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Productivity and profitability of upland crop rotations in Northwest Cambodia

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ABSTRACT

The upland cropping region of Northwest Cambodia exhibits limited crop diversity, with maize and cassava dominating rain-fed production systems. Farmers in the Districts of Sala Krau in Pailin Province, and Samlout in Battambang Province, report soil fertility decline in upland cropping systems with associated reduced yields and profitability compared with five years ago. Research was conducted at one site in each of these Districts over a two year period. The purpose of the study was to investigate crop rotations in this system with a focus on better use of soil water throughout the year to increase crop yields and profitability. This included an experiment to investigate increasing cropping intensity from the usual two crops per year to three and evaluate which crop sequences would be feasible. Out of a total 15 crop sequences evaluated, only four were successful in producing viable grain yields. These were the same sequences at both sites and included maize-maize-fallow, maize-maize-sunflower, maize-soybean-fallow and maize-soybean-sunflower. At Pailin, the sequence with the highest overall mean yield (4.3 t/ha) and profit was maize-maize-sunflower which returned a gross margin of $USD3700/ha over two years. The sequences with a fallow instead of a third crop produced the lowest financial returns at Pailin. However, in Samlout the maize-fallow was the most profitable sequence with an overall mean yield of 3.0 t/ha, returning $1680/ha over two years. The least profitable sequences at Samlout were the two soybean sequences. This study was successful in growing five crops in two years at Pailin, but could not reach the goal of six due to cultivar maturity length. At Samlout four crops over two years were produced, as the pre-monsoon crop was not planted in either year due to lack of sowing rainfall. Seasonal climatic factors had the greatest effect at both field sites on gross margins, which emphasized the importance of matching sowing date to rainfall to make better use of stored soil moisture to optimise yield and profitability. At Pailin, mean seasonal surface soil moisture, hundred seed weight and harvest index also impacted gross margin returns. This research validated the stability of maize in the farming system while sunflower should be further investigated in cropping sequences.

1. Introduction

Today, the Northwest region is a major centre for upland crop production in Cambodia. However prior to 1998, during more than two decades of war, the area consisted of mainly thick tropical forest (Touch et al., 2013). Peace in the region brought an influx of displaced persons who instigated widespread land clearing for agricultural production, despite the Cambodian region still being the most heavily landmined area (The HALO Trust, 2016). When upland cropping first began in the Northwest, a range of crop types were grown which included maize and soybean as the primary crops and minor crop types of mungbean, peanut and sesame (Provincial Department of Agriculture, 2015). Soil fertility of recently cleared rainforest was high and maize production was very profitable, which resulted in the domination of continuous maize in the farming system and a subsequent decline in crop diversity (Brown and Johnstone, 2012).

In recent years farmers have observed a drop in soil fertility, declining maize yields and visual symptoms of nutrient deficiencies, such as N and P, in crops (Touk, 2004; National Institute of Statistics, 2009; National Committee for Sub-National Democratic

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Development, 2012; Montgomery et al., 2016b; Touch et al., 2016). In response to this, inorganic fertiliser application of upland crops has increased in the region, with farmers reporting that their crops grow better with fertiliser and it helps to prevent yield decline (Montgomery et al., 2016b). In 2012, 50% of farmers interviewed in the Sala Krau District applied fertiliser to their upland crop and 60% of farmers did so in the Samlout District, producing an average maize yield of 3.4 t/ha (Montgomery et al., 2016b). This is a rapid increase in fertiliser use from 2011 when only 21% of farmers in Pailin Province and 16% in the Samlout District reported using fertiliser on their crops and produced a lower average maize yield of 2.9 t/ha (Brown and Johnstone, 2012). Cassava has emerged as a new crop for the region over the last 10 years, due to reduced profits from maize and a strong market demand from Thailand (FAOSTAT, 2015; Martin et al., 2015), and in 2015 the hectares sown to cassava covered 97% of the Pailin Province upland crop production area (Provincial Department of Agriculture, 2016). However, there is evidence that Cassava can be detrimental to systems such as the upland cropping area of Northwest Cambodia, and can result in increased soil erosion, nutrient losses and decreases in pH (Howeler, 2002). At Pailin, 97% of cassava farmers are planting on top of the ridge and 49% are cultivating up-down slope, both of which will increase the erosion risk (Wenjun et al., 2016).

Currently farmers plant two crops per annum and land preparation involves extensive ploughing and burning of crop residues on highly erodible soil (Chan et al., 2009; Brown and Johnstone, 2012). On average, two thirds of farmers plough their fields and one third also burn them, with an increase in these figures for the high biomass cereal residue produced by maize (Montgomery et al., 2016b). Rainfall patterns in Northwest Cambodia are monsoonal with the majority of rain falling from July to October (Montgomery et al., 2016c), which combined with the current farming practices results in high annual soil erosion losses (Montgomery et al., 2016c). Farmers attempt to plant the first crop in March if rainfall conditions allow which are erratic in this month, and harvest in June/July, unless the crop has failed due to lack of rainfall (Chan et al., 2009). Climate data for the region shows a trend in recent years for a later onset of the monsoon season, and rainfall extended slightly into the traditional dry season (Touch et al., 2015). Depending on rainfall, they sow a second crop in July after burning or incorporating crop residues, ploughing and preparing the seed bed (Brown and Johnstone, 2012). This crop is usually harvested from late October into November and can be subject to wet weather constraints at harvest (Martin et al., 2016).

Ninety one percent of farmers surveyed in the Districts of Sala Krau and Samlout have reported cash flow shortages at certain periods throughout the year and are seeking alternative options to increase productivity and profitability (Montgomery et al., 2016b). The level of education for farmers in this region is low, due to interruptions by war and limited access to education facilities in remote rural areas (Touk, 2004). Hence, it is difficult for them to comprehend the consequences of complex farming decisions. Currently 95% of farmers do not record rainfall or understand the concept of growing crops from residual water stored in the soil (Montgomery et al., 2016b). Opportunity cropping is a farming technique used by many farmers in marginal cropping areas, in which they make planting and crop choice decisions based on the amount of water in the soil profile at a given point in time (Thomas et al., 1997). This method relies less on a calendar date and more on reducing the risk of crop failure through soil moisture knowledge and may be applicable to Northwest Cambodia.

This study sought to find options for sustainable intensification (Pretty and Bharucha, 2014) of the farming system that resulted in improved productivity and profitability for landholders without detriment to the environment. Farmers in this variable climate need to become more climate smart to ensure the family farm is not only profitable but also sustainable into the future, as the pressure to improve livelihoods and feed the worlds expanding population increases (St. Clair and Lynch, 2010). The authors surmise that implementing conservation agriculture principles including no-till farming, retention of crop residues and crop rotations with grass and broadleaf species (Kassam et al., 2009) will assist in improving the sustainability of this farming system.

Our research investigated the viability of two cropping sequence alternatives to current widespread practices. These alternatives included improved fallow management of the current system of two crops per year, or increase the cropping intensity to three crops per year, to entirely remove the fallow period. Typical crop sequences for the region were evaluated alongside alternative sequence options to determine the most productive and profitable options for local farmers.

2. Materials and methods

2.1. Site selection and characterisation

An experiment was conducted in Northwest Cambodia at two on-farm sites leased for the duration of the trial (Fig. 1). The first site was located 3 km north of the town of Pailin (12°52′15″N, 102°36′38″E) on a Red Brown Vertosol (Isbell, 2002) at an elevation of 170 m. The second site was located on a farm in Kantout Village, Samlout District (12°40′7″N, 102°44′43″E), Battambang Province on a Red Dermosol (Isbell, 2002) at an elevation of 180 m. Both of these soil types fall in the Labanseak soil group in the Cambodian classification (White et al., 1997) and were classified by Crocker (1962) as Latosols.

Northwest Cambodia has a monsoonal climate which, in this study, is defined as having three distinct seasons; a pre-monsoon period from March to June, the monsoon season from July to October and a post-monsoon period from November to February (Montgomery et al., 2016c). Long-term climate data for Pailin and Samlout is limited with annual rainfall available for 12 years at Pailin (2002–2013) and the last 10 years at Samlout (2006–2015). Average total rainfall for those periods is 1194 mm at Pailin and 2003 mm at Samlout.

An automatic tipping bucket rainfall gauge with data logger (Davis Instruments, Model No. 7852M) and maximum/minimum temperature and relative humidity data logger (Lascar Electronics, Model No. EL-USB2$^+$) were located on-farm at the Samlout site and 3 km south of the Pailin site at the Provincial Department of Agriculture building (Table 1). There was one data logger for temperature and humidity and another for rainfall per site.

The mean annual rainfall observed during the two year study at Pailin was 1088 mm with 268 mm, 719 mm and 101 mm falling in the pre-monsoon, monsoon and post-monsoon periods, respectively (Table 1). The mean daily temperature at Pailin was 28 °C, with the maximum temperature reached in the pre-monsoon of 45 °C and a minimum in the post-monsoon of 13 °C. Relative humidity ranged from 25 to 98% with a mean of 72%. The mean annual rainfall recorded for the two year period at Samlout was 1845 mm with 495 mm, 1211 mm and 139 mm falling in the pre-monsoon, monsoon and post-monsoon periods, respectively. The mean temperature at Samlout was 27 °C, with the maximum temperature reached in the pre-monsoon of 46 °C and a minimum in the post-monsoon of 8 °C. Relative humidity ranged from 27 to 99% with a mean of 78%.

Soils at the sites and across the region have not been extensively described, as this is the most heavily landmined area of Cambodia (The HALO Trust, 2016). The risk of triggering an anti-tank mine whilst deep soil sampling was assessed as being too high to safely undertake full soil descriptions or subsoil sampling (MJP, 2014).