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. The traditional establishment practice of puddled transplanted rice (PTR) exposes 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).

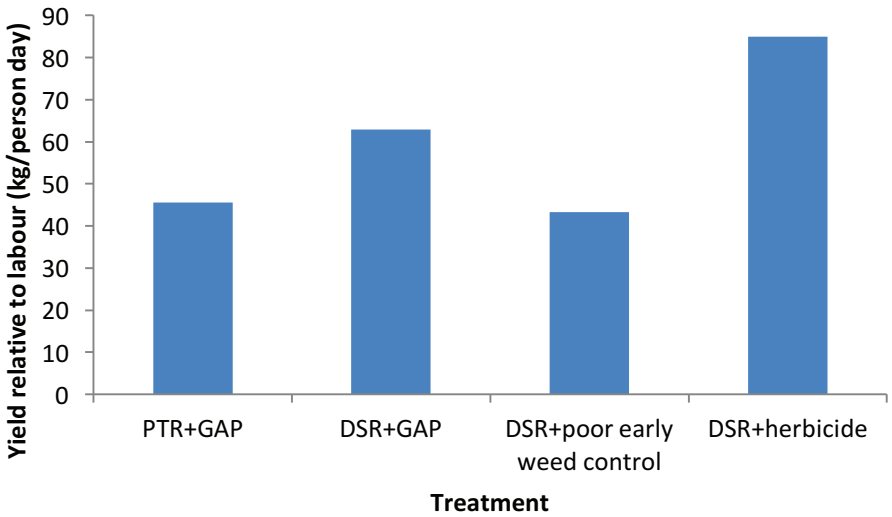

Figure 1: Yield relative to labour required to produce a rice crop (kg/person day)

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.

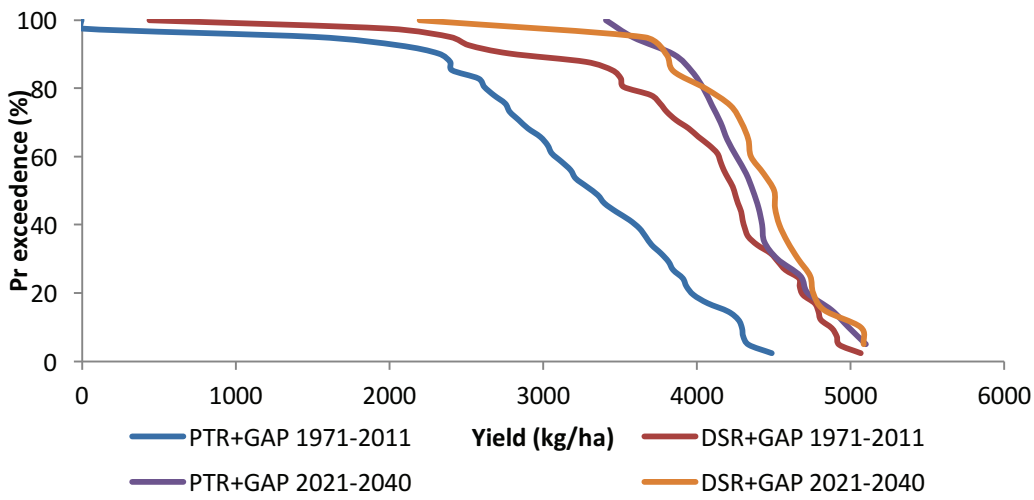

Figure 2: Probability of exceedence curves for yield (kg/ha) for PTR+GAP and DSR+GAP under present day (1971 to 2011) and future (2021-2040) climate data

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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