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Wet cultivation in lowland rice causing excess water problems for the subsequent non-rice crops in the Mekong region

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ABSTRACT

Crop diversification is advocated for improvement of income of lowland rice farmers in the Mekong region, including Laos, Cambodia and Thailand. One common problem of adding non-rice crops after wetland rice is excess water caused by reduced drainage associated with the hard pan that is commonly created to store water in the paddy for the rice crop. This paper firstly describes the water balance in the lowland fields particularly on how deep percolation is decreased by the hard pan, and the effect of wet cultivation on soil compaction and water availability in the subsequent crops such as mungbean. Experimental work in Cambodia shows how non-rice crops such as mungbean and peanut often fail completely or partially due to excess water. The common experience is complete failure of the early wet season non-rice crop when rain started earlier and the lowland paddy is saturated with water, but also non-rice crops often do not grow well due to shallow root systems confined to the top soil above the hard pan. Destructing the hard pan may help non-rice crops, but the process is expensive and may have an adverse effect on subsequent rice crops. Experimental work has also demonstrated that where irrigation water is available, irrigation is often not effective as it causes soil saturation in the top soil. Ways to minimize the excess water problem are discussed.

1. Introduction

In the Mekong region that covers North and Northeast Thailand, Laos and Cambodia, rainfed lowland rice is the dominant rice ecosystem covering about 80% of total rice fields in each country. The total area occupied by rainfed lowland rice in the region is 9.5 m ha in 2009 (Thailand 6.7 m ha, Laos 0.6 m ha and Cambodia 2.2 m ha). While water supply depends on rainfall alone, the use of bund and wet cultivation (puddling) prior to rice planting ensures standing water for at least part of the growing period in the wet season in most rainfed lowland rice. Rice is commonly grown only once a year as a mono-crop in the wet season and typically rice is consumed by the household. Thus, traditionally the rainfed lowland rice system in the region is of subsistence agriculture with low input and low output (Schiller et al., 2006). While rice yield has increased for the last 20 years from 2.1 to 2.8, 2.3 to 3.6 and 1.4 to 2.8 t/ha in Thailand, Laos and Cambodia, respectively (Fukai and Ouk, 2012), crop intensification to further increase production and diversification to grow a higher value crop such as mungbean, peanut and vegetables offers an opportunity to move into the market orientated agricultural system. Double cropping of rice for crop intensification has been successful in areas where irrigation water is available in dry season (e.g. Sipaseuth et al., 2007 for Laos where around 20% of rice is produced in dry season), or where a wet season is sufficiently long to grow two crops of rice particularly where supplementary irrigation is available to grow early wet season rice (e.g. Mak, 2001; Chea et al., 2004; Ouk et al., 2007 for Cambodia). Rice produced in the wet season is the main crop, but rice produced in other seasons (i.e. the dry season or early wet season rice) is often sold at a market providing the farmers valuable income. On the other hand, there are limited areas growing non-rice crops after or before wet season rice to diversify the cropping system to further improve cash income. The main non-rice crops currently planted in the region are maize, soybean, mungbean, peanuts or vegetable crops, and they can be commercially successful in some areas such as maize in Vientiane in Laos and Kampot in Cambodia, and peanuts in Northeast Thailand, particularly where sufficient irrigation water is available to provide adequate water input throughout crop growth. Areas of non-rice crops grown in the dry season after harvesting rice in the wet season are limited in general. Maize is the largest crop in Laos and Cambodia, but only several villages would grow it on a large commercial scale. In a survey of maize growers in two of such villages (Ban Keun in Vientiane Province and Ban Muangkai in Savannakhet Province) in Laos, the number of families that grew maize was 27 and 30, respectively, among 318 and 632 households in these

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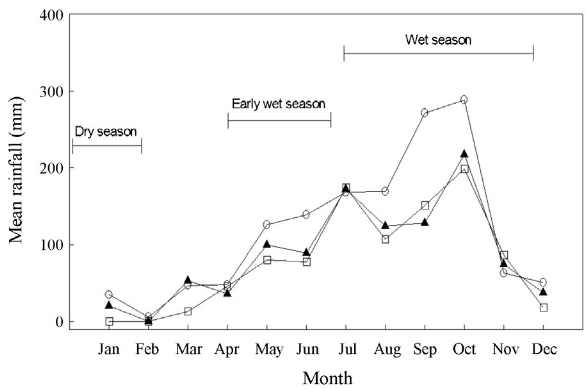

Fig. 1. Five year (2000–2004) average monthly rainfall for the experiment sites at CARDI (◯), Slarkou (▲) and Baneav (□) in Cambodia. Common time of crop growth in dry season, early wet season and wet season are also shown.

Source: From Ouk et al. (2007).

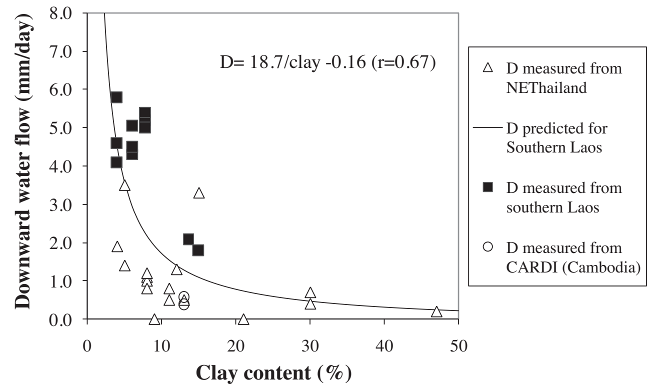

Fig. 2. The relationship of $D_{topsoil}$ and clay content in topsoil to a depth of 200 mm. The triangle, square and circle symbols refer to *D* measurements obtained in North-east Thailand, Southern Laos, and CARDI in Central Cambodia, respectively. The solid line is the predicted *D* values for these three regions.

Source: From Inthavong et al. (2011b).

villages, respectively (Sourideth et al., 2011). Just about all families grew rice in the wet season. To be commercially successful, these non-rice crops would need to produce a level of yield so that the net income from the crop would exceed that from the current crop of rice in the dry season or early wet season. This can be achieved with growing a crop with high market value of produce or lower cost of production, as shown for maize and soybean in Laos (Sourideth et al., 2011). Non-rice crops may be the preferred farmer option when the amount of irrigation water available in the dry season is not sufficient to grow rice but sufficient to grow short duration crops like mungbean.

In Cambodia the wet season often starts around April with peak rainfall in September/October, and the season ends in November (Fig. 1). In NE Thailand and Laos, rain generally stops earlier. Most rice grown in the wet season is transplanted in July/August in Cambodia, and about one month earlier in NE Thailand and Laos. Early wet season rice crops are common in the rainfed lowlands in Cambodia which commence with the wet season. Dry season crops may follow immediately after the harvest of the wet season rice crop.

The limited adoption of non-rice crops in the rainfed lowland rice based cropping system in the region may be caused by socio-economic factors, but another reason is that they are not necessarily well adapted to lowland growing conditions where the rice crop is wet cultivated in the wet season. The lowland soil is often compacted and forms a hard pan which reduces drainage of water from the field. This often causes excess water problems for non-rice crops grown in rotation with rice in the lowlands. This paper examines the excess water problem and describes ways to minimize it, using examples mostly from a recently completed Australian Centre for International Agricultural Research (ACIAR) funded project in Cambodia.

It should also be pointed out that excess water can cause a problem to the rainfed lowland rice. This is particularly the case when rice is completely submerged and prolonged submergence can kill the rice plants. This paper does not discuss the submergence problem in rice.

2. Soil water balance – how excess water problem may develop for non-rice crops in lowland-rice based cropping systems

The development of the excess water problem for non-rice crops in the rainfed lowland rice-based cropping systems may be readily understood by examining components of the water balance equation for the lowlands. Following Inthavong et al. (2011b), the water balance for the lowland fields may be considered in two layers, one above the hard pan here considered to be the top 20 cm soil layer (Kirchhof et al., 2000), including standing water if it exists, and the other below that level, and the total amount of stored water (W_{total}) is the sum of that in the two layers.

$$W_{total(t)} = W_{surface(t)} + W_{subsoil(t)} \quad (1)$$

$$\text{Layer 1}: \quad W_{surface(t)} = W_{surface(t-1)} + RF_{(t)} - ET_{c(t)} - D_{topsoil(t)} - RO_{(t)} \quad (2)$$

$$\text{Layer 2}: \quad W_{subsoil(t)} = W_{subsoil(t-1)} + D_{topsoil(t)} - D_{subsoil(t)} \quad (3)$$

where *RF* is rainfall (irrigation water may be added if irrigation is applied), ET_c is crop evapotranspiration, $D_{topsoil}$ and $D_{subsoil}$ are downward water loss from the topsoil and subsoil layers, respectively, *RO* is surface runoff, and *t* is time (Inthavong et al., 2011b). One key aspect of the water balance for the lowland fields is the relatively small downward water loss, so that the total stored water is high to provide standing water to the rice crop in the wet season. Inthavong et al. (2011b) found that the rate of downward water flow in typical lowland fields in the Mekong region was inversely related to the clay content of the soil (Fig. 2 from Inthavong et al., 2011b). Sand or loamy sand soils that are common in the region may lose more than 3 mm of standing water a day due to downward water flow. Commonly there is no standing water when a non-rice crop is grown in lowland fields, but after heavy rainfall or irrigation, drainage from the field is still poor, causing the soil to be saturated. In the case of fields with low *RO* such as at the bottom of the toposequence of a series of rice fields on sloping land, the slow water flow may result in inundation of water in the field for extended periods.

The amount of water available to non-rice crops depends on water holding capacity of the soil. Inthavong et al. (2011b) used the model by Saxton and Rawls (2006) for estimation of soil water characteristics, i.e. volumetric soil water content at saturation ($\ominus_s$), field capacity ($\ominus_{33}$) and wilting point ($\ominus_{1500}$).The model estimates soil water characteristics based mostly on the variables of sand, clay and organic matter percentage. Table 1 (from Inthavong et al., 2011b) gives the mean values of these soil characteristics for the topsoil (0–20 cm) and subsoil (20–100 cm), for various soil textures available in Savannakhet Province in Laos. According to the estimation, the top 20 cm of soil can hold 26 mm in loam, but this is reduced to around 10 mm for loamy sand and sand. With the increase in sand content, soil water content at field capacity decreases sharply while soil water content at saturation changes only a little, thus