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Promoting resilience in Cambodian lowland rice ecosystems—Farming system research to support flexible climate response strategies for smallholder farmers☆

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ABSTRACT

With high levels of seasonal climatic variability impacting on the consistency of rice production in Cambodian rainfed, lowland systems, there is a need to identify strategies that improve farmer food security and better meet national domestic and export demands. While there is a substantial gap between actual and potential rice yield, little research has been undertaken in Cambodia to improve rainfed rice agronomy or the efficiency of use of natural resources which, in a climate constrained environment can hold the key to better productivity and food security.

On-station and on-farm research, in combination with farming systems simulation and social research provide the capacity to evaluate cropping options through the lens of climate variability. The testing of technologies and strategies, including the use of modern, short and medium duration varieties, opportunistic timing of crop establishment, mechanisation, supplementary irrigation and improved agronomic practice has shown that there is potential to mitigate the effects of variable climate on farm productivity and household income. However, this requires an increased level of farmer/systems flexibility to allow for near to real-time changes in cropping response to observed seasonal conditions. These factors differentiate this research and provide the opportunities to improve the individuals' livelihood and in meeting national rice production targets.

1. Introduction

The production of rice (*Oryza sativa* L.) is an important contributor to the Cambodian economy and critical to the food security of its 14.5 million people (World Bank, 2014). With the national government aiming to increase annual paddy rice production from 6.8 million tonnes in 2010–12 (IRRI, 2013) to 15 million by 2015 (USDA, 2010), and to significantly increase annual exports, there is an imperative to improve the national rice yield which currently averages 2.41 t/ha^{-1}, which is lower than that of neighbouring Thailand (2.86 t/ha^{-1}), Laos (2.67 t/ha^{-1}) and Vietnam (5.6 t/ha^{-}) (2010–12 data) (IRRI, 2013). As rainfed, lowland rice constitutes around 90% of the annual harvest area of 2.4 million hectares (MAFF, 2011), this is an obvious starting point in meeting national goals and in supporting the food security of a nation where 15.4% of the population suffered undernourishment in 2011–13 (FAO, 2014).

Overarching the agronomic and social challenges facing policy makers and farmers attempting to meet national goals, are the current effects of seasonal climate variability on productivity (Schiavone, 2010), and the vulnerability of agriculture to the future impacts of climate change. These impacts are predicted to increase the frequency, severity and unpredictability of extreme weather-related events including hurricanes, droughts, floods, and rising sea levels (IPCC, 2007). Nowhere is this likely to have more impact than in the south-eastern provinces of Svay Rieng (11.089N, 105.819E) and Prey Veng (11.485N, 105.328E) where a combination of variable climate and low quality soils affects rice productivity (average provincial yield of 2.29 t/ha^{-1}) (IFAD, 2013). In response,

Abbreviations: FP, farmer practice; SSD, single crop, short duration modern rice variety, direct seeded; SST, single crop, short duration modern rice variety, transplanted; SDD, modern, short duration, double direct seeded rice; SDT, double crop sequence of short duration modern rice varieties, transplanted; MSD, single crop, medium duration modern rice variety, direct seeded; MST, single crop, medium duration modern rice variety, transplanted.

☆ Research conducted in Svay Rieng Province, Cambodia.

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economic migration to population centres has been an important societal trend, with resultant labour shortages further exacerbating the challenges of increasing agricultural productivity (Roth et al., 2013).

1.1. Environment

The majority of annual rainfall (mean of 1568 mm) (1980–1993 record) in Svay Rieng and Prey Veng provinces falls during the monsoonal period from May to November-December. Seasonal rainfall variability is both temporally and spatially high, often resulting in early to mid-monsoon season dry periods and later-season flooding (USDA, 2010). The majority of rainfed rice production in these provinces is undertaken on the older and highly weathered alluvial, acidic Prateah Lang and Koktrap soils. While the Prateah Lang soil has a sandy surface texture, and the Koktrap a loamy or clayey texture, rooting depth is limited in both cases by a hard pan at a depth of 15–20 cm resulting in there being little difference in water holding capacity. Nutrition is higher on the Koktrap soil, although both soils require the application of nitrogen (N), phosphorus (P) and potassium (K) fertiliser to optimise yield (White et al., 1997).

1.2. Traditional rice systems

1.2.1. Rainfed, monsoon season production

Rainfed rice cropping in Svay Rieng and Prey Veng provinces is based around the production of locally sourced, medium to long duration rice lines grown using low levels of nutrient input. It is a climatically and financially risk averse system based on traditional knowledge and designed to meet family food security requirements estimated to be 200 kg of rough rice/person/year (Santacroce, 2008). Primary tillage to control weeds and to prepare for rice seedling transplant occurs after the land is suitably moistened by rainfall at the onset of the monsoon (from April onwards). If available, irrigation may be used to facilitate timely land preparation and the establishment of seedling nurseries. A secondary tillage operation prior to transplant is then used to level and puddle the land. Traditionally, these operations have been undertaken using animal draft power although mechanised tillage using two-wheeled tractors is increasingly common (Fukai and Ouk, 2012). The transplanting of seedlings in late-June to early-July is laborious and locally reported to require 25 person days ha^{-1} to complete (Lon, iDE pers. comm.). This observation is supported by Sri Lankan and Philippine research which report periods of 21–24 person days ha^{-1} (Barker et al., 1985).

Crop production may be adversely affected by a mid-season dry period in late July-August, locally described as a ‘drought’. Farmers with access to irrigation supplement crop water supply during this period (Lonh, iDE, pers. comm.). Heavy rains in the latter half of the monsoon season may cause serious crop damage with farmers mitigating flood risk by actively draining fields where possible. Rice is harvested in November/December (130–140 days after transplant) as wet season rainfall declines, paddy water levels drop and conditions become more conducive to crop harvesting and post-harvest processing. The crop is typically gathered by hand although the use of mechanised harvesting is increasing. Yields of 1.5–2.5 t/ha are common, with rice, surplus to family food security requirements, sold. Santacroce (2008) suggests that in any particular year, 32% of farmers on the Mekong River plains have a surplus (median 750 kg). Forms of the monsoonal, rainfed rice production system have been used successfully for generations on the lowland plains (medium and high lands) surrounding rivers in many parts of South-East Asia (Barker et al., 1985). However sub-optimal yields often result because of seasonal climate variability, poor agronomic management, nutrient deficiency, the impacts of disease, weeds and insects and the use of lower yielding traditional varieties.

1.2.2. Recession production

The other most common provincial rice based farming system is practiced on the lower lands adjacent to the Vietnam border which are flooded during the monsoon period (Williams et al., 2015). Seed of modern, short duration varieties is hand broadcast as the flood waters recede, with a second crop grown during the dry season where canal water is available for irrigation. Recession rice is often complemented by the production of rainfed rice on the higher lands during the monsoon season.

1.3. Opportunities for an improved rainfed, wet season rice production system

Given the expanding demand for rice from an increasing Cambodian population, there are policy pressures to intensify rice production. It was hypothesised, that there was potential to increase productivity under variable seasonal conditions, while mitigating production risk, using a range of agronomic adaptation strategies. These strategies could include the use of improved rice genetics, better crop nutrition and agronomic advice and the increased use of mechanisation. However, for these strategies to impact on production and income, farmers also needed to know when particular strategies were an appropriate response to particular seasonal conditions.

The ability to formulate a cropping response, based on seasonal conditions, was termed ‘Response Farming’ by Stewart (1988), with the first system implemented in Kenya. This approach relied on seasonal rainfall prediction at the start of each new rainfall/cropping season, coupled with advice on modifying cropping systems/practices in accordance with the predicted rainfall and rainy season characteristics (Stewart, 1988).

A modified response farming approach has been investigated in Cambodia in which seasonal cropping response is based on achieving a specific depth of water in the rice field prior to commencement of cropping. This method was considered more appropriate than a direct measurement of rainfall, given the existing low levels of skill in regional seasonal climate forecasting and a lack of understanding and history of conventional rainfall measurement at the village level. The measurement of water depth integrates information on spatial variation in rainfall distribution and quantity, and small differences in soil water holding capacity, resulting from spatial variation in soil texture and depth to hard pan. Importantly, this method enabled farmers to make cropping decisions based on field observation, something with which they were already familiar.

1.3.1. Coupling on-farm biophysical and financial research with systems modelling

A combination of on-station and on-farm biophysical research and financial analysis, coupled with application of the farming system model, APSIM (Keating et al., 2003; Holzworth et al., 2014) was used to test the hypothesis that it was possible to increase productivity under variable climatic conditions. Biophysical research was underpinned by social investigation to identify the farm household types likely to adopt identified technologies and the potential fit of any such technologies within the farmer's broader livelihood strategies (Williams et al., 2015). While the biophysical aim was to investigate the potential for agronomic interventions to assist the individual farmer to better respond to seasonal variability, the broader goal was to contribute to national policy debate on rice intensification in rainfed systems (Roth and Grünbühel, 2012; Roth et al., 2014).

This paper describes the outcomes of on-farm biophysical research and financial analysis undertaken at 65 sites in Svay Rieng province during 2011 and 2012, and 57 sites in Svay Rieng and Prey Veng provinces in 2013 (Table 1). Poulton et al., 2016Poulton et al. (2016, in review) describe the parameterisation of the