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Agro-economic evaluation of fertilizer recommendations for rainfed lowland rice

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ABSTRACT

Soils used for cropping of rainfed lowland rice are frequently rather poor, and nutrient limitation is known to be a major constraint for grain yields. However, actual fertilizer use by most rainfed rice farmers is still very low even if input-responsive rice varieties are widely adopted. To address this contradiction, this study, conducted in central and southern Laos, intended to test existing fertilizer recommendations in farmers' fields and under their crop management, to evaluate the effect of topographic field position on fertilizer response, and to conduct an economic evaluation of fertilizer use based on farmers' input and output prices. Trials were conducted for two seasons in three different agroecological environments (rainfed rice in lower fields and in middle/upper fields, and irrigated rice in lower fields). Tested were five different fertilizer treatments in four farmers' fields per site and season. Commercial organic fertilizer increased yields but resulted in negative economic returns in almost all cases because of its unfavorable nutrient/price ratio. In lower fields, farmyard manure and inorganic fertilizer gave good yield responses and positive economic returns but the average value/cost ratios of 1.3–1.6 were at the lowest level required for widespread adoption of fertilizer use. Water limitation reduced attainable yields in middle/upper fields and in this environment good fertilizer response was observed only for farmyard manure and half the recommended rate of inorganic fertilizer. The actual benefit of fertilizer use depended strongly on the input/output price ratios at each site. Thus, site-specific fertilizer management options, including economic parameters, are required to make fertilizer use in rainfed lowland rice more profitable. The necessary information for such guidelines is available but needs to be prepared in the form of decision tools to help farmers choose the optimal nutrient management option for their agroecological and socioeconomic production environment.

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1. Introduction

Agriculture is the main livelihood of approximately 95% of the rural households in Laos, and rice (*Oryza sativa* L.) is the single most important crop. Rice provides about 64% of the total calorie supply (FAO STAT, 2010a) and constitutes around 52% of the total value of agricultural production (FAO STAT, 2010b). Given this situation, any increase in rice production and productivity contributes to a general improvement in the welfare of rural households (Schiller et al., 2000). Demand for increased production comes also from fast population growth. The population of Laos is growing at 2.5% per annum and is expected to increase from 5.3 million in 2000 to about 8.8 million in 2020. Another factor contributing to growing rice demand is the expected increase in per-capita consumption connected to the fast development process in Laos. The major share of the necessary production increase can come only from rice-based lowland systems, which currently supply 88% of the total rice production. Although varying from year to year, the majority of lowland rice is produced in rainfed systems (about 80%), whereas irrigated lowlands contribute about 20% of lowland rice production (e.g., MAF, 2002).

Modern high-yielding and input-responsive varieties for the lowlands were introduced from 1993 onwards. They spread fast and replaced the mostly traditional varieties grown until then. By 2005, more than 70% of the rainfed and irrigated wet-season rice cultivation was based on improved varieties, and, because traditional germplasm is photosensitive and cannot be used in the dry season, 100% of the dry-season rice came from improved varieties (Inthapanya et al., 2006). Simultaneously, dry-season irrigated area increased from 12,000 ha in 1990 to 102,000 ha in 2001. These developments were complemented by intensive research on improved crop management techniques to accompany the new varieties and irrigated rice cultivation. Although this research covered many aspects of crop management, a major emphasis was on improved nutrient management because of the dominance of poor soils in the region (Linquist and Sengxua, 2001). The same authors

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documented more than 250 individual multi-location trials on various aspects of nutrient management between 1990 and 2000 in rainfed and irrigated lowlands, and the data were used to develop detailed nutrient management recommendations (Linquist et al., 1998; Linquist and Sengxua, 2001, 2003). However, actual fertilizer use by farmers remained low. Fertilizer imports, which are the only inorganic fertilizer source in Laos, did increase continuously from 1990 onwards and reached more than 12,000 tons in 2001 (FAO STAT, 2010c; the most recent data from 2002 indicated a slightly lower value). But, even when assuming that all this fertilizer was used for lowland rice, and based on the mean annual lowland rice area of around 0.5 million ha, the total average fertilizer rate would not have been above 24 kg per ha. This estimate is confirmed by a study of Pandey (2001), whose survey of 700 rainfed lowland farmers in 1996 found that 66% of them used inorganic fertilizer on 48% of their rice-growing area, with an average rate of 18 kg ha^{-1} of inorganic (NPK) fertilizer. A later survey of 240 households in the lowlands by Shrestha (2004) found that 93% of the farmers used inorganic fertilizer but did not report the quantity used. This low fertilizer rate seems surprising, considering the generally low soil fertility in the lowland rice environment of Laos, which is typical for large areas of rainfed lowland rice in southeast Asia (Haefele and Hijmans, 2007). And as mentioned above, responsive improved varieties are widespread, and acceptable fertilizer responses were repeatedly reported (Linquist and Sengxua, 2001, 2003; Linquist et al., 2007). However, such low fertilizer rates are typical for many rainfed lowland systems: data from 2005 to 2007 covering 1215 fields in Cambodia, India, Indonesia, Laos, Nepal, Thailand, and Vietnam, showed an average inorganic fertilizer use of only 47 kg per hectare (unpublished, provided by S. Pandey).

So why do rice farmers in rainfed lowlands not use more inorganic fertilizer? Is it that researchers overestimated the average yield response because they conducted their trials under carefully controlled conditions not achievable by farmers? Did researchers choose sites not representative for the system targeted, or did they disregard the economic conditions farmers were operating in? Or does the dissemination and adoption of adjusted crop and natural resource management technologies just take more time because farmers need to acquire the necessary knowledge and build up the confidence for successful inorganic fertilizer use? Addressing these questions for the specific case of lowland rice in Laos was the objective of this study. In particular, we intended to test the existing fertilizer recommendations for lowland rice in Laos in farmers' fields and under their crop management, to evaluate the effect of topographic field position on fertilizer response, and to conduct a simple economic evaluation of fertilizer use based on farmers' input and output prices. The results were meant to contribute to further improving the understanding of fertilizer use in the target system and to adjust the existing recommendations, if necessary.

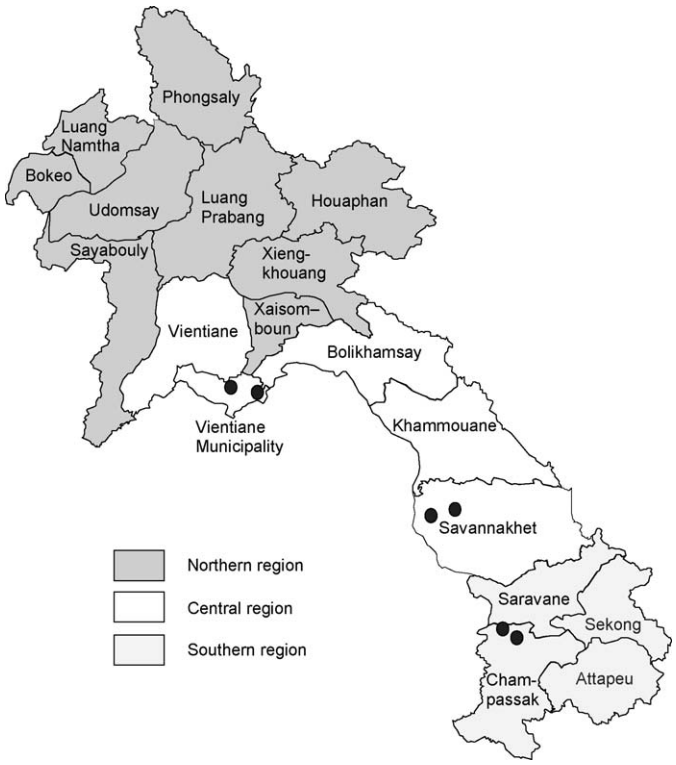

Fig. 1. Map of Laos showing the different regions and provinces and the location of experimental sites.

2. Materials and methods

2.1. Site description

The agro-climatic conditions in the central/southern lowland region are characterized by a mean annual rainfall of 1920 mm $year^{-1}$ (Linquist and Sengxua, 2001), but the long-term average rainfall varies considerably within that region (Linquist and Sengxua, 2001; Basnayake et al., 2006). Mean annual rainfall is high in Vientiane, Xaisomboun, and Bolikhamsay provinces (2000–3000 mm), relatively low in Savannakhet Province (about 1400 mm), and again high in Champassak Province (about 2200 mm) (Fig. 1). No rainfall data were recorded at the experimental sites but annual rainfall data were available from meteorological stations close to the Vientiane airport (2003: 1481 mm; 2004: 1629 mm; 2005: 1668 mm), the rice research station at Savannakhet (2003: 1199 mm; 2004: 1650 mm; 2005: 1768 mm), and the rice research station at Pakse (2003: 2029 mm; 2004: 1977 mm; 2005: 1956 mm). Thus, relatively low annual rainfall occurred only

Table 1
Overview of all environments, sites, and experimental seasons. The number of participating farmers is valid for each individual cropping season.

Year	Season[a]	Province	District	Village	Farmers
Low-lying fields, rainfed, low drought risk					
2003 + 2004	WS	Vientiane	Xaythany	Ban Hai	4
2003 + 2004	WS	Savannakhet	Champhone	Ban Nongkhouvieng	4
2003 + 2004	WS	Champassak	Sanasomboune	Ban Nguadeng	4
Middle/upper fields, rainfed, medium drought risk					
2004 + 2005	WS	Vientiane	Nasaythong	Ban Namkieng Tai	4
2004	WS	Savannakhet	Champhone	Ban Nong Veng	4
2004 + 2005	WS	Champassak	Sanasomboune	Ban Nakhoung	3
Low-lying fields, irrigated					
2003/04 + 2004/05	DS	Vientiane	Xaythany	Ban Hai	4
2003/04 + 2004/05	DS	Savannakhet	Champhone	Ban Nakhou	4
2003/04 + 2004/05	DS	Champasak	Sanasomboune	Ban Nguadeng	4

[a] Cropping seasons were the wet season (WS) and the dry season (DS).

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