects in 2013 and 2014. For most of the households which participated in the testing demonstrations this was the first opportunity to experiment with mechanised dry direct seeding of rice (DSR).

In 2013 on-farm trials were conducted to introduce rainfed rice farmers in the districts of Outhoumphone and Champhone to dry direct seeding of wet season rice, provide them with training and support throughout the growing season and learn with them the potential for direct seeding in this region. Sixty six farmers participated in the on-farm testing and over 100ha was sown with the direct seeder. Farmers were most interested in the potential benefits from reduced labour required to establish a rice crop. Through the season we learned that traditional weed control methods (in particular, using standing water to suppress weeds) cannot be relied on in a direct seeded crop and farmers must use other techniques, often at different times of the growing season (e.g. prior to sowing) to control weeds.

In 2014 in a smaller trial, on nine farms, a new locally produced seeder which dispersed fertiliser with the seed at sowing was tested. As well, a large emphasis was placed on weed control through land preparation prior to sowing; manual weeding was compared to the application of a post-emergent herbicide. Yield results demonstrated that comparable results could be achieved under both DSR and transplanted rice (PTR), and that similar results can be obtained under manual or chemical weed control. Farmers are reluctant to rely on herbicides for weed control.

Gross margins calculated using average 2014 data are higher under DSR+GAP than under PTR+ GAP (and higher again under DSR with chemical weed control). Under a range of labour cost and rice price sensitivities, producing rice under DSR+GAP compared to PTR+GAP, where weeds are well controlled, buffers against an increase in labour cost of up to 50 per cent.

These on-farm trials are a proof of concept that DSR is a viable technology to reduce production costs in rainfed lowland Lao PDR; additionally it holds promise to reduce farmers' exposure to climate risks. A number of key challenges remain outstanding, in particular development of supply chains which will enable all farmers who are interested in mechanised rice to have access to DSR. Many of these issues, in particular sourcing machinery and increasing the capacity and training of key extension partners such as DAEC, PAFO and DAFO will need to be addressed at the policy level.

The trials demonstrated many research questions remain to be investigated to better understand DSR in lowland rainfed areas of Lao PDR and to support the households who farm there. These include optimal weed management; timing and placement of fertiliser; time of planting; variety selection; tailoring DSR use to specific soils and/or positions within the toposequence; and practical seeder modifications and improvements.

Farmers who participated in this research expressed a keen interest in DSR and, with assistance from local research and extension agencies, are eager to continue to engage in and experiment with dry direct seeded rice to decrease their production costs while maintaining or improving food security and resilience against increasing climate variability and change.

Rationale for direct seeding

Rice production practices

Rice is traditionally transplanted in rainfed lowland areas of Lao PDR. Farmers plant between two and four nursery crops at staggered intervals approximately two weeks apart from late April to early June, on pre-monsoon showers or, if it is available, with supplementary irrigation from ponds. When the monsoon rains come, in late June or July, the most viable nursery seedlings are transplanted into bunded paddies. Once the nursery is established farmers plough and prepare their main paddies. Rice is optimally transplanted into standing water, which also suppresses weeds and into which fertiliser is broadcast. If there is insufficient rain for standing water to accumulate in bunded paddies farmers will apply supplementary water in the event that it is available (on limited rainfall this is not an option for many farmers) or will delay transplanting beyond the optimal window. Rice transplanted without standing water does not generally thrive nor produce yield sufficient for households' needs.

In many years rice yields are constrained by a lack of, or poorly timed, rainfall (Schiller et al., 2006). Year to year wet season rainfall in southern Lao PDR is highly variable, in terms of the onset and cessation of the rains as well as the timing of the intra-monsoon dry period, which generally occurs for two to four weeks between mid-June and mid-July (Schiller et al., 2006). The amount of rainfall received during any wet season varies greatly and there is little to no correlation between early season rainfall amounts and the total wet season rainfall received (Lacombe et al., 2012). In general only a few spatial or temporal trends in rainfall have been identified; those which do exist are of low statistical significance and cannot be used to accurately predict rainfall throughout the growing season (Lacombe, 2012).

Most rice produced in lowland rainfed Lao PDR is for domestic food consumption: rice prices are low and input costs comparatively high (and the use of inputs not well enough understood) that few farmers aim to grow more rice than they expect their household to eat (Schiller et al., 2013).

Most rural households have experienced some labour migration; family members work off farm for some or all of the year to increase the family's food security and to facilitate the education of others, the purchase of machinery, agricultural tools and inputs, and other household expenses.

Directly sowing rice into prepared paddy land, in contrast to sowing a nursery and transplanting seedlings into paddies, has been practised in the dry season in small irrigated areas of lowland Lao PDR since the early 2000s (Schiller et al., 2006). This dry season rice is established by broadcasting seed or, more recently, through mechanised establishment. Direct seeding[1] in rainfed paddies in the wet season is a new innovation which has been concurrently introduced into the region by a number of research projects, including the ACIAR-funded ACCA (LWR/2008/019: *Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India*) and ACCA-SRA (LWR/2012/110: *Regional co-learning in simple mechanised tools for rice planting*) projects. An important, and unique, approach of these two projects has been to support the introduction of the direct seeder through interactions between key Thai and Lao researchers and to facilitate the transfer of knowledge from

[1] We follow the general IRRI terminology, whereby direct seeding rice (DSR) is the sowing of seed into the soil, in contrast to transplanting rice (PTR). Direct seeding can be undertaken as dry direct seeding into tilled soil using a tractor-mounted seeder, (as used here) or by broadcasting into dry soil, often followed by cultivation. Wet direct seeding is either undertaken with a drum seeder on puddled soil or done by broadcasting seed directly onto wet soil

north east Thailand (where rainfed, wet season direct seeding has been practised for some time) to Savannakhet Province of Lao PDR.

Reducing exposure to climate risks

By direct seeding rice farmers can take advantage of the same early-season rains (in late May and early June) which germinate and sustain their seedling nurseries. Because the rice is planted in situ in the paddies from where it will be harvested, standing water (required for transplanting) is not necessary at any time during the wet season. Instead smaller rainfall events early in the wet season are sufficient for germination and crop development.

Physiologically, direct seeded rice plants are better protected against early and/or intermittent droughting events as root systems are better developed earlier in the season and are thus better able to withstand short term rainfall deficits. In lower terraces or floodplains, early seeded rice plants are also taller sooner and better able to withstand short-term flooding events during the main season rains (Figure 1). Additionally, direct seeded rice matures earlier in the wet season and is less likely to be exposed to terminal drought stress around harvest.

Planting rice with a direct seeder will increase the year to year reliability of crop production. This increased food security will enable farmers to more reliably plan other activities and to budget for agronomic inputs.

Figure 1: Direct seeded rice at the farmer demonstration trials in Ban Wattana (Champhone) at the top (left), middle (centre) and lowest (right) points in the toposequence (pictures taken on 8 July 2013)

Economic savings

DSR is faster and requires significantly less labour than PTR to establish a crop: a skilled tractor operator plants around 1ha per day with a seeder, while it takes about 20 people to transplant 1ha per day. The reduction in hired labour required to establish the crop greatly reduces the cost of production; additionally it reduces the number of household members necessary on farm for crop establishment, with the result that they are able to seek alternative, often more remunerative, off-farm work. For most farmers the potential to reduce labour, and thus input costs, by using the direct seeder is its primary attraction.

Where weeds are well controlled, e.g. via thorough land preparation and manual weeding early in the season, gross margins from DSR are higher than those under PTR, due to labour savings.

Direct seeder demonstration trials

On-farm trials: 2013

In 2013 66 farming households participated in on-farm demonstrations of the direct seeder under the ACCA and ACCA-SRA projects. The key aims of the trials were to raise awareness of the direct seeder in rainfed lowland Savannakhet and to identify key strengths and weaknesses of planting with the seeder. Participating households came from the villages of Phin Nua (9 farmers), Nonsavang (6), Phin Thai (3), and Sibounheuang (3) in Outhoumphone district, and in the villages of Toad (9 farmers), Taleo (9), Sakheun (9), Sivilay (9) and Vangmao (9) in Champhone district. Farms in Outhoumphone are largely drought-prone; those in Champhone are a mixture of drought- and flood-prone.

The seeder tested was a Thai-built model which uses discs to plough furrows into which seed is sown (Figure 2). Farmers tested three fertiliser options:

T1: Fertiliser applied as soon as possible after sowing at a rate recommended by NAFRI;

T2: Fertiliser applied approximately ten days after plant emergence, into standing water, at a rate recommended by NAFRI. In many instances fertiliser application was delayed due to insufficient rainfall; and

T3: No fertiliser applied.

There was considerable interest by Savannakhet farmers in testing the direct seeder: for the most part farmers, who had no previous experience with mechanised establishment, were interested in potential labour savings.

Figure 2: The Thai-built, disc-based direct seeder used in the farmer demonstration trials in western Savannakhet

In addition to the planned demonstration sites, PAFO Savannakhet facilitated the use of the direct seeder in other villages; in total an area of approximately 100 ha was direct seeded in the 2013 wet season across Savannakhet Province. A key constraint to increased adoption was the lack of access to more direct seeding machines.

2013 trial results and farmer feedback

A visit to Savannakhet Province in late June and early July 2013 showed promising trial results, ranging from plots with excellent establishment and high yield potential, to some plots where weed pressure of lack of fertiliser was likely to depress yields. In most areas the seeder had been tested on fields in higher positions within the toposequence, on more marginal land, due to farmers' inherent risk aversion and cautious engagement with a new technology: the primary goal for most rainfed farmers in lowland Lao PDR is food security, not high yield or maximising profit.

In some areas traditional transplanting of nursery-matured seedlings had not been possible due to poor rains to at the beginning of the 2013 wet season, and the direct-seeded rice paddies were the only well established plots. In other areas transplanted rice was significantly less well matured than the direct seeded rice.

Farmer focus groups discussions were conducted prior and after the wet season 2013 trials. The results have been reported by Chialue *et al* (2013), and are summarised below.

Twenty-two farmers were interviewed about their initial experiences with the direct seeder in early July: overall farmers were cautiously positive about their testing of the direct seeder. They noted that mechanised establishment brought new challenges in terms of weed control, however they also appreciated the potential savings in labour, time and costs, as well as the reduced exposure to climate risks such as the severe early season drought experienced in 2013. Many farmers highlighted that direct seeding was the only technique which enabled them to plant rice where otherwise the lack of rain precluded timely transplanting. Overall, farmers were keen to compare their yields under PTR and DSR at the conclusion of the season, and reflect on the inputs required to achieve these yields.

During a return visit to Savannakhet Province in December 2013 farmers were interviewed again about their experiences with the direct seeder. Farmers remained interested in the direct seeder, in particular its potential to save labour and reduce production costs, however they very clearly identified that weed control is important, and traditional methods (which rely on ponded water to suppress weeds and growing seedlings to outcompete any surviving weeds) are no long appropriate. Some farmers stated that they had not followed NAFRI recommendations relating to weed control in the on-farm testing as they had not, previously, appreciated their value. Farmers and researchers reflected that better field trial results were obtained from fields in the middle and lower positions within the toposequence: greater water availability and ponding resulted in better weed control and application of fertiliser in a timely manner. Farmers also observed that row planting made weeding much easier, regardless of whether the weeding was done with a hoe or a rotary weeder.

Households' experiences with DS varied significantly, and depended on factors such as the toposequential position of the field in which the seeder was tested, paddy size, and availability of (paid and unpaid) labour. Despite many farmers expressing some concerns with the seeder, particularly around weed control, they noted their limited experience in using it, and were interested in testing the seeder again in 2014 with some modifications (e.g. a new field, better soil preparation prior to sowing, different fertiliser regimes).

Limited quantitative data were available for analysis from the 2013 field trials, however yield results (Table 1 and Figure 3) show inconsistent trends between the three fertiliser treatments. There is a trend of DSR achieving lower yields than PTR which is reported in the literature (e.g. Cabangon et al., 2002; Lantican et al., 1999).

In the fertiliser treatments the high degree of variation between yields suggests farmers may interpret fertiliser application advice differently. Anecdotal evidence suggests that where fertiliser is applied at sowing (close to the rice seed) it is preferentially used by rice plants and enables them to develop faster than proximate weed seeds. Where fertiliser is applied after crop emergence, into standing water, it is used by both rice and weeds: greater weed growth was reported by farmers in these treatment groups. However applications of fertiliser after crop emergence were, in many cases, delayed by late rains: this is likely to have affected the growth of rice plants.

Table 1: 2013 field trial results from Outhoumphone and Champhone villages

Village	n	T1: PTR + sowing N (kg/ha)[1]	T2: PTR + post sowing N (kg/ha)[1]	T3: PTR no N (kg/ha)[1]	T4: DSR + sowing N (kg/ha)[1]	T5: DSR + post sowing N (kg/ha)[1]	T6: DSR no N (kg/ha)[1]
Sakheun	3	2303.0 (2359.3, 2213.4)	2006.2 (2306.0, 1775.5)	1975.6 (2044.7, 1931.8)	2520.6 (2908.5, 2238.4)	2576.2 (2963.6, 1801.4)	1850.8 (2274.0, 1595.7)
Phin Neua	3	2919.9 (3417.8, 2241.6)	3012.8 (3174.1, 2757.8)	2507.5 (2821.0, 1957.5)	2502.0 (3354.0, 1956.0)	2570.0 (2759.0, 2470.0)	1706.7 (2481.0, 1159.0)
Nonsavang[2]	3: T1, T2, T4, T6 1: T3 & T5	4197.3 (4932.6, 3289.1)	3566.3 (3587.2, 3545.3)	3875.0	3079.4 (3437.7, 2566.2)	4171.7 (5672.9, 2670.6)	2489.0
Phin Thai[2]	1	5684.9	3009.9	2852.7	4258.5	3171.6	2312.3
Sibounheuang[2]	1	2646.0	2639.0	2947.0	2116.0	1801.0	2562.0
Average	11	3326.5 (5684.9, 2213.4)	2783.8 (3587.2, 1775,5)	2569.3 (3875.0, 1931.8)	2789.1 (4258.5, 1956.0)	2875.5 (5672.9, 2562.0)	2004.0 (2562.0, 1159.0)

[1] Maximum and minimum yields are shown in parentheses, where n >1

[2] For Treatments 3 and 6 in Nonsavang and for all treatments in Phin Thai and Sibounheuang results from only one farm are available

In many instances, average PTR treatments yielded higher than the corresponding average DSR treatments. DSR was established early in the season, in a year where low early-season rains resulted in excellent conditions for weed growth which was matched by little management response from farmers who were unable to rely on ponded water to suppress weeds, could not afford (or source) labour to manually weed larger areas, and who are not interested in chemical weed control. Once established, traditionally (although late-sown) PTR crops had sufficient water and were judged by most farmers to result in average yields. Another possible source of yield depression in DSR may be discrepancies in the interpretation of GAP advice by individual farmers in relation to DSR.

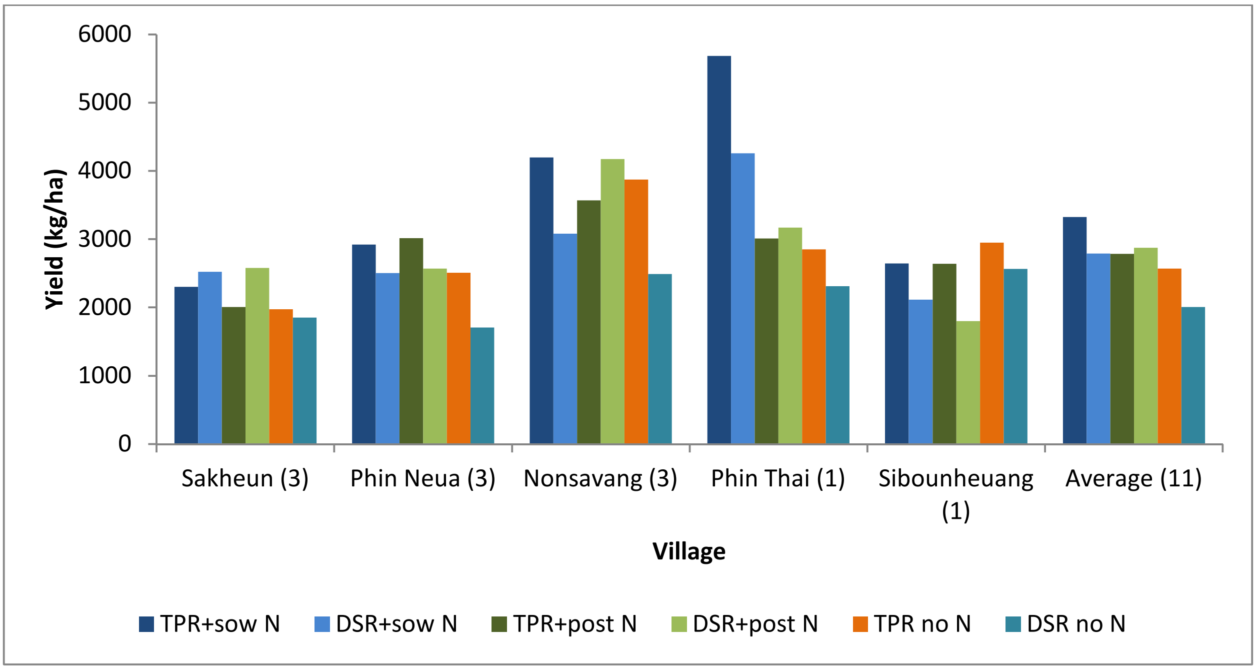

Figure 3: Average on-farm yields from the 2013 wet season at five villages across Savannakhet Province, and across all farms. Numbers in parentheses refer to the number of farmers participating in each village. "+ sow N": fertiliser added at time of sowing; "+ post N": fertiliser added at emergence; "no N": no fertiliser added.

Where farmers were able to manage weeds well in DSR (by using some or all of sufficient ponded water, good land preparation prior to sowing, and comprehensive weeding) yields were comparable to transplanted crops. These farmers were more positive in their reflections on the DSR than those who had experienced greater weed challenges.

On-farm trials: 2014

The focus of on-farm testing in 2014 was to work with a smaller cohort of farmers and to concentrate on collecting higher quality data throughout the wet season. Nine farmers in three villages in Outhoumphone (Phin Neua village) and Champhone (Alan Wattana and Toad villages) districts participated in testing of the DSR in fields at the middle position within the toposequence. The key aims of the testing were i) to explore avenues to control weeds and ii) to test placing fertiliser with the seed in the soil at sowing, using a new DSR machine which was modified in collaboration with Dr Leigh Vial (Figure 4). Four treatments were tested relative to a control:

T1: PTR with GAP weed control as recommended by NAFRI

T2: DSR with GAP weed control as recommended by NAFRI;

T3: DSR with post emergent herbicide weed control;

T4: DSR with farmer weed management practices; and

C1: PTR with farmer weed management practices. Results from this control treatment were recorded in Phin Neua only.

Figure 4: The modified, tine-based Thai seeder with dual seed and fertiliser box trialled by farmers in Savannakhet in wet season 2014

Many farmers who began testing DSR in 2013 continued to experiment with the seeder through the 2014 wet season independently of the ACCA and ACCA-SRA projects. NAFRI data show that 103.87ha in Savannakhet Province were sown with a mechanical seeder: 91.03ha were sown with a dry direct seeder and the remainder were sown with a drum seeder. Independently of the ACCA-SRA testing 47 farmers used the DSR in six districts; the majority of these were in Champhone. Additionally, DAFO staff and village heads who have been involved in DSR testing with the ACCA and ACCA-SRA projects have each bought their own direct seeders which they used on their own farms and contracted out to other farmers. Many farmers were interested in accessing machines and ongoing frustration at difficulties acquiring access to a seeder in a timely manner was reported.

2014 trial results and farmer feedback

DSR was established in early June 2014; in contrast sufficient rain for transplanting nursery-established rice seedlings was only received in early July and transplanting was late in many areas (Figure 5). Due to the lateness of PTR farmers were concerned about increased risk of terminal drought stress towards the end of the wet season.

Figure 5: Direct seeded rice (fore) and less mature transplanted rice (rear) in Alan Wattana, early July 2014

Farmers had learned from the weed challenges experienced in 2014 and controlled weeds well in DSR plots. Land preparation prior to DSR had been more rigorous than in 2013; as well a greater amount of standing water had better contributed to weed suppression. There was little difference in weed presence between plots where weeds were manually controlled and those in which chemical herbicide had been applied.

The DSR treatment in which fertiliser was applied into the soil with seed at sowing was greatly favoured by farmers compared to the previous method of broadcasting fertiliser into the paddy as soon after sowing as there was sufficient water. Farmers reported that drilling the fertiliser into the soil advantaged rice seed over weeds. Some paddies, however, displayed evidence of intermittent uneven distribution of seed and fertiliser: the ongoing development of dry direct seeders which dispense both seed and fertiliser and which are light and readily manoeuvrable is an area of high research need.

Farmers particularly appreciated the labour savings (and subsequent reduction in labour costs) gained by using the dry direct seeder, while remaining cautious about weed control under a range of growing season conditions in the longer term. More research is required to ensure weeds are adequately controlled in all years.

Average yields (Table 2) across the nine farms were 3.3t/ha for both PTR+GAP and DSR+ GAP; 3.4t/ha for DSR with herbicide; 2.3t/ha for DSR with farmer weed management practices (FP); and 2.0t/ha for PTR with farmer weed management practices (this last result is the average of three farms, from Phin Neua only).

Table 2: 2014 field trial results from Outhoumphone and Champhone villages

Treatment	Number of farms	Average yield (kg/ha)[1]
1: PTR + GAP	9	3330.7 (242.1)
2: DSR + GAP	9	3271.9 (271.7)
3: DSR + herbicide	9	3398.0 (262.2)
4: DSR + FP	9	2271.8 (193.1)
5: PTR + FP	3	2014.9 (106.8)

[1] Standard deviations are shown in parentheses

Yields under GAP management are consistently higher, regardless of establishment method, than those with traditional farmer weed management practices (Figure 6). In 2014 main wet season rains were later than normal: transplanting in field trial paddies occurred in mid to late July, which is at the late end of the transplanting window and, in many cases, was earlier than was possible for many paddies not in the field trial. DSR was sown in June which is later than recommended: the late sowing was also as a result of dry conditions early in the growing season.

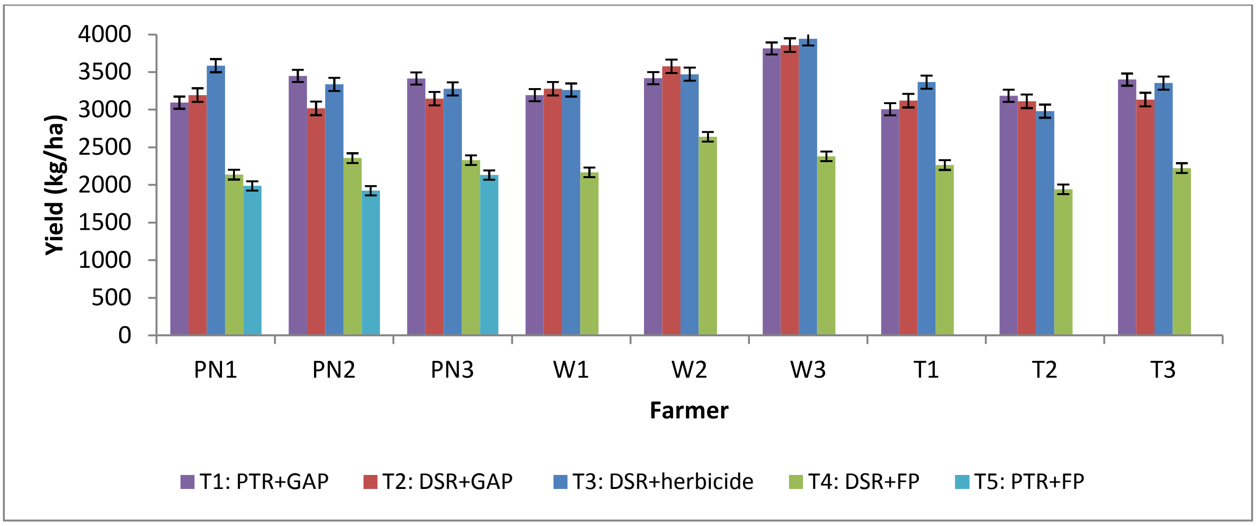

Figure 6: Average yields (kg/ha) from nine field trial sites in Savannakhet Province for the 2014 wet season. Error bars show one standard deviation; data for the PTR+FP treatment are only available for the three Phin Neua sites

In all GAP treatments weeds were well controlled: paddies were tilled twice before sowing and, during the growing season, weeds were removed soon after emergence. Compared to DSR testing in 2013, when farmers had not realised the importance of thorough and early weed control, there were few weeds this wet season. There is very little yield difference between the PTR+GAP (T1) and DSR+GAP (T2) treatments and the DSR + herbicide treatment (T3).

Economic analyses of direct seeding

Comparison of gross margins

DSR has the potential to return a higher gross margin than PTR, regardless of weed management practices (manual or chemical), as long as weeds *are* well managed. Good agricultural practice provides a useful framework for weed management.

As rice is produced largely for domestic consumption in Lao PDR (primarily using unpaid household labour) these gross margin (GM) calculations do not represent a cash gain or loss a household incurs: rather GMs are a tool to compare the opportunity costs of different establishment methods.

Using data from the 2014 wet season on-farm demonstration trials (averaged across participating households) gross margins have been calculated for:

T1: PTR + GAP;

T2: DSR + GAP;

T3: DSR + poor early weed control necessitating additional labour later in the wet season (for weeding) and a yield penalty relative to DSR+GAP; and

T4: DSR + herbicide.

The calculations of GM for each treatment are detailed in Appendix A and summarised in Table 3.

Table 3: Gross margins under different establishment treatments

Treatment	Yield (t/ha)	GM (LAK[1])/ha	Change from baseline (per cent)	Labour to achieve yield (person days/ha)	Change from baseline (person days)
T1: PTR+GAP	3.3	2,053,200	0 (baseline)	73	0 (baseline)
T2: DSR+GAP	3.3	3,128,400	52.4	52	-21
T3: DSR+poor early weed control	2.9	1,409,000	-31.4	68	-5
DSR+herbicide	3.4	3,885,600	89.2	40	-33

[1]In April 2015 1 AUD = 6,500 LAK

Using herbicide returns a higher GM than manually controlling weeds because labour demand is lower, however farmers consistently report that they are not interested in chemical weed control as it increases their input costs. As well, farmers are not confident they know how to use herbicide safely and they are concerned about the potential negative impacts on paddy biota (frogs, fish, snails, etc), which are important protein sources during the wet season. Applying herbicide is not supported by the Lao PDR government.

Economics under different labour and rice prices

Using the gross margins calculated in Table 3 as a baseline, a sensitivity analysis has been performed to examine changes in rice and labour prices, as these are elements of the cropping systems which are likely to vary and which directly affect GMs (Tables 4 to 7). Variability in the rice price has been reflected by examining increases and decreases of 10 and 20 per cent from a baseline of 2,200 LAK/kg; the cost of labour has been modelled at a 50 per cent increase (to 75,000 LAK/day) and at a 100 per cent increase (to 100,000 LAK/day) from a baseline of 50,000 LAK/day.

Table 4: Gross margins (LAK/ha) under a range of labour costs and rice prices for transplanted rice where weeds are well controlled manually through GAP

Change in rice price[1]	Labour: 50,000 LAK/day	Labour: 75,000 LAK/day	Labour: 100,000 LAK/day
-20%	237,560	-1,587,440	-3,412,440
-10%	970,380	-854,620	-2,679,620
0%	1,703,200	-121,800	-1,946,800
+10%	2,436,020	611,020	-1,213,980
+20%	3,168,840	1,343,840	-481,160

[1]Change is relative to a baseline rice price of 2,200 LAK/kg

Table 5: Gross margins(LAK/ha) under a range of labour costs and rice prices for direct seeded rice where weeds are well controlled manually through GAP

Change in rice	Labour: 50,000	Labour: 75,000	Labour: 100,000

price[1]	LAK/day	LAK/day	LAK/day
-20%	1,488,720	188,720	-1,111,280
-10%	2,208,560	908,560	-391,440
0%	2,928,400	1,628,400	328,400
+10%	3,648,240	2,348,240	1,048,240
+20%	4,368,080	3,060,080	1,768,080

[1]Change is relative to a baseline rice price of 2,200 LAK/kg

Table 6: Gross margins(LAK/ha) under a range of labour costs and rice prices for direct seeded rice where weeds are poorly controlled manually

Change in rice price[1]	Labour: 50,000 LAK/day	Labour: 75,000 LAK/day	Labour: 100,000 LAK/day
-20%	113,200	-1,586,800	-3,286,800
-10%	761,100	-938,900	-2,638,900
0%	1,409,000	-291,000	-1,991,000
+10%	2,056,900	356,900	-1,343,100
+20%	2,704,800	1,004,800	-695,200

[1]Change is relative to a baseline rice price of 2,200 LAK/kg

Table 7: Gross margins (LAK/ha) under a range of labour costs and rice prices for direct seeded rice where weeds are well controlled with herbicide

Change in rice price[1]	Labour: 50,000 LAK/day	Labour: 75,000 LAK/day	Labour: 100,000 LAK/day
-20%	2,190,480	1,190,480	190,480
-10%	2,938,040	1,938,040	938,040
0%	3,685,600	2,685,600	1,685,600
+10%	4,433,160	3,433,160	2,433,160
+20%	5,180,720	4,180,720	3,180,720

[1]Change is relative to a baseline rice price of 2,200 LAK/kg

Where weeds are well controlled with GAP GMs are above 0 LAK/ha when the cost of labour is 50,000 LAK/day for both PTR (i.e. the baseline scenario) and DSR (Figure 7). Increasing labour costs in a TPR+GAP system, from 50,000 LAK/day to 75,000 LAK/day, reduces GMs by around 40 per cent. This loss can be considerably offset (all but 9 per cent) by changing from PTR to DSR, regardless of rice price and without introducing chemical herbicides.

Under PTR when labour costs increase to 75,000 LAK/day GMs fall below 0 LAK/ha when the rice price declines from the current baseline (2,200 LAK/kg). When labour costs increase to 100,000 LAK/day, GMs fall below 0 LAK/ha in all rice price scenarios simulated (i.e. between -20 per cent and +20 per cent from the baseline). Under DSR with a labour price of 100,000 LAK/day GMs are above 0 LAK/day for rice prices 5 per cent below the current baseline or higher.

Where rice prices remain about the same and labour doubles farmers who change to DSR+GAP will reduce their GMs relative to the baseline but will be significantly better off (in terms of GM) compared to those farmers who remain with PTR+GAP. Where PTR becomes unattractive from a GM perspective it may still be an attractive option for some risk averse households seeking to ensure food security, particularly under low rice prices and where uncosted labour is available.

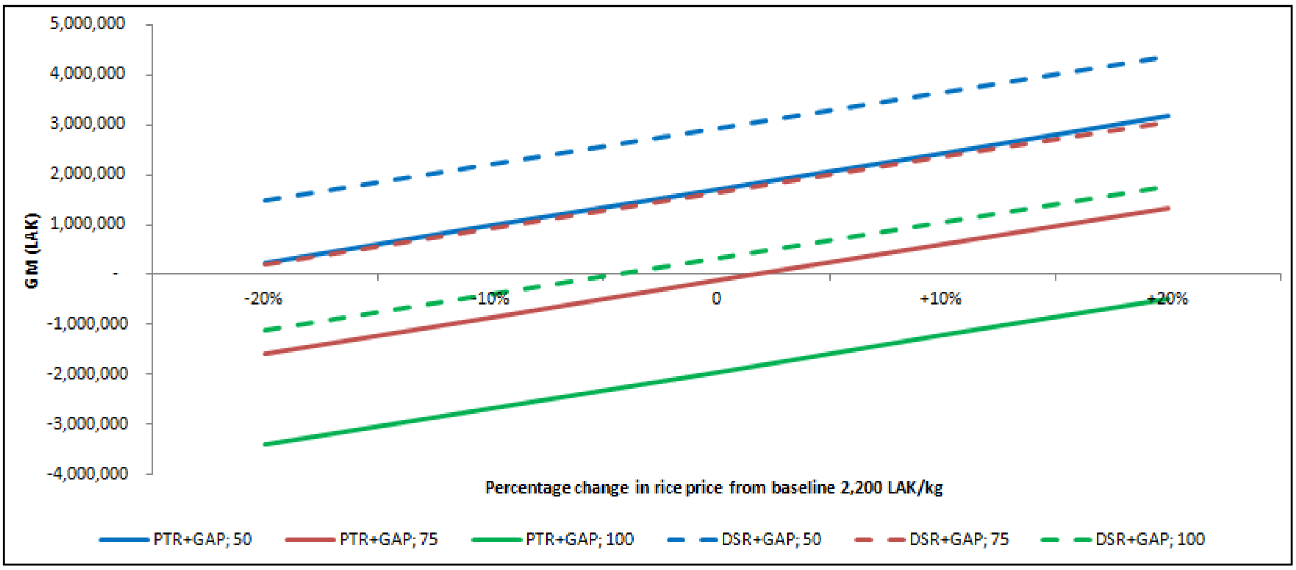

Figure 7: Gross margins (LAK/ha) under PTR+GAP (baseline scenario) and DSR+GAP for a range of rice prices and labour costs. The number in the description of each element represents the daily labour cost in '000 LAK

Under DSR where weeds are poorly managed, GMs are lower than the PTR+GAP baseline for all scenarios (Figure 8). Poor early management of weeds under DSR doubles the labour required for weeding during the growing season and reduces crop yield.

Where labour costs increase to 75,000 LAK/day, GMs for DSR with poor weed control reduce below 0 LAK/ha for a rice price below 2,200 LAK/kg; where labour costs increase to 100,000 LAK/day, GMs reduce below 0 LAK/ha for all rice prices simulated.

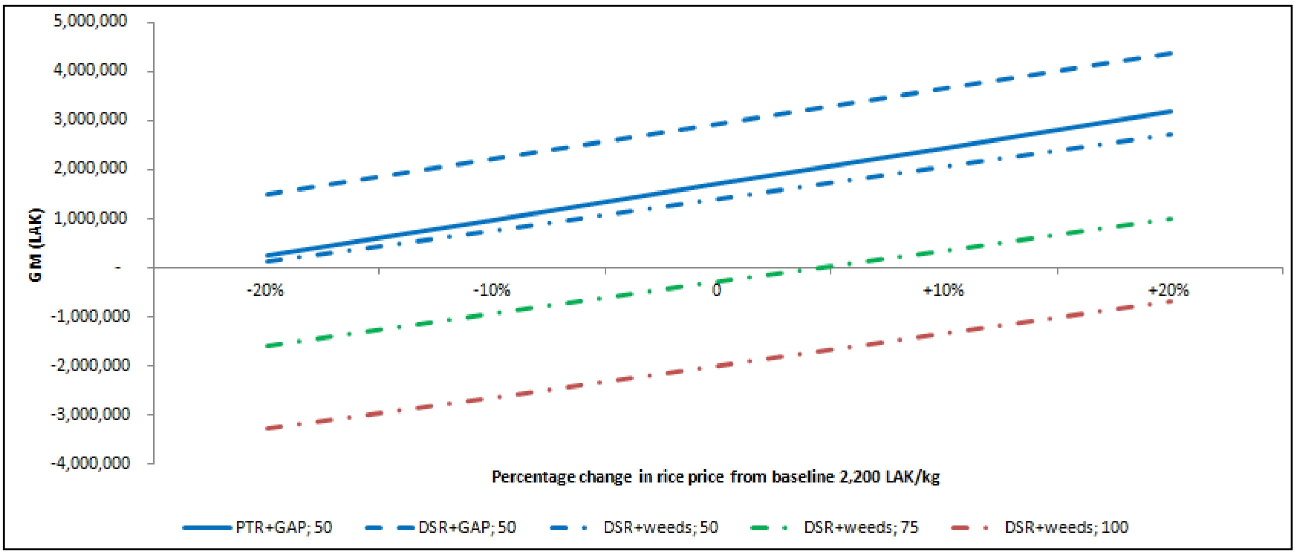

Figure 8: Gross margins (LAK/ha) under PTR+GAP (baseline scenario), DSR+GAP and DSR with poor weed control for a range of rice prices and labour costs. The number in the description of each element represents the daily labour cost in '000 LAK

Using herbicide to control weeds – and thus reduce labour required to produce a crop – will return a higher GM than PTR+GAP for all labour cost and rice price scenarios (Figure 9). Where herbicide, rather than manual labour, is used to control weeds GMs increase around 116 per cent over the PTR+GAP baseline scenario (for no change in rice price or labour cost). This increase is due to the considerable reduction in person days required to produce the crop under DSR (40) compared to that required for PTR+GAP (73).

Where labour prices increase to 100,000 farmers who use DSR with chemical weed control will see comparable GMs to those achieved under TPR+GAP and a labour price of 50,000 LAK/day, regardless of rice price.

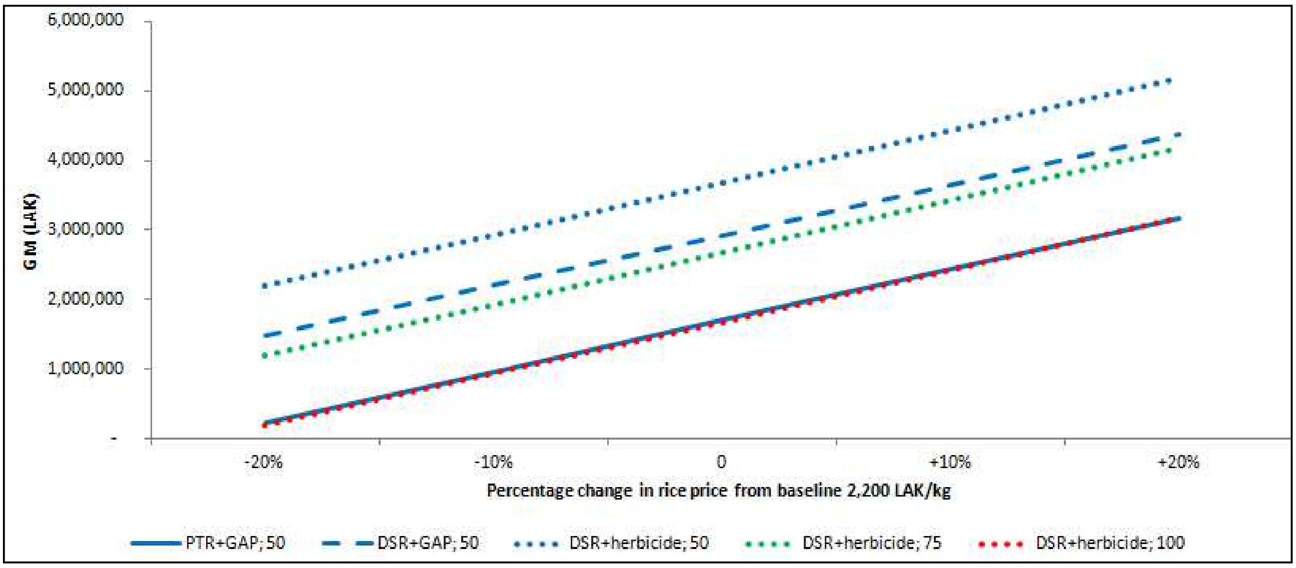

Figure 9: Gross margins (LAK/ha) under PTR+GAP (baseline scenario), DSR+GAP and DSR with chemical weed control for a range of rice prices and labour costs. The number in the description of each element represents the daily labour cost in '000 LAK

The yield return on labour required to produce a rice crop under DSR+GAP is 62.9 kg/person day (Figure 10). This is a more attractive establishment option than PTR+GAP (yield return 45.6 kg/person day), DSR+FP (43.3 kg/person day) or DSR+herbicide (85.0 kg/person day) which is not attractive to farmers because of the greater risks (in terms of inputs required and environmental and personal health concerns) surrounding the additional use of chemicals.

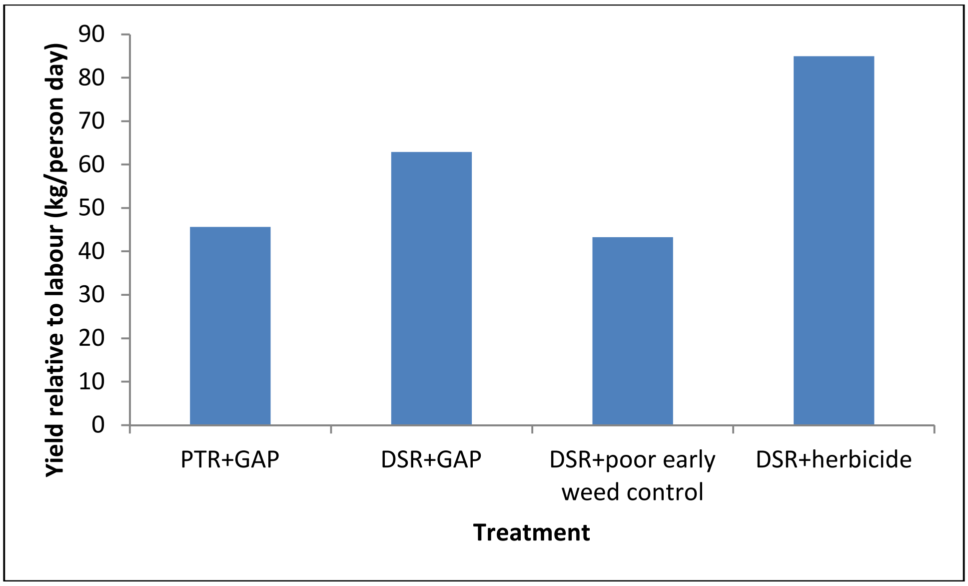

Figure 10: Yield relative to labour required to produce a rice crop (kg/person day)

Key findings

Introducing the direct seeder to farmers in Savannakhet Province in 2013 and extending and improving on-farm testing in 2014 has resulted in encouraging results and interest from rainfed rice farmers and other direct stakeholders in NAFRI, PAFO and DAFO. At the same time there are a range of agronomic, technical and institutional capacity issues which need to be addressed in order to support a wider dissemination and use of direct seeders in rainfed lowland rice growing areas of Lao PDR. These considerations are briefly summarised below.

Agronomic considerations

Weed control

Weeds are a greater challenge in a direct seeded crop than in a traditionally transplanted crop. Two main strategies are necessary to adequately control weeds: thorough land preparation and manual weeding early in the growing season.

The current minimum land preparation recommended prior to direct seeding is to plough the rice fields twice, with a period of about 10 days between each cultivation to allow weed germination. This should be followed by harrowing just before sowing. This recommendation requires at least three weeks' land preparation and may be more (and differently timed) preparation than that to which farmers are currently accustomed.

In-crop weeding was commonly implemented with a small hoe-like tool (Figure 11). Rotary weeders (Figure 12) are also available but can only be used when standing water is present. Many farmers found weeding easier to manage when the crop was in clear rows and did not experience any difficulty controlling weeds early in the wet season. Some farmers, however, were put off by the unexpected weediness of their plots – whether this resulted from insufficiently thorough land preparation is unclear. The farmers experiencing greater weed problems were those at higher toposequences, where soil moisture is lower, increasing the labour involved in both pre-sowing land preparation and manual weed cultivation.

Figure 11: A farmer demonstrates weed removal using a small handheld tool

Most farmers perceive herbicides as a high-cost input, the use of which jeopardises the safe human consumption of small in-paddy animals (e.g. fish, snails, frogs and crabs) which are often relied upon as protein sources in the wet season. Some farmers (those with larger landholdings) were attracted by the labour savings possible in applying herbicides rather than paying for labourers to weed crops.

The issues around weed management in direct seeded rice crops notwithstanding, most participating farmers viewed weed management as a challenge to be overcome and/or managed rather than a factor which would prevent the adoption of the direct seeding.

Figure 12: (left) Rotary weeding tools; (right) Mr Lytoua Chialue, a project researcher from NUOL, demonstrating the rotary weeder in Ban Sakheun, Champhone

Fertiliser: timing and placement

In traditional transplanted rice cropping systems there are a range of fertiliser application regimes followed by farmers in lowland Lao PDR: applying fertiliser basally; after transplanting; both basally and after transplanting; and not fertilising at all. The decisions to fertilise or not are informed by the position of the farmer's field in the toposequence, relative soil fertility, previous experience and training, land and household size, financial position and how well the season is developing.

Most farmers interviewed believe they have insufficient knowledge to optimise their fertiliser use: very few farmers have an understanding of the appropriate selection, timing and application rates for the fertilisers they access. Extension and agricultural services within Savannakhet province work hard to pass on their knowledge, but are often under-resourced and capacity-constrained themselves.

In direct seeded systems fertiliser applications at sowing can be made either in the furrow, with the seed, or on the soil surface, after sowing is complete. The latter method is likely to result in less fertiliser available to and taken up by rice plants as it is at risk of volatilisation and/or an uneven redistribution in the paddy following untimely rain. Adding fertiliser into the furrow with the seed is likely to promote rice plant growth over early weed development and was preferred by the farmers who tested this option. This requires seeders that have dual seed and fertiliser boxes and separate seed and fertiliser dispensing systems.

Top dressing is applied into standing water; usually approximately 25 and 40 (if two top dressings are applied) days after transplanting. If sufficient rainfall to achieve standing water does not occur in an appropriate interval top dressing will be delayed. While the direct seeding method cannot influence the amount of standing water in the paddy, and thus farmers' ability to top dress (under current methods), a direct seeded crop which has been fertilised at sowing is likely to be better nourished early in the season (before standing water is more reliable). Equally, a direct seeded crop, established earlier in the season, may reach a growth stage where top dressing is desirable before standing water occurs in the paddy: alternative methods of in-crop fertiliser application may become more attractive in future.

Planting time

Early sowing may have challenges which will need to be resolved by local communities (i.e. not individual households) in order for the practice to be successful. These include: livestock management, 'green island' effects and rice maturation times. Advancing the sowing date may also enable farmers to combat a key pest, gall midge.

Currently, livestock (particularly cattle and buffalo) are allowed to roam fairly freely until seedbed nursery establishment; many farmers who participated in the direct seeding demonstrations erected fences around their demonstration plots to protect them from livestock. Fencing may cease to be a practical solution if larger areas are sown with the direct seeder in future. One option which was mentioned a number of times is to pen animals and, concurrent with the introduction of the direct seeder, move to a cut-and-carry livestock production system for at least part of the year: this may have follow-on implications in labour-constrained environments.

If a few farmers in an area plant early, with the direct seeder, their ripening crops are likely to form a 'green island' which may be targeted by birds and other pests. A critical mass of farmers planting early will minimise this effect and protect each other's yields.

Farmers currently plant their nursery seedlings in about three tranches, each sown approximately two to three weeks apart. This spreads farmers' exposure to short term climate stressors (droughts, floods) and reduces the intensity of transplanting, and therefore the daily labour requirements (although this practice also extends the duration of the transplanting window). With direct sowing areas of the farm can be sown in discrete, temporally distinct, blocks, continuing the climate risk mitigation strategies farmers currently practise.

A significant pest in rainfed rice crops is gall midge, against which the most effective strategy identified to date is the early planting and transplanting of crops. The aim is to get the young cultivated rice crop past the growth stage where its yield potential can be affected by gall midge before the midge becomes active in nearby wild rice plants, in which it is endemic. Using the direct seeder both to plant earlier in the season and to eliminate plant growth delays associated with transplant shock may help protect domesticated rice plants from gall midge attack at critical plant growth stages.

Varieties

The maturity time, and photoperiod sensitivity, of varieties used with the direct seeder are important: if rice is sown earlier in the season farmers need to ensure their harvest is likely to be well-timed in terms of end-of-season rainfall.

At this stage, the selection of rice varieties used in the demonstration trials has not included consideration of whether particular varieties are better suited to direct seeding than others. As farmers become more confident in the technology and are gradually able to plant earlier, choice of varieties will become a research priority to ensure there is no mismatch between harvest date and end of wet season, as well as considering photoperiodicity.

Soils

The projects' direct seeders work best on sandy soils and loams and is likely to be inappropriate for use on heavier loam or clay soils that may form clods. Surface soils in Outhoumphone and Champhone districts are generally loamy sands and or sandy loams over a lateritic pan.

Sowing into different soil types is likely to require sowing at different depths. Also, a range of implements to open the soil may be necessary, depending on variations in soil type. Different implements can be used to create furrows in which to place seed, and they can be broadly categorised into disc or tine based openers. Depending on the furrow opener being used and on the soil condition and type, different implements to close the furrow may be required (e.g. press wheels in conjunction with discs; chains or scrapers following tines). Smaller, lighter direct seeders than the one being tested by the projects, while they have many benefits, may not always be strong enough to dig furrows deep enough to sow at appropriate depths.

Position in toposequence

Rice grown at higher toposequences is generally at greater risk of droughting while that at low toposequences is more flood prone. Early sowing using the direct seeder has the potential to mitigate farmers' exposure to both. Soil properties differ across toposequences: drainage is usually greater in fields positioned higher in the toposequence, while water logging is a concern in lower-lying paddies. Different management strategies for direct seeding apply at different positions and toposequence-specific management guidelines for the use of the direct seeder need to be developed.

Machinery considerations

Accessing seeders

The small number of seeders available to farmers in Outhoumphone and Champhone have been in high demand: many farmers stated that they would have preferred more time with the seeder and more flexibility when they used it, relative to their land preparation regimes. Many were considering buying, either individually or in small family groups, their own direct seeders for future wet seasons.

The first seeders used by the projects in 2013 were sourced from Thailand; despite access being facilitated by researchers from a recently completed ACIAR-funded project in north east Thailand (CIM/2007/215: *Improving the reliability of rainfed rice/livestock farming systems in NE Thailand*) the projects were unable to buy as many seeders as originally contemplated. It is highly likely that, as awareness of the seeders increases, demand will increase in lowland Lao PDR and access for farmers will remain a challenge. In 2014, a modified version of the Thai seeder was used. This had a dual seed and fertiliser box (but no separate dispenser) and used tines instead of disc coulters. The modifications were carried out in Savannakhet with the assistance of PAFO and Dr Leigh Vial, then with IRRI. Figure 4, above, shows this modified version.

Alternative seeders are also available: one farmer had bought a smaller, cheaper seeder (Figure 13) in Mukdahan, Thailand, and had used it to sow all his 2013 wet season rice. He stated that the limitations of his seeder were different from those of the projects' seeders (his seeder is smaller and lighter than the projects' seeders; it is also less robust and requires more thorough land preparation prior to sowing) and that he is very pleased with his purchase. He feels the labour savings he will make will more than compensate him for any additional weed control measures needed, and that he will recoup his investment in the short term.

Figure 13: The smaller, lighter, tine-based Thai seeder trialled independently by farmers in Savannakhet in wet season 2013

The projects' seeders cost approximately 20,000 THB each in 2013[2]; the smaller Thai seeder cost around 10,000 THB. It is anticipated that as supply is increased (and perhaps made available locally) seeders will become cheaper and more readily accessible to more farmers.

Significant progress has been made on the modification and deployment of a Brazilian dry direct seeder by the IFAD-funded Sustainable NRM and Productivity Enhancement Program (SNRMPEP). A local manufacturer in Pakse (Champassak Province) is now constructing 140 units using imported components, ordered and based on modifications and suggested by SNRMPEP (Figure 14). The machine has a dual seed/fertiliser seed box, with separate delivery tubes, and variable rate meters, which makes it very versatile and capable of being used for sowing different grain crops with varying fertiliser rates. The current estimated cost of this machine is around 500-600 USD.

Figure 14: The modified Brazilian, disc based, dry direct seeder being manufactured in Pakse, Lao PDR

Ease of use and seeder design

The seeders purchased by the projects, particularly the first model tested, were found by some farmers to be heavy and difficult to manoeuvre. Many farmers relied on assistance from government or village officials to sow with the direct seeder. Some farmers, in particular those

[2] *In April 2013 1 AUD was approximately equal to 30 THB*

who were older, more risk averse, or who currently contracted out land preparation, expressed interest in hiring a contractor to directly sow their paddies in future.

In general terms, the design of seeders is a compromise between ease of use, machinery cost and its versatility to cope with a range of soil and planting conditions. The current machines are functional, but they need to be refined for local edaphic and topographic conditions. Dr Jacky Desbiolles, who in Cambodia evaluated the Thai seeder being tested by the projects in Lao PDR, has recommended analysis and improvement in the following areas:

- *Seed dispersal mechanism*: currently creates seed damage. Modifying hard edges with brushes or soft rubber could ameliorate this.
- *Metering system*: most seeders have a fixed rate of around 80kg/ha. An adjustable seed rate would be more attractive to farmers.
- *Road travel clearance:* little clearance for road travel makes the handling cumbersome and tiring for the operator unless the discs are allowed to run on the ground.

The lighter, cheaper Thai seeder was viewed as a more attractive option by some farmers, however many acknowledged that seed was not sown as deeply as when the project seeders were used. If planting was followed by heavy rain this dispersed the seed from the initial row alignment and impeded crop management and weeding. Additionally there was no capacity with the lighter seeder to pause seed discharge while there was seed in the dispensing drum. The larger seeders have a gearing mechanism which enables the user to initiate or pause seed flow and to control the rate at which seed is discharged.

Seeders with tines, which create more permanent furrows than do disc seeders, may be more advantageous at higher toposequences: the furrows may help to channel the small rainfall received early in the wet season down to seeds (and away from weeds) whereas a flatter paddy surface may not encourage preferential watering of crop seeds. Conversely, tines are more prone to raking residues and clogging.

Development considerations

Village-level planting decisions

As noted earlier, village communities may need to reconsider the timing of events in the agronomic calendar which will be optimally managed as a group. These include: the timing of sowing; the timing and allocation of communal irrigation water (if available); and livestock grazing near rice paddies. Other research projects (e.g. the ACIAR-funded World Vision project, *Improving the reliability of rainfed rice/livestock farming systems in NE Thailand*) have demonstrated the potential, in comparable smallholder farming systems, of implementing cut-and-carry systems of livestock production. If done communally penning livestock, for at least some months of the year, would eliminate the need to erect fences around rice paddies and may bring additional benefits, in terms of increased liveweight gain and animal production, to farmers. Another benefit of longer periods of cattle penning is that greater amounts of manure can be collected for use as fertiliser.

Implications for women and marginal farmers

Transplanting and weeding are traditionally mainly done by women whereas land preparation and other tractor-oriented tasks are done by men. Changing from PTR to DSR is likely to reduce the amount of work required by women to produce a rice crop (particularly where weeds are well controlled), while making little change to the time and labour required by men. This will mean women have greater opportunities to seek off farm income: farmers observed that family economics were changing as it was the young female members who had greatest access to cash, which they provided to their parents.

Conversely, marginal and landless farmers rely on transplanting and other labour-intensive activities on larger farms as a key income source. Reducing the amount of labour required over the cropping season is likely to increase migration away from rural areas and into urban centres.

The longer-term social and cultural implications of DSR for marginalised groups are not well understood in Lao PDR.

Sourcing machines

In order to ensure the continued uptake and use of direct seeding, adequate production and supply, as well as post-sales support, is required. This may be best facilitated by targeted government policies encouraging the importation and sale of the seeders, as well as domestic production (the seeder design has deliberately not been patented to encourage widespread uptake in developing countries). National, provincial and district government organisations have valuable roles to play linking traders and input suppliers to farmers and ensuring that domestic manufacture of seeders is facilitated where possible. Additionally, NGOs may be able to demonstrate, through established practices and outscaling networks, methods to source additional machines and distribute them to interested communities.

Poorer farmers and those with smaller landholdings are more likely to be challenged by sourcing seeders at fair prices and, ultimately, by purchasing them. These groups are likely to rely on contractors for land preparation and seeding. As more large farmers acquire seeders and act as contractors, access to seeders should also improve for small farmers. However, it is important to ensure no farmer groups are overlooked in the extension of this new technology; hence government institutions have a critical support role for these groups. Another option might be to establish communal access to seeders (e.g. in small family groups).

Capacity and training

If the interest in, and uptake of, direct seeding continues at current high levels DAEC, PAFO and DAFO may experience resource limitations to adequately train all farmers in lowland Lao PDR interested in the seeder. Private sector third parties are likely to have a role in this process: the model successfully developed by the NGO SNV where millers work with farmers and end-users to enable high-quality rice production tailored to consumers' needs is a model to explore further.

Provision of information and training on the direct seeder may be facilitated by millers and/or other third parties keen to see the development of more reliable rice production: in this process government organisations such as DAEC, PAFO and DAFO would play a vital role training contractors and other third parties to use, service and adapt seeders. The process would also contribute to and expedite locally appropriate adaptations of the basic seeder. While regional capacity is limited and interest is growing it is imperative to bring in private industry, donor organisations and NGOs and to facilitate their interactions with key government organisations in order to increase availability and timely uptake of the direct seeder. To date IFAD and the NGO SNV have expressed an interest in piloting the wider dissemination and provision of direct seeders.

Conclusions and issues for future action

The 2013 and 2014 on-farm demonstration trials of the direct seeder in Outhoumphone and Champhone districts of Savannakhet undertaken as part of the ACCA and ACCA-SRA projects have provided a widespread proof of concept that direct seeding is a viable technology to reduce labour costs, as well as holding promise to reduce climate risk and the following conclusions can be drawn:

- Direct seeding into unpuddled soils is proving to be an effective alternative to traditional transplanting.

- Farmers in Outhoumphone and Champhone districts of Savannakhet have continued to show a very strong interest in direct seeding (even independently of the on-farm trials) largely because of the significant potential labour savings.
- The dry start of both the 2013 and 2014 wet seasons showed that direct seeding can help reduce the impact of climate risk. In several locations farmers were not able to transplant rice on upper and middle terraces in a timely manner due to drought; however, in all of these sites, direct seeded rice had been established successfully and was growing well.
- In lowland areas, early direct seeding of rice is likely to reduce the risk of crop damage due to flooding, as the rice is already tall enough to avoid being fully submerged when heavy rainfall commences in July and August.
- At all toposequence positions weeds need to be well managed in DSR and different strategies to those traditionally used in PTR will be appropriate. Formal training and guidance for farmers around weed control in DSR will reduce their exposure to this risk.

Despite proof of concept and initial strong interest by farmers, we caution against rolling out the technology too rapidly and without taking into consideration some of the constraints and problems discussed in this report. Key issues that will need to be addressed include:

- *Closing the gap between farmer demand and access to direct seeders*: this will require support from relevant Lao PDR government institutions and international donors to support the development of supply chains to source direct seeders and make them available at low cost to farmers. Alternatively, consideration should be given to establishing a local manufacturing base in Lao PDR, supported by improved seeder designs (e.g. the IFAD-SNRMPEP supported manufacturing of machines in Pakse)
- *Capacity building needs:* successful out-scaling of the technology will also require dedicated training of PAFO and DAFO extensionists, future contractors/tractor operators and input suppliers.
- *Weed management:* farmers will need to adhere to recommended land preparation practices prior to sowing, and to rigorously control in-crop weeds manually.
- *Matching the technology to local conditions:* direct seeding is not suitable to all locations, for all rice varieties or for all soils: more research needs to be done to determine in which soils direct seeding is appropriate, for which varieties, and how the planters can be improved to better match different soil conditions and to simultaneously place fertilisers with the seeds.
- *Establishing farmer groups:* many farmers expressed the wish to participate in farmer groups designed to share knowledge on using direct seeders (and, potentially, other agronomic topics). NAFRI, DAEC and PAFO are keen to establish such groups.

While direct seeding in itself is not a complex technology, its widespread uptake is likely to trigger major changes across the wider farming system (e.g. changes to whole farm systems through alterations in livestock management, timing of the cropping season and labour demands). Understanding and facilitating altering agronomic practices into whole farm and village-wide cultural and socio-economic contexts will require ongoing systems research.

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Appendix A: Gross margin calculations for PTR and DSR

1. Per-hectare GM for PTR+GAP. Yield and labour data are averaged from figures reported from farmers participating in the 2014 on-farm testing in Outhoumphone District; input costs were provided by NAFRI

	Unit	Amount	Cost/unit	Total LAK
Establishment				
Nursery cultivation (2x ploughing, 1x harrowing)	Person day	1	50,000	50,000
Nursery bed preparation, sowing, fertiliser application	Person day	1	50,000	50,000
Gasoline for nursery cultivation (5l/day @ 10,000 LAK/l x 2days)	LAK	10	10,000	100,000
Seed cost[1]	Kg	60	6,000	360,000
Transplanting cultivation	Person day	3	50,000	150,000
Puddling and levelling	Person day	2	50,000	100,000
Gasoline for cultivation before TP (5l/day @10,000 LAK/l x 5 days)	LAK	25	10,000	250,000
Uprooting nursery	Person day	4	50,000	200,000
Transplanting	Person day	20	50,000	1,000,000
			Subtotal: establishment	***2,260,000***
Fertiliser				
Nursery fertiliser (urea) cost	Kg	7	5,000	35,000
Applying basal fertiliser (NPK)	Person day	3	50,000	150,000
Fertiliser (NPK) cost	Kg	120	4,000	480,000
Applying top dressing #1 (urea)	Person day	3	50,000	150,000
Applying top dressing #2 (urea)	Person day	3	50,000	150,000
Fertiliser (urea) cost for 2 top dressings	Kg	150	5,000	750,000
			Subtotal: fertiliser	***1,715,000***
Weed control				
Hand weeding	Person day	11	50,000	550,000
			Subtotal: weed control	***550,000***
Harvesting and processing				
Harvesting	Person day	18	50,000	900,000
Threshing and cleaning	Person day	2	50,000	100,000
Drying and weighing	Person day	2	50,000	100,000
			Subtotal: Harvesting and processing	***1,100,000***
Total average cost	**LAK**			**5,675,000**
Average yield	Kg	3331		
Rice price	Kg	2,200		
Average income	**LAK**			**7,328,200**
Average gross margin	**LAK/ha**			**1,703,200**

[1] In all years there is a cost for seed – either a direct financial cost (seed is purchased about one year in three) or a loss of potential "income" from the previous year's yield as rice which could otherwise have been eaten or sold is retained for the next season's crop.

2. Per-hectare GM for DSR+GAP. Yield and labour data are averaged from figures reported from farmers participating in the 2014 on-farm testing in Outhoumphone District; input costs were provided by NAFRI

	Unit	Amount	Cost/unit	Total LAK
Establishment				
First cultivation	Person day	2	50,000	100,000
Second cultivation	Person day	2	50,000	100,000
Gasoline for cultivation (5l/day @ 10,000 LAK/l x4 days)	LAK	20	10,000	200,000
Seed cost	Kg	40	6,000	240,000
Sowing	Person day	4	50,000	200,000
			Subtotal: establishment	***840,000***
Fertiliser				
Fertiliser (NPK) cost	Kg	120	4,000	480,000
Applying top dressing #1 (urea)	Person day	3	50,000	150,000
Applying top dressing #2 (urea)	Person day	3	50,000	150,000
Fertiliser (urea) cost for 2 top dressings	Kg	150	5,000	750,000
			Subtotal: fertiliser	***1,530,000***
Weed control				
Hand weeding	Person day	16	50,000	800,000
			Subtotal: weed control	***800,000***
Harvesting and processing				
Harvesting	Person day	18	50,000	900,000
Threshing and cleaning	Person day	2	50,000	100,000
Drying and weighing	Person day	2	50,000	100,000
			Subtotal: Harvesting and processing	***1,100,000***
Total average cost	**LAK**			**4,270,000**
Average yield	Kg	3272		
Rice price	Kg	2,200		
Average income	**LAK**			**7,198,400**
Average gross margin	**LAK/ha**			**2,928,400**

3. Per-hectare GM for DSR with poor weed control. Yield and labour data are averaged from figures reported from farmers participating in the 2014 on-farm testing in Outhoumphone District; input costs were provided by NAFRI

	Unit	Amount	Cost/unit	Total LAK
Establishment				
First cultivation	Person day	2	50,000	100,000
Second cultivation	Person day	2	50,000	100,000
Gasoline for cultivation (5l/day @ 10,000 LAK/l x4 days)	LAK	20	10,000	200,000
Seed cost	Kg	40	6,000	240,000
Sowing	Person day	4	50,000	200,000
			Subtotal: establishment	***840,000***
Fertiliser				
Fertiliser (NPK) cost	Kg	120	4,000	480,000
Applying top dressing #1 (urea)	Person day	3	50,000	150,000
Applying top dressing #2 (urea)	Person day	3	50,000	150,000
Fertiliser (urea) cost for 2 top dressings	Kg	150	5,000	750,000
			Subtotal: fertiliser	***1,530,000***
Weed control[1]				
Hand weeding	Person day	32	50,000	1,600,000
			Subtotal: weed control	***1,600,000***
Harvesting and processing				
Harvesting	Person day	18	50,000	900,000
Threshing and cleaning	Person day	2	50,000	100,000
Drying and weighing	Person day	2	50,000	100,000
			Subtotal: Harvesting and processing	***1,100,000***
Total average cost	**LAK**			**5,070,000**
Average yield	Kg	2945		
Rice price	Kg	2,200		
Average income	**LAK**			**6,479,000**
Average gross margin	**LAK/ha**			**1,409,000**

[1] Poor land preparation and early weed control necessitates both a doubling of the labour required to control weeds and a 10 per cent yield penalty relative to the DSR+GAP scenario

4. Per-hectare GM for DSR with chemical weed control. Yield and labour data are averaged from figures reported from farmers participating in the 2014 on-farm testing in Outhoumphone District; input costs were provided by NAFRI

	Unit	Amount	Cost/unit	Total LAK
Establishment				
First cultivation	Person day	2	50,000	100,000
Second cultivation	Person day	2	50,000	100,000
Gasoline for cultivation (5l/day @ 10,000 LAK/l x 2 days)	LAK	20	10,000	200,000
Seed cost	Kg	40	6,000	240,000
Sowing	Person day	4	50,000	200,000
			Subtotal: establishment	***840,000***
Fertiliser				
Fertiliser (NPK) cost	Kg	120	4,000	480,000
Applying top dressing #1 (urea)	Person day	3	50,000	150,000
Applying top dressing #2 (urea)	Person day	3	50,000	150,000
Fertiliser (urea) cost for 2 top dressings	Kg	150	5,000	750,000
			Subtotal: fertiliser	***1,530,000***
Weed control				
Applying herbicide	Person day	4	50,000	200,000
Herbicide cost	Kg	1	120,000	120,000
			Subtotal: weed control	***320,000***
Harvesting and processing				
Harvesting	Person day	18	50,000	900,000
Threshing and cleaning	Person day	2	50,000	100,000
Drying and weighing	Person day	2	50,000	100,000
			Subtotal: Harvesting and processing	***1,100,000***
Total average cost	**LAK**			**3,790,000**
Average yield	Kg	3398		
Rice price	Kg	2,200		
Average income	**LAK**			**7,475,600**
Average gross margin	**LAK/ha**			**3,685,600**

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11.2 Appendix B: Conference paper submitted to 17th Agronomy Society of Australia

Combining field trials and crop modelling of dry direct seeded rice to reduce production risks in Lao PDR under current and future climates

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Abstract

Rice in lowland Lao PDR is produced under rainfed conditions with little or no access to supplementary irrigation. Farmers operate on small scales with the primary aim of achieving food security. Traditional transplanting methods (PTR), expose farmers to climate risks at both the commencement and conclusion of the wet season. Additionally, PTR has high labour requirements at the time of transplanting. Over four years, a research team from CSIRO (Australia), the National Agriculture and Forestry Research Institute (NAFRI, Lao PDR) and the Provincial Agriculture and Forestry Office Savannakhet (PAFO, Lao PDR) has worked with farmers in Savannakhet Province to explore on farms the potential benefits of dry direct seeding rice (DSR). DSR enables farmers to sow, and to grow to maturity, a comparably-yielding rice crop with less water than is needed for PTR. As the crop can be sown earlier in the season (without having to wait for the presence of ponded water) risks of terminal drought stress are also reduced. Provided that weeds are well managed the labour demand is significantly reduced relative to PTR, thus decreasing farmers' production costs. Crop system modelling using APSIM has demonstrated the advantages of DSR apply over the longer term, for both current and future climates. Participatory engagement with farmers and extension agencies indicates many farmers' strong interest in DSR and determination to continue to engage in mechanised rice establishment to decrease their production costs while maintaining or improving food security.

Keywords: dry direct seeding, crop modelling, climate change, rainfed rice

Introduction

Rice is the staple food crop in Lao PDR. In lowland areas of southern Lao PDR it is predominantly produced in the wet season (May to October), with very little, if any, access to supplementary irrigation. Wet season rainfall is highly variable temporally (both within a wet season and from year to year) and spatially (Basnayake et al., 2006). The traditional method of crop establishment, transplanting (PTR), exposes farmers to climate risks at both the commencement (highly variable rains impede successful nursery propagation and transplanting) and conclusion (terminal drought stress) of the wet season. Additionally, PTR has high labour requirements at the time of transplanting.

Most farmers operate on small scales (0.5-2 ha) and are constrained by access to labour; in most households at least one member provides an off-farm income (Chialue et al., 2013). Accessing additional labour on-farm in times of high demand (e.g. at transplanting) either reduces the household's external earnings potential or requires expenditure to hire labour. Farmers are risk averse and keen to maintain sufficient yield for food security while reducing input costs: for most farmers the primary production goal is food security not a marketable rice surplus.

Dry direct seeded rice (DSR; Lantican et al., 1999) is an alternative establishment technique with potential benefits for farmers in rainfed lowland Lao PDR: a DSR crop can be sown early in the season, on limited pre-monsoon rainfall and can be grown to maturity on less water: there is no need for water to pond in paddies, as there is for traditionally established rice which requires standing water for transplanting. Sowing the rice crop earlier in the wet season reduces the risk of terminal drought stress; additionally plants establish sooner, do not suffer transplant shock and are better positioned to resist short-term drought or flooding events. Where weeds are well managed the labour demand of a DSR crop is considerably lower than that of a PTR crop; farmers' production costs are consequently lowered, even allowing for additional expense incurred managing weeds.

Examining dry direct seeded rice establishment in rainfed lowland Lao PDR

Between 2011 and 2014 a research team from CSIRO, NAFRI and PAFO Savannakhet worked with farmers in Savannakhet Province to explore the potential benefits of mechanised establishment. The aims were to introduce farmers to the new establishment technique and to examine if DSR is suitable for use in lowland rainfed areas of Lao PDR. On-farm trials were established in 2011-2013 on up to 66 farms each year to expose as many farmers as possible to DSR, using Thai dry direct seeders. Training in the use of the seeders was provided to farmers and local extension staff by experts from World Vision Thailand; training in Good Agricultural Practices (GAP), including weed control via thorough land preparation and early manual weeding, was provided by NAFRI. In 2014 a locally modified seeder, which placed fertiliser with seed in the soil at sowing, was introduced following feedback from farmers. Testing on nine farms compared four treatments: 1) PTR+GAP; 2) DSR+GAP; 3) DSR with poor early weed control (resulting in a reduced yield and higher labour requirements for weeding during the season); and 4) DSR with a chemical herbicide.

Simple gross margins (GMs) were calculated to compare the potential economic differences between the treatments. As well, the labour required to produce each rice crop was examined relative to the yield obtained.

The APSIM cropping systems model (Holzworth et al., 2014) was used to extend results from on-farm field trials to compare PTR and DSR between 1971 and 2011 and for a future climate (locally relevant climate data were simulated using the GFDLCM 2.0 GCM as described by Kokic et al. (2011)) between 2021 and 2040. Initial field trial data, supplemented from the published literature, were used to parameterise and calibrate APSIM for Outhoumphone and Champhone districts. Subsequent field trial data were used to validate the model before it was used for scenario analysis.

Results and discussion

On-farm DSR testing and economic analysis

Table 1 shows average yields results from 2014, the labour requirements to achieve these yields and the calculated gross margins from the nine farms which participated in the on-farm testing. Comparable yields were achieved under Treatments 1 (PTR+GAP: 3.3t/ha); 2 (DSR+GAP: 3.3t/ha) and 4 (DSR+herbicide: 3.4t/ha), indicating that (relatively) high yields can be achieved under both

PTR and DSR with or without the use of chemical herbicides, as long as weeds *are* well controlled (i.e. in contrast to Treatment 3, DSR+poor early weed control, which achieved an average yield of 2.9t/ha; or average yield from participating farmers' fields under traditional PTR which was 2.0t/ha in 2014). Farmers establishing a DSR crop can no longer rely on traditional practices, in particular the presence of standing water in paddies, to control weeds. However, farmers expressed a strong preference against chemical weed control because it increases input costs and negatively affects paddy biota (frogs, fish, snails, etc) which are important protein sources for farming households during the wet season. Many farmers reported that manual weeding was easier in the straight rows between plants in DSR paddies than between the less rigidly-placed plants in PTR paddies.

Farmers are attracted to DSR largely because of the potential overall savings with reduced labour requirements for crop establishment (these savings are achieved notwithstanding a higher labour budget for weed management): Table 1 illustrates that all DSR treatments required fewer person days per hectare (40 to 52) to produce a crop than were required in the PTR treatment (78). As rice is produced largely for domestic consumption in Lao PDR (primarily using unpaid household labour) the gross margin calculated for each treatment does not represent a cash gain or loss the household would incur: rather GMs are a tool used here to compare the value of establishment methods under different treatments. Table 1 shows that DSR with good weed control (Treatments 2 and 4) improves GM relative to PTR+GAP (Treatment 1). Where weeds are not well controlled early in the season (Treatment 3) subsequent high labour requirements and a yield penalty result in a GM lower than that of PTR+GAP.

Table 1: 2014 average yield and labour requirements, and gross margins under DSR and PTR treatments

Treatment	Yield (t/ha)	Labour (person days/ha)	Gross margin (LAK/ha)[1]
1: PTR+GAP	3.3	73	1,703,200
2: DSR+GAP	3.3	52	2,928,400
3: DSR+poor early weed control	2.9	68	1,409,000
4: DSR+herbicide	3.4	40	3,685,600

[1] 1 AUD is approximately 6375 LAK

Figure 1 illustrates the yield return on labour required to produce a rice crop: DSR+GAP results in 62.9kg/person day and is a more attractive option than PTR+GAP (45.6kg/person day), DSR+FP (43.3kg/person day) or DSR+herbicide (85.0kg/person day: this option is not attractive to Lao farmers because of the additional use of chemicals).

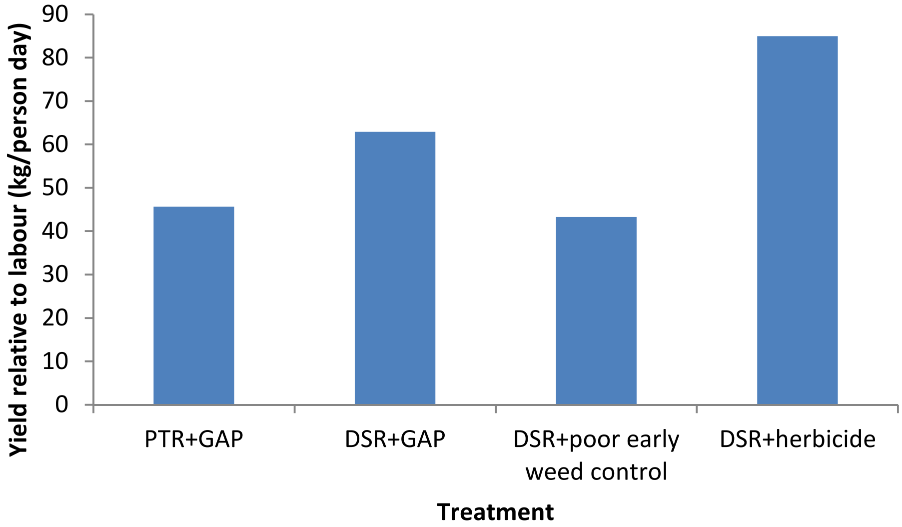

Figure 1: Yield relative to labour required to produce a rice crop (kg/person day)

Crop simulation modelling

Field trial data indicated comparable yield results between PTR and DSR for years in which the on-farm testing was run. A comparison using APSIM, in which weeds were assumed to be well controlled, suggests that in the longer term (i.e. over 40 years between 1971 and 2011) DSR is likely to perform better than PTR: the number of crop failures (i.e. 0t/ha yield) will reduce and average yields will increase from 3.3t/ha under PTR+GAP to 4.0t/ha under DSR+GAP (Figure 2).

Under a future climate, between 2021 and 2040, yields are likely to increase above present day long term estimates under both PTR+GAP (4.3t/ha) and DSR+GAP (4.5t/ha) (Figure 2). In both treatments crop failures are no longer simulated: these results are largely due to increases in rainfall during the wet season, in particular early in the wet season. In the best 30 per cent of years there will be little difference in crop yield between that achieved under DSR+GAP in the historical simulation and that achieved under either DSR+GAP or PTR+GAP in the 2021 to 2040 scenarios: in these years water stress does not impede crop growth; rather, greater yield production is inhibited by a lack of nitrogen.

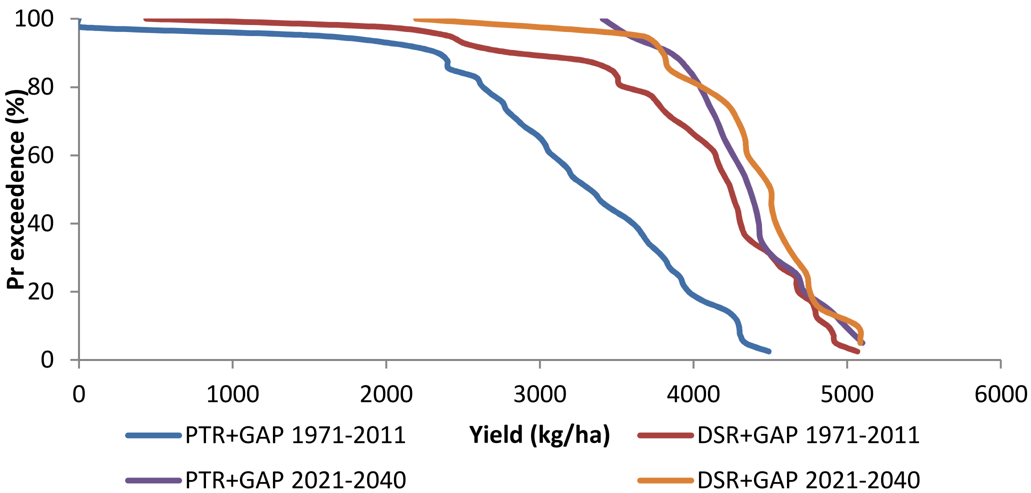

Figure 2: Probability of exceedence curves for yield (kg/ha) for PTR+GAP and DSR+GAP under present day (1971 to 2011) and future (2021-2040) climate data

Conclusion

On farm testing of DSR has demonstrated its potential for rice farmers in rainfed lowland Lao PDR. DSR enables farmers to sow, and to grow to maturity, a comparably-yielding rice crop with less water than is needed for PTR. Where weeds are well managed the labour demand is significantly reduced relative to PTR, thus decreasing farmers' production costs and enabling greater opportunities for off-farm income generation for the household. In the longer term under both current and future climates DSR remains an attractive option to maintain or increase yields and to reduce farmers' exposure to climate risks.

Throughout this research farmers have maintained a keen interest in DSR and, with assistance from local research and extension agencies, have expressed a determination to continue to engage in and experiment with dry direct seeded rice to decrease their production costs while maintaining or improving food security.

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11.3 Appendix C: Pamphlet on the dry direct seeder in Savannakhet Province, Lao PDR produced by Mr Sysavanh Vorlasan and Mr Khammone Thiravong, PAFO Savannakhet

ສະດວກໃນການຢອດ ແລະ ບໍ່ສິ້ນເປືອງທາງດ້ານແນວ ສັນຍິກ.

ການປູກເຂົ້າໂດຍການນຳໃຊ້ຈາກເຄື່ອງຢອດແມ່ນ ເໝາະສົມໃນນາທີ່ມີລັກສະນະດິນໜຽວປົນດິນຊາຍ ເພື່ອເປັນການຫຼຸດຕົ້ນທຶນ ເພີ່ມທຶນຜະລິດໂດຍການປູກ ທັນເວລາ

5 ຂໍ້ດີ ແລະ ຂໍ້ອ່ອນໃນການນຳໃຊ້ເຄື່ອງຢອດເມັດ

⇒ ຂໍ້ດີ:

- ❖ ສາມາດຜະລິດໄດ້ໃນນາໂຄກ
- ❖ ປະຫຍັດຕົ້ນທຶນໃນການຜະລິດ
- ❖ ປະຫຍັດແຮງງານ
- ❖ ສາມາດຜະລິດໃນເນື້ອທີ່ເປັນຈຳນວນຫຼວງຫຼາຍ.
- ❖ ການປູກເປັນຖັນແຖວລະບຽບດີ
- ❖ ສາມາດປູກໄດ້ໃຫ້ທອງທັນກັບເວລາ.
- ❖ ເຄື່ອງອາໄລ່ຫາງ່າຍ

⇒ ຂໍ້ເສຍ:

- ❖ ບໍ່ສາມາດຢອດໄດ້ໃນນາທີ່ມີນ້ຳຂັງ.

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ເອກະສານອ້າງອີງ:

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ຂະແໜງປູກຝັງ ແຂວງ ສະຫວັນນະເຂດ

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ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ

ສັນຕິພາບ ເອກະລາດ ປະຊາທິປະໄຕ ເອກະພາບ ວັດທະນະຖາວອນ

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ພະແນກ ກະສິກຳ ແລະ ປ່າໄມ້

ປະຈຳແຂວງ ສະຫວັນນະເຂດ

ຂະແໜງປູກຝັງແຂວງ

ການນຳໃຊ້ເຄື່ອງຢອດເມັດພັນ

ຮຽບຮຽງໂດຍ : ທ. ສີສະຫວັນ ວໍລະສານ

ກວດແກ້ໂດຍ: ທ່ານ ຄຳມອນ ທິລະວົງ

ກຸມພາ 2012

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ການນຳໃຊ້ເຄື່ອງຢອດເມັດເຂົ້າ

ການປູກເຂົ້າຖືວ່າເປັນການປະຕິບັດທີ່ຕ້ອງໄດ້ເອົາໃຈໃສ່ເປັນຢ່າງດີ ແລະ ຕ້ອງໃຊ້ເວລາໃນການເບິ່ງ ແລະປົກປັກຮັກສາ ພ້ອມທັງໃຊ້ແຮງງານຫຼາຍອີກ ແຕ່ໃນທ້ອງຖິ່ນທີ່ມີການປູກເຂົ້າຫຼາຍເຫັນວ່າຈະເປັນເຂດທີ່ຕ່າງໆ ມີບັນຫາຂາດແຄນແຮງງານ ຫຼື ນ້ຳຝົນ ຕ້ອງໄດ້ລະດົມທາງດ້ານເນື້ອທີ່ອອກຫຼາຍ ຈຶ່ງຕ້ອງໄດ້ໃຊ້ງົບປະມານສູງໃນການການຜະລິດເປັນຕົ້ນ ແມ່ນໄດ້ຈ້າງຕົ້ນຕໍ, ຈ້າງໄຖ, ຄ່າຫວ່ານ...

ດັ່ງນັ້ນ, ທາງວິຊາການທາງດ້ານການກະເສດ ຈຶ່ງໄດ້ຄົ້ນຄິດ ຊອກວິທີທາງໃນການຜະລິດເຄື່ອງຢອດເມັດພັນເພື່ອນຳໃຊ້ ເຂົ້າໃນການກະສິກຳ.

1. ເຄື່ອງຢອດເມັດ
   - ❖ ມີຂະໜາດນ້ອຍ 4 ແຖວຢອດ
   - ❖ ໃຊ້ຕິດກັບລົດໄຖນາເດີນຕາມ
   - ❖ ຢອດໄດ້ 4 ແຖວ, ໄລຍະຫ່າງລະຫວ່າງແຖວ ແມ່ນ 25 ຊມ.
   - ❖ ຄວາມສາມາດໃນການບັນຈຸຂອງຖັງເຂົ້າ 10 ກິໂລ/ຖັງ.
   - ❖ ອຸປະກອນໃນການເປີດລ້ອງແມ່ນ ຈານເປີດມີ 4 ຈານ.

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- ❖ ອຸປະກອນໃນການກວດກົບລ້ອງແມ່ນແບບໄມ້ກວາດ ສາຍຫຼັງຈານເປີດລ້ອງແລ້ວ ແລະ ຢອດເມັດລົງ.
- ❖ ອັດຕາການນຳໃຊ້ເມັດພັນແມ່ນ 8-10 ກລ/ໄຮ່
- ❖ ຄວາມອາດສາມາດທີ່ຢອດໄດ້ 1.5-2 ໄຮ່/ຊົ່ວໂມງ.
- ❖ ມີບ່ອນສາມາດປັບໄດ້ຕາມຕ້ອງການ ວ່າຕ້ອງການຢອດຢ່ອນໄດ້
- ❖ ລາຄາປະມານ 208.000-260.000 ກີບ

2. ອຸປະກອນ
   - ❖ ລົດໄຖນາເດີນຕາມ
   - ❖ ຖັງໃສ່ເມັດພັນ
   - ❖ ເຄື່ອງເປີດລ້ອງ
   - ❖ ທໍ່ຢາງ
   - ❖ ເຄື່ອງປັບຄວາມຫ່າງຄວາມຖີ່ຂອງເມັດ.
3. ວິທີການນຳໃຊ້

ການນຳໃຊ້ສ່ວນໃຫຍ່ແມ່ນເຮົານຳໃຊ້ເຂົ້າໃນການກະສິກຳເປັນຫຼັກເປັນຕົ້ນແມ່ນເຂົ້າ ເມື່ອກະກຽມສະພາບພື້ນແລ້ວກໍ່ເລີ່ມ ໂດຍຈະປະກອບແຕ່ລະຊິ້ນສ່ວນຕິດກັບລົດໄຖນາເດີນຕາມ ການຢອດແມ່ນເໝາະສົມກັບສະພາບພື້ນທີ່ທີ່ມີລະ ຂະໜາດກາງ ແລະ ຂະໜາດນ້ອຍ ເຊິ່ງສາມາດຢອດໃນເນື້ອທີ່ປະມານ 50-500 ໄຮ່ ຂະໜາດຂອງແປງ

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ຄວນເປັນຮູບ 4 ຫຼ່ຽມ ເພາະສະດວກໃຫ້ແກ່ຊາວກະສິກອນແມ່ນເຊີດນາເປັນໄຮ່ເປັນຕອນ

3. ເວລາທີ່ເໝາະສົມໃນການປູກ

ເວລາທີ່ເໝາະສົມໃນການປູກ ໂດຍການນຳໃຊ້ເຄື່ອງແມ່ນຂຶ້ນຢູ່ກັບ ກັບຊາວກະສິກອນເຊີດນາ ເຊິ່ງເລີ່ມ ແຕ່ປາຍເດືອນເມສາ ເຖິງປາຍເດືອນມິຖຸນາ ສະເໝາະສົມ ເຊິ່ງຊ່ວງນີ້ແມ່ນ ໃຫ້ຜົນຜະລິດດີກວ່າ ແຕ່ຖ້າຫາກວ່າຊາວກະສິກອນມີພື້ນທີ່ຫຼາຍສາມາດນຳໃຊ້ເຄື່ອງຢອດເມັດໄດ້ ແຕ່ຖ້າຫາກວ່າ ການຜະລິດເຂົ້າຫາກວ່າ ຢອດຊ້າເກີນໄປອາດເຮັດໃຫ້ຜົນຜະລິດຕົກຕ່ຳ

4. ອັດຕາການນຳໃຊ້ຂອງເມັດພັນ

ໃນການນຳໃຊ້ເຄື່ອງຢອດເມັດແມ່ນ ເຮົານຳໃຊ້ຢູ່ປະມານ 8-10 ກລ/ໄຮ່ ໃນການຢອດເມັດເຮົາຕ້ອງໄດ້ມີການຈັດການດ້ານພື້ນທີ່ປາງລະອຽດເພື່ອຄວາມ

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11.4 Appendix D: Poster on the dry direct seeder in lowland Lao PDR produced by NAFRI

11.5 Appendix E: Poster on the dry direct seeder in lowland Lao PDR produced by NAFRI