New farming systems for upland cropping in Northwest Cambodia

Stephanie Clare Montgomery
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Certification of Originality

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis and all sources used have been acknowledged in this thesis.

[redacted]

Stephanie Clare Montgomery

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Abstract

Northwest Cambodia has undergone rapid land use change over the last 20 years. Since the end of civil war in 1998, extensive areas of primary forest have been cleared for agriculture. The major agricultural enterprise in the region is upland cropping of cash crops which previously included a range of crops including maize, soybean, mungbean, sesame and peanut. However crop diversity has decreased over the last 10 years, to the extent that the farming system is now dominated by continuous cropping of maize or cassava. The region receives monsoonal rainfall, with the majority of rain falling between July to October, and has a climate of three distinct seasons. Farming methods are plough based on friable dermasol and vertosol soils, which results in visible soil erosion duirng the monsoon season. Crop yields are declining, the area is remote, farmers are poorly educated and there is a dearth of agricultural research and extension. The region is of particular significance to the wider catchment area as it contains the headwaters of the Sangker river system that supplies drinking and sanitation water for over one million people living in the Northwest Provinces of Battambang and Pailin.

This thesis investigates new farming techniques for the areas of Pailin and Sala Krau Districts, Pailin Province, and Samlout District, Battambang Province in Northwest Cambodia. The aim of the study was to evaluate and develop novel agronomic practices to assist in sustainable intensification of the upland cropping system, that results in improved productivity and profitability for the land holder without detriment to the environment. The potential to halt further land degradation in this important upper catchment, in a relatively short timeframe since the development of agricultural systems in the region, would have local and far reaching benefits.

Initially, a baseline survey of 391 farmers in the focus regions was undertaken to gain insight into the complexities of their farming system, and to aid in setting research priorities. The survey identified the major constraints to production, provided information about current farming practices, as well as farmers ideas for the future of the farming system. The major production constraints reported centred on extremes of climate, cash flow shortages at certain periods throughout the year and insect pests.

This research is based on a series of three field experiments, conducted with small plot replicated trials at two sites, one in each Province. The first trial investigated the viability of two cropping sequence alternatives to current widespread practices and was conducted for two years. These alternatives were to implement 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. Due to the longer maturity length of commercially available crop cultivars in Cambodia, it was not possible to increase the cropping intensity to three crops per year. However, this research did present findings to show that opportunity cropping in response to residual soil water availability would be an option in some instances to produce five crops in two years. This work suggested further research into moisture management and sowing times was needed to manage current climate conditions as well as potential future climate changes. The most successful sequences in this study were maize-maize-fallow, maize-maize-sunflower, maize-soybean-fallow and maize-soybean-sunflower. Whilst the gross margin returns from sequences that contained soybean were not as profitable as maize alone or maize-maize-sunflower, the added

benefit to the overall farming system of soybean as a soil ameliorant and rotation crop, should be considered as part of sustainable intensification. The productivity of maize in the current system was evident and when combined in a sequence with sunflower was highly profitable at Pailin. However this was not replicated at Samlout, which I surmise was due to sowing sunflower too late into the post-monsoon season.

To further investigate these research questions another experiment evaluating a delay in the traditional time of sowing back two months was conducted at Samlout. Crop failure in the pre-monsoon season is commonplace, with 95% of farmers sowing during the hottest period of the year (Feb-April) which has highly unpredictable rainfall. I hypothesized that a delay in sowing time from the typical Northwest Cambodian planting time (Feb-April) towards that used in Central Thailand (mid-May) may improve crop yield and reduce the risk of crop failure in comparison to the results achieved from current planting times. Crop sequences comprising the traditional upland crops of maize, cowpea and peanut, together with possible new crop choices for the region including sorghum and sunflower were also assessed. I believed that the contrast in success of sunflower in the first experiment between the two sites, was due to sowing date. Hence there was a need to further investigate the optimal planting windows for upland crops to maximise yield and profitability. For this experiment, the pre-monsoon crop was sown in late May each year and the monsoon crop in early October over a period of two years.

Results demonstrated high crop yields and a low probability of crop failure when sowing time was delayed by two months. Maize, sunflower and sorghum planted in early October produced good yields largely through access to stored soil moisture,

which is a novel concept for this cropping region. The sequence of maize-sunflower was the most profitable, returning a gross margin of almost $2500 USD/ha yr^{-1}. This was $500 per hectare per annum greater than the continuous maize sequence and over $1000 USD/ha yr^{-1} better than the maize-sorghum and maize-legume sequences. Increased gross margin returns are an attractive outcome for farmers in the region, as our survey revealed that 35% of farmers suffer major financial constraints to production and 91% of farmers experience cash flow shortages every year.

Aside from seasonal variability, the other significant factor that affected gross margins was the average moisture in the top 5 cm of soil for the season, which was also highly correlated with the climate variables of seasonal rainfall, humidity, and day and night temperatures. This illustrates the importance of water as a driver in rainfed cropping systems and shows that seasonal rainfall and soil moisture are intrinsically linked. To investigate this relationship further, we created a novel major technique to estimate plant available water (PAW) down the soil profile for maize in a land mine constrained soil. To do this we entered the data collected from this on-farm trial into the APSIM crop model calibrated for the focus region. Data input included yield, soil moisture at 5 cm depth (recorded every two weeks in the growing season), rainfall, temperature and surface soil characterisation data from the site. The correlation between observed yield and simulated yields as well as observed soil moisture and simulated soil water was high. The subsequent prediction of PAW down to a depth of 1.4 m throughout the year conferred with our hypothesis and results. The APSIM simulations indicated that the soil water profile fills above 100 mm PAW in May and increases until September, suggesting May is a safer time to plant than the preceding three months. The model also suggests that when planting

the second crop in early October there is a full profile of moisture available to the plant during its growing season.

This research recommends a delay in the traditional time of sowing by two months, which results in better alignment of crop growth to rainfall, residual soil moisture and cooler conditions for optimal plant growth and yield. The extension of the APSIM model to predict the subsoil profile moisture is an important development for practitioners working in land mine affected soils and is applicable on a global scale. Sunflower is a viable new crop choice for the region and is recommended to be implemented in combination with maize and legumes such as soybean. The suitability of conservation agriculture to the soils and topography of this region was demonstrated by the success of no-till planting and management of crops and residues throughout a two year rotation cycle. The implementation of no-till provides farmers with increased flexibility in sowing date due to less time constraints and the potential for maintaining more soil moisture.

To further quantify the effects of conservation agriculture, another trial was conducted at both sites to evaluate the effects of varying rates of maize stover mulch (0, 2.5, 5, 10 and 20 t/ha) on yields of maize and sunflower using no-tillage farming practices. Small plot replicated experiments were undertaken in the pre-monsoon and post-monsoon seasons. The pre-monsoonal maize experiment illustrated that the 5 t/ha mulch treatment attained the highest yield, which suggests that if farmers retain crop residues they can increase their chances of successful crop establishment and optimise yield during this hot and variable rainfall period. During the post-monsoon period at the same site maize yield increased by 0.4 t/ha with every 2.5 tonnes of mulch applied, whereas nil mulch resulted in near crop failure. Post-monsoon

sunflowers failed to respond to mulch treatments at either site. The lack of response at the higher rainfall site was probably due to mild seasonal conditions and adequate stored soil water. This also proved that a successful crop can be grown in the untraditional sowing period when it would normally be fallow. Maize was more responsive to mulch than sunflower in both seasons with mulch application always increasing yield.

Overall this thesis provides evidence that environmentally sustainable farming systems are achievable through the implementation of novel conservation agriculture practices in the upland regions of Cambodia. This was illustrated through reduced tillage, better use of residual soil water, reduced soil and nutrient loss and consequently increased yields, profitability and cropping opportunities. This study demonstrated how modifications to the current traditional farming system, such as a shift in crop sowing windows, change in crop sequencing and conversion to no tillage, can greatly increase productivity and profitability.

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
APSIM	Agricultural Production Systems sIMulator
B	Boron
CN	Carbon Nitrogen
Ca	Calcium
DUL	Drained Upper Limit
EC	Electrical Conductivity
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics Division
GAM	Generalised Additive Model
HI	Harvest Index
HSW	Hundred Seed Weight
K	Potassium
KCl	Potassium chloride
LL15	Soil Water Lower Limit

Mg	Magnesium
MJP	Maddox Jolie-Pitt Foundation
N	Nitrogen
Na	Sodium
NGO	Non Governmental Organisation
OC	Organic Carbon
OM	Organic Matter
P	Phosphorus
PAW	Plant Available Water
PAWC	Plant Available Water Capacity
PWP	Permanent Wilting Point
S	Sulfur
SOC	Soil Organic Carbon
UNE	University of New England
UXOs	unexploded ordnances
VIF	Variation Inflation Factor