Field Crops Research 225 (2018) 32–46

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Mechanised dry seeding is an adaptation strategy for managing climate risks and reducing labour costs in rainfed rice production in lowland Lao PDR

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ARTICLE INFO

Keywords:
APSIM
Climate variability
Dry seeded rice
Participatory engagement
Rice production
Simulation modelling

ABSTRACT

Rainfed rice production in Lao PDR is critical to national food security; under traditional transplanting methods farmers are exposed to climate risks at both the onset and the conclusion of the wet season. Production of the annual crop has a high labour requirement especially during transplanting and harvesting. We engaged with smallholder farmers to investigate the feasibility of one form of dry seeding of rice, i.e. mechanised dry drill seeding, which in this paper we refer to as "dry seeding". We hypothesised that dry seeded rice crops will be established earlier in the wet season and will produce a comparable yield while requiring less water and labour than transplanted rice. Field trials, supported by scenario modelling using the APSIM model, indicated average dry seeded rice yields are comparable to average transplanted yields over the longer term but with reduced risk of crop failure, under both current (1971–2011) and near-future (2021–2040) climates, for two common soil types. Net overall labour savings reduce the cost of rice production under mechanised dry seeding, better positioning households against fluctuations in labour costs and rice prices. Mechanised dry seeding requires different crop management to traditional methods and will not be appropriate for all farmers. Performance of DSR under future climate scenarios is projected to be as good as or better than under current climate conditions.

1. Introduction

Lao PDR is experiencing rapid social change in agriculture with the rise in alternative income streams from non-farm, (relatively) high-earning income opportunities for rural households (Cramb et al., 2015; Manivong et al., 2014). Largely this change is experienced in rural areas where traditional incomes are derived from work which is both menial and poorly paid. Most rural households still aim to produce sufficient rice annually to ensure food security (Cramb et al., 2015; Manivong et al., 2014; Newby et al., 2013) and for many households remittances from younger members working in regional cities are used to hire labourers at key times in the cropping calendar to ensure household food security (Manivong et al., 2014). As access to household labour through the growing season has reduced (due to temporary or permanent migration), the demand for hired labour has increased and thus the cost of hiring workers for transplanting, weeding and other labour-intensive tasks has also increased. Farming households are keen to maintain current rice yields while reducing the costs of production, in particular labour costs. Farmers perceive little benefit in increasing production above that necessary for domestic consumption as input costs are relatively high and rice prices volatile and uncertain (Newby et al., 2013).

Lowland Lao PDR has a climate with highly variable short-term fluctuations (e.g. flooding along the Mekong River basin, and intra- and inter-season drought; Lacombe et al., 2012) and little institutional or community capacity to adapt to these risks (Roth and Grünbühel, 2012). In Lao PDR almost all rice is grown on the lowland plains in the annual wet season (May to November), under rainfed conditions, using traditional methods of puddling and transplanting (Sengxua et al., 2017; Inthavong et al., 2011b; Linquist et al., 2006). This high dependence on rainfed rice production, combined with likely projections for

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https://doi.org/10.1016/j.fcr.2018.05.020
Received 21 May 2018; Accepted 28 May 2018
0378-4290/

current or increasing variability in the timing, onset and/or duration of the wet season rains (Lacombe et al., 2012; Roth and Grünbühel, 2012), leaves Lao PDR vulnerable to reduced and more risky rice production. There are conflicting reports estimating the impacts of future climates on rice production in Lao PDR: Mainuddin et al. (2011) suggest that average rice yields in Southeast Asia may remain stable or increase, while other work (Snidvongs et al., 2003; Parry et al., 2004; Wassmann et al., 2009) forecasts less positive outcomes in future yields across the region.

Strategies which help farmers better manage risk under current patterns of climate variability are likely to also assist them transition the production system under future climates (Howden et al., 2010, 2007). A challenge for researchers is to identify the strategies which will best assist farmers: one option often considered is improved seasonal climate forecasting, which enables farmers to better target their management decisions to the likely upcoming seasonal conditions. Lacombe et al. (2012) conducted a detailed statistical analysis of rainfall data in the region covering the southern Lao rice production zone over a period of up to 60 years (1951–2010). They derived 37 variables from daily rainfall records and examined the main climate features that affect rainfed agriculture and farmers' livelihoods, including the onset, duration, cessation and intensity of rainfall through the wet season. Lacombe et al. determined that observed rainfall trends across Savannakhet Province are heterogeneous and variable across temporal and spatial scales. They found little correlation between wet season onset and cumulative rainfall over all or part (e.g. the first 30 days) of the wet season, and no correlation between wet season onset and the wet season retreat. These observations of high season-to-season rainfall variability, lack of predictive ability before or during a wet season, and subsequent challenges to rice production are in line with those observed previously (e.g. Hijioka et al., 2014; Fukai and Ouk, 2012; Basnayake et al., 2006). Hence, it has been concluded that current seasonal climate forecasting technology has little value for farmers in Lao PDR.

An alternative strategy is to change traditional management options to increase flexibility and permit better alignment of rice crops to seasonal conditions as they unfold. Fukai et al. (1998), working in irrigated dry season rice production systems, demonstrated that mechanised dry drill seeding of rice (DSR; referred to as 'dry seeding' in the remainder of the paper) enables flexibility in the timing of rice establishment for the southern Lao rice production area. There has been little subsequent work to extend DSR into rainfed wet season production systems in Lao PDR.

In traditional rainfed transplanted rice (PTR), farmers rely on monsoonal rains to produce a single wet season rice crop annually. Between two and four nursery crops are sown at staggered intervals approximately two weeks apart from late April to early June, on premonsoon showers. Once the nursery is established and sufficient rain has fallen to saturate soils, farmers plough, puddle, and prepare their main paddies. When monsoon rains arrive, in late June or July, the most viable seedlings are transplanted into bunded paddies. Rice is transplanted into standing water, which also suppresses weeds and into which fertiliser is broadcast. If rainfall is insufficient or late, crop yields are negatively affected by delayed transplanting of older-seedlings, poorly-timed fertiliser applications, and increased risk of drought stress at the end of the growing season (Linquist et al., 2006).

In contrast to PTR, the mechanised DSR practice tested here involves sowing directly into tilled, unpuddled soil using a tractor-mounted seeder: farmers take advantage of the same early-season rains which germinate and sustain their seedling nurseries to germinate and grow paddy rice. Because the rice is planted *in situ* in the paddies from where it will be harvested, standing water is not necessary during the growing season (weeds must be well managed by alternative means). Physiologically, mechanised DSR is better protected against early and/or intermittent drought as root systems develop sooner and more robustly (Sudhir-Yadav et al., 2014): crops are thus better able to withstand short term rainfall deficits. In lower terraces, early-sown rice plants are taller earlier in the wet season and better able to withstand short-term flooding events. Mechanised dry seeding is much faster than transplanting: to establish one hectare takes approximately one person-day with a seeder compared with about 20 person days to transplant (Pheng Sengxua pers. comm., Fukai and Ouk, 2012). DSR crops mature earlier in the season than PTR crops, and although they might therefore appear less at risk of terminal drought stress, the situation in reality is less clear. Due to the puddling process, soils under PTR crops will have lower saturated percolation rates than the same soils under DSR (puddled soil percolation rates are around 50% that of non-puddled soils: Gathala et al., 2011), and consequently surface water is retained longer as ponding in PTR systems. This means that although DSR crops finish earlier, ponded water may also disappear earlier. Conversely, PTR crops finish later but any rainfall will maintain and pond for longer.

Williams et al. (2015) document the diversity in livelihoods in southern Lao PDR. While DSR is a feasible establishment practice for farming households in irrigated systems, it has not been previously determined if DSR will meet the needs and goals of households in rainfed wet season rice production systems. Management strategies which address multiple production objectives are attractive to farmers and more likely to be adopted than those which only address a single objective (Roth and Grünbühel, 2012). Mechanised DSR which, compared to PTR, facilitates earlier-season planting, faster physiological development and reduced water demand has the potential to reduce farmers' exposure to the high rainfall variability (Lantican et al., 1999).

Accordingly, this study aims to examine if DSR: i) is a technically feasible establishment strategy to manage climate risk (in other words, does it reduce the frequency of crop failures or poor crop yields in dry years); ii) is sufficiently attractive to farming households to encourage them to adopt this technology; and iii) is likely to assist farmers manage future climate risks. Our approach integrates agronomic and social research by combining participatory farmer engagement, on-farm trials, and cropping systems modelling to make comparisons between DSR and PTR for the farming communities in which they are based. While this research was conducted in lowland Lao PDR, we suggest the results are broadly applicable across rainfed lowland rice production areas in developing countries facing agronomic challenges as a result of climate change and labour shortages.

2. Materials and methods

2.1. Study sites

Research was conducted in two districts, Outhoumphone and Champhone, in western Savannakhet Province, Lao PDR (Fig. 1). These districts are representative of the lowland, rainfed rice-growing plains from which almost 80% of the country's rice is produced (Linquist et al., 2006; Roth and Grünbühel, 2012). Rainfall in this region is highly variable year to year (Basnayake et al., 2006; Lacombe et al., 2012). Farms in Champhone district are relatively low-lying and subject to flooding during the wet season, but are endowed with deeper sandy loam soils. Farms in Outhoumphone are located on drier, more undulating toposequences with shallow loamy sands, often underlain by laterites, making these sites more drought prone.

2.2. Analysis of planting window

Daily rainfall data from seven observation stations within Savannakhet Province were analysed for spatial and temporal trends to identify earliest possible sowing windows, using the methods and definitions described in Lacombe et al. (2012), noting that the earliest sowing window occurrence is the commencement of the wet season in any particular year and any sowing window is followed by a 30-day nursery period (see Fig. 1 for station locations). Two stations (Seno and