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Factors explaining variability in rice yields in a rain-fed lowland rice ecosystem in Southern Cambodia

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ABSTRACT

There is a growing body of literature documenting higher productivity of the System of Rice Intensification (SRI) than conventional practices; however, few studies have been conducted to explore the factors explaining this higher productivity. This paper investigated key factors influencing yields in a rain-fed lowland rice ecosystem in Cambodia under farmer's SRI and conventional management practices (CMP). Rice yields from 70 plots with recorded management practices (36 plots under farmer's SRI and 34 plots CMP) were measured. Composite soil samples (210 in total) were collected from the harvested plots and analyzed for physical and chemical properties. Stepwise multiple regression analysis was performed to identify important predictors explaining rice yield variability. Variables contributing significantly to yield variation included: number of cattle (access to farmyard manure [FYM]), farmer's SRI practices, planting density and soil organic carbon (SOC). These four variables explained 39% of variance in rice yield. Keeping other variables constant, rice yields were increased by 14% (458 kg ha^{-1}) by shifting from CMP to farmer's SRI practices. The change of one unit in cattle (head), hill density (hill m^{-2}) and SOC (g kg^{-1}) results in an increase of rice yield by 5% (153 kg ha^{-1}), 2% (66 kg ha^{-1}) and 9% (289 kg ha^{-1}), respectively. The higher rice yield obtained by transplanting with narrower spacing suggests that the wider spacing recommended by SRI is not likely advisable, especially in nutrient-poor soil. Although the application of manure did not emerge as a key variable, three out of the four key variables (farmer's SRI, access to FYM, and SOC) are directly linked to its use. Farmer's SRI was strongly associated with the use of FYM, and the plots that received more FYM and belonged to farmers with more cattle had higher total soil N. Total soil N was positively correlated with SOC. The results highlighted the important role of livestock in crop-animal integration and the contribution of animal manure to increase agricultural productivity within smallholder farmers on infertile sandy Cambodian soils.

1. Introduction

Rice grown under rain-fed lowland ecosystems accounts for approximately 29% of the 140 M ha under rice globally [32,11,14], and over 90% of the rain-fed lowland area is located in South and Southeast Asia [32,51]. These agroecosystems are characterized by a high degree of variability in soil conditions and uncertainty of water supply, which are unfavorable for rice production [12,51,49]. They are also generally operated by small-scale farmers with limited access to capital. Rice crop performance is thus very low compared to intensive irrigated systems [12,51], and yields vary from year to year and from location to location [7].

In Cambodia, rain-fed lowland rice accounts for about 80% of the total rice area [28] and is a major source of local employment and food energy. Nationally the average rice yield for the cropping season 2010–2011 was 2970 kg ha^{-1} [29]. Ly et al. [25] reported striking variation in yield across regions and villages, as well as within villages, ranging from 600 to 5500 kg ha^{-1}. The problem of yield variability in these systems is complex, but several key factors have been identified, including management practices (farming practices and nutrient management) [7,35,25], soil properties [5,7,6,49], environmental factors (e.g. rainfall) [49], pest and disease incidence, and rice varieties. A clearer understanding of the relative importance of individual factors is necessary for any development intervention aiming at helping resource-poor farmers increase the rice productivity. Research to improve rice production in rain-fed lowland systems has largely focused on the development of rice varieties that are resilient to flooding, droughts,

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temporary submergence, pests, and soil stresses (e.g. salinity, acid sulphate, iron toxicity, peat soils) [2,26,27]. Limited success has been achieved, because these varieties still perform poorly compared with traditional varieties in cases of prolonged drought or sudden submergence of the plant due to unpredictable monsoon climate conditions [20]. Zeigler and Puckridge [51] have suggested that adoption of modern varieties in rain-fed lowland ecosystems is primarily limited by their poor performance under variable and challenging growth conditions, rather than by farm size, land tenure, or the impoverished growing environment.

Alternative approaches to increasing rice productivity in these environments have emerged, some involving shifting from conventional methods based on intensive external inputs to those with much lower external inputs. There is a growing interest in the System of Rice Intensification (SRI), a set of methods that originated in Madagascar about 30 years ago and which has shown potential for increasing total rice productivity (land, water, labor and capital). SRI practices differ from conventional rice management on several parameters, including raising seedlings in a carefully managed nursery; early transplanting of 8–15 day old seedlings; careful transplanting just after uprooting in a shallow depth (1–2 cm); a single transplant per hill and wider spacing of transplants; careful water management (avoiding flooding, keeping soil well drained and moist); regular weeding with a rotary hoe to also facilitate soil aeration; and liberal use of organic fertilizers (farmyard manure, plant residues) [39,40]. SRI has been adopted by farmers in 50 countries, and the governments of some major rice producing countries such as Cambodia, China, India, Indonesia, and Vietnam accept and promote SRI as an alternative method for small-scale farmers to raise output and income from rice farming [47,21,45]. Researchers studying SRI claim that the agronomic benefits of the system are scientifically sound [31] and report that large numbers of rice farmers in dozens of countries benefit from it [16]; however, many eminent rice scientists have argued that every component of SRI has been studied before and found to have little effect [41], and that the extraordinary yields reported in SRI have resulted from methodological errors [36]. The merits of SRI have been intensively debated between 2003 and 2008; since then the resistance and skeptics have been silent from the scientific articles but have rather appeared on the blogsphere (e.g. [8,9,13]). Although there is a growing body of literature documenting higher productivity of SRI than conventional practices, few studies have been conducted to explore the factors explaining this higher productivity. A recent extensive review on on-farm impact of SRI by Berkhout et al. [4] with 345 documents including peer reviewed journal articles, draft scientific papers, consultants' reports, working papers, project documents, unpublished memos, and a few official documents, suggested that a considerable part of higher yields under SRI management may be attributed to a preferential allocation of SRI to more fertile plots, and/or to a preferential allocation of fertilizer and labour to SRI plots. Tsujimoto et al. [43] found that higher productivity in the SRI plots in the central highland of Madagascar is attributed to soil fertility (soil organic carbon and high content of mineralizable nitrogen) rather than synergetic effects of the SRI components. An investigation by Ly et al. [25] to document the adopted and adapted practices of SRI by Cambodian farmers reported higher yields in plots with SRI-like practices than in plots under conventional management. However, as information about biophysical properties of the plots under SRI or CMP was not available, it is not clear whether the higher yields achieved under SRI can be attributed solely to SRI per se or are caused by other factors, i.e. plot biophysical properties. The present research addressed these questions by investigating key factors (production systems and soil properties) which determined the yield outcome of rice farming under a rain-fed lowland rice ecosystem in Cambodia. Stepwise multiple regression analysis was performed to identify important factors and the relative power of each key factor to explain rice yield variability. Since SRI practices are only partially implemented by farmers in the study area, the term "farmer's SRI" is used throughout the manuscript, to highlight we investigate farmer's practices, not model SRI systems.

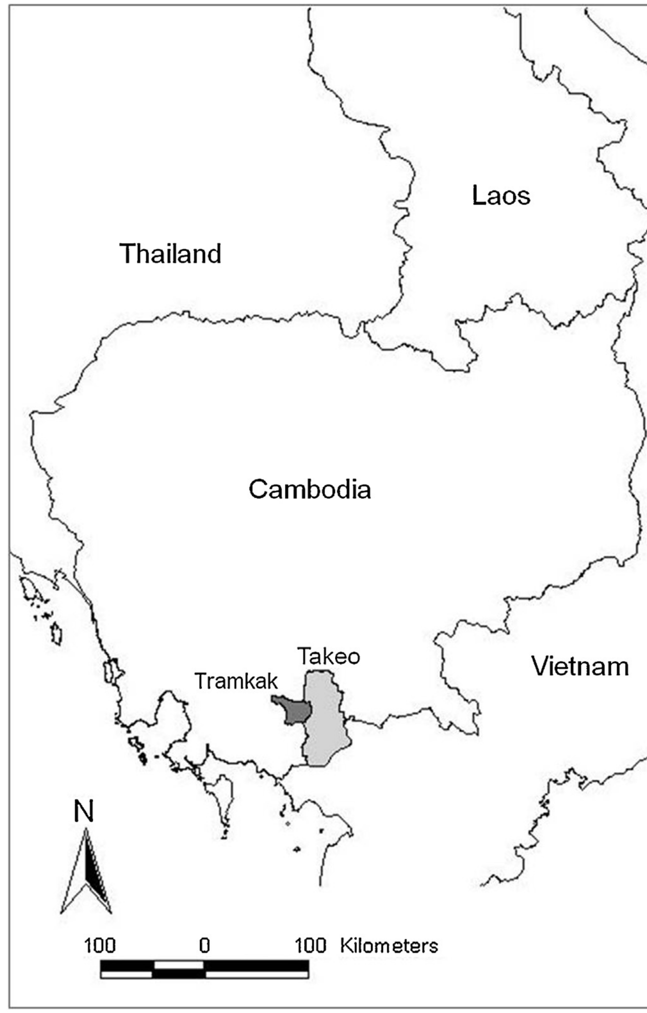

Fig. 1. Map of the study area.

2. Methodology

2.1. Study sites

The study was conducted in three villages—Ta Suon, Prey Taley and Trapaing Srangeir—located in Tramkak district, Takeo province (Fig. 1). A detailed description of the study sites is provided in Ly et al. [25].

2.2. Rice harvest, classification of farming practices and measurement of crop performance

Rice was harvested from 70 plots in the cropping season 2010–2011 (November-December). The 70 plots belonged to 24 households (8 farmers in each village) randomly selected from among 106 households previously surveyed by the same authors Ly et al. [25]. The System of Rice Intensification (SRI) has been widely promoted in the study area since 2001. It is well known by local farmers and has strongly influenced the way rice is grown in the region; however, as it entails a flexible set of practices which may be adopted whole or in part, it is difficult to definitively cat-