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Understanding the adoption of system technologies in smallholder agriculture: The system of rice intensification (SRI) in Timor Leste

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ABSTRACT

Against the background of rising food demand, decreasing productivity growth, and environmental degradation, natural resource management technologies, such as the system of rice intensification (SRI), have been propagated, especially in a smallholder farm context. However, system technologies are often location specific and characterized by partial adoption and disadoption. Previous studies were often not able to fully explain this, because they mostly relied on farm and household level data, neglecting plot level differences that may be important. We address this limitation, using SRI adoption in Timor Leste as an example. Regression models are specified and estimated to explain the farmers' decision-making processes. Participation in training programs and household labor availability increase the probability and intensity of adoption, as SRI is knowledge and labor intensive. However, many other household variables are not significant, while plot level characteristics, such as proximity to the homestead, water control capacity, slope, and soil conditions, have more explanatory power. The results suggest that plot level data are important to understand the adoption of system technologies. Moreover, technology adaptation to different plot conditions seems to be a precondition for widespread diffusion.

1. Introduction

The rise in global food grain prices continues to threaten food security in many low income countries. Besides wheat and maize, rice is the main affected cereal, which has faced an average price increase of 50% between 2007 and 2010 (Food and Agriculture Organization, 2010). In the Green Revolution period, global rice production had increased remarkably, largely due to the widespread adoption of high-yielding varieties and high-input packages in Asia. While rice production is still increasing, more recently farmers have experienced a downturn in productivity growth, which is partly associated with a loss of soil fertility, salinization, and other forms of land degradation (International Food Policy Research Institute, 2009; Foresight, 2011). Moreover, climate change is expected to lead to higher temperatures, greater water demand by crops, more variable rainfall, and extreme weather events, causing negative effects for agriculture in many regions (Intergovernmental Panel on Climate Change, 2007). Sustainable agricultural innovations are needed to meet rising food demand in an environmentally and socially acceptable way.

The system of rice intensification (SRI) could potentially be an approach to increase rice production at affordable costs for small-scale farmers, without harming the environment (Stoop et al., 2002; Mishra et al., 2007). SRI principles focus on neglected potentials to raise yields by changing farmers' agronomic practices towards more efficient use of natural resources (Uphoff and Randriamiharisoa, 2002; Barah, 2009; Zhao et al., 2009). SRI was initially developed in Madagascar, but recently it has been widely promoted also in several Asian countries by governmental and non-governmental organizations (European Technology Assessment Group, 2009). Existing impact studies show mixed results. In some cases, SRI was associated with high rice yields (Anthofer, 2004; Barrett et al., 2004; Senthilkumar et al., 2008), whereas other studies detected no significant yield gains or even negative effects (Dobermann, 2004; McDonald et al., 2006; Tsujimoto et al., 2009). The yield effect seems to depend crucially on the reference system. While SRI may outperform average conventional practices with sub-optimal conditions, McDonald et al. (2006) showed that it is yield reducing compared to conventional best management practices for rice in many regions. Hence, impacts are context specific. Yet, almost all studies on SRI point at positive environmental and resource conserving effects due to reduced use of external inputs. Thus SRI may be suitable for small-scale farmers, who often have limited access to inputs and credit markets.

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In this article, the focus is not on analyzing impacts of SRI, but on better understanding the factors that influence farmers' adoption decisions. Even though SRI has been widely promoted, partial adoption and discontinuance are commonplace (Moser and Barrett, 2006; Senthilkumar et al., 2008). This may be related to the mixed yield experience. Furthermore, Moser and Barrett (2003) showed that the additional labor requirement associated with SRI may represent a constraint for smallholders facing seasonal labor shortages. As the suitability of SRI is context specific, we hypothesize that additional micro level factors may influence adoption, including the characteristics of individual plots. Understanding these micro level factors is important to design appropriate technology delivery strategies. Beyond SRI, our hypothesis may hold more generally for system technologies. We define a system technology as an integrated innovation to improve agricultural productivity and agroecosystem resilience, involving different agronomic and management components with synergistic relationships, as opposed to a single new high-yielding crop variety for instance. System technologies often focus on general principles rather than standardized practices or specific inputs. Prominent system approaches other than SRI are conservation agriculture, agroforestry, or organic farming. Such technologies have received considerable attention, but many of them have not seen widespread adoption (Knowler and Bradshaw, 2007). Often, system technologies are not only labor intensive, but also knowledge intensive, as synergies between different components have to be understood; this may also require experimentation and adaptation by farmers themselves. Suitable adaptations are location-specific, which complicates farmer-to-farmer transfer of concrete practices and experiences (Lee, 2005; Giller et al., 2009). To control for heterogeneity of agroecological conditions, regional proxy variables are commonly used in adoption research (Doss, 2006). This is insufficient, however, as regional proxies cannot properly capture micro level variation across and also within individual farms.

Here, we address this limitation by using detailed household and plot level data to explain the adoption of SRI among smallholders in Timor Leste. The rest of this article is organized as follows. The next section describes SRI and its role in Timor Leste. Section 3 presents the analytical framework and describes the data and descriptive statistics. Section 4 presents and discusses results from the econometric models, while section 5 concludes.

2. SRI in Timor Leste

Agriculture accounts for one-third of gross domestic product in Timor Leste; about 80% of the population are engaged in agricultural activities (Correia et al., 2009). Rice is the main staple food in the country and a widely grown field crop. However, domestic rice production is not sufficient to meet the demand of the fast growing population. The absence of irrigation facilities is one major constraint for increasing productivity beyond the subsistence level (World Food Program, 2005). Timor Leste is a net importer of rice, and these imports are subsidized, entailing a big and rising burden on the government's budget (Ministry of Agriculture and Forestry, 2008). Against this background, the country is emphasizing strategies to increase domestic rice production and to reduce import dependency, including the promotion of new technologies.

In 2007, SRI was jointly introduced in Timor Leste by the Ministry of Agriculture and Fisheries (MAF) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in two major rice producing districts, namely Bobonaro and Covalima. SRI was chosen for promotion by these organizations, because it may increase yields while addressing constraints of limited water availability. The SRI program was introduced by the national extension service through farmer groups; it covered 35 farmers in 2007, 450 in 2008, and 1228 in 2009, which is equivalent to 28% of all rice farmers in the two target districts (Deichert et al., 2009). In 2008, SRI was declared a national extension strategy in Timor Leste.

In general, SRI is understood as a set of agronomic and natural resource management (NRM) principles, without prescribing a standardized toolkit (Stoop et al., 2002). On the one hand, this might seem risky for farmers for whom a fixed technology package may be easier to understand and implement. On the other hand, on-farm participatory experimentation offers opportunities for better adaptation to local conditions, which may reduce adoption risks in the long run. Nonetheless, SRI involves a set of core components, which may be flexibly extended by additional practices. In accordance with the SRI International Network and Resources Center (SRI-Rice, 2011) of the Cornell International Institute for Food, Agriculture and Development, we define the following four components as core SRI components in our context:

- *Intermittent irrigation*: Rice fields should be kept moist but not continuously flooded, in order to minimize anaerobic conditions that hamper the growth of roots and soil organisms.
- *Early transplanting*: Rice seedlings should be transplanted at an age of younger than 15 days, to minimize the transplant shock.
- *Single seedlings*: Rice seedlings should be planted singly to permit better root growth and tillering.
- *Wide spacing*: Rice plants should be planted in square patterns of a minimum distance of 20 × 20 cm, in order to keep all leaves photosynthetically active.

We define farmers as SRI adopters only when they have adopted all four core components. SRI-Rice also defines organic fertilization as an essential SRI component. The use of compost or manure stimulates growth-promoting bacteria in the soil (Mishra et al., 2007). However, this has not yet been an important element in the Timorese program, so that we do not consider organic fertilization as a core component in this analysis. Additional recommended practices include the establishment of carefully managed mat or tray nurseries and regular weeding (McDonald et al., 2006; Glover, 2011). Weeding is more important in SRI than in traditional rice, because weeds spread more rapidly under non-flooded conditions. Hence, weeding is strongly related to intermittent irrigation, but it is not defined as a core component itself by SRI-Rice.

All different components involve synergistic effects, which may vary from one place to another (Glover, 2011). Therefore, it is necessary for farmers to adapt the general principles to local conditions, which requires detailed knowledge not only on 'how to do it' but also on 'why to do so'. Understanding this enables farmers to make important decisions on aspects such as optimal water levels, planting distance, or timing of transplanting. Good extension and training programs are likely to increase farmers' ability to adopt SRI successfully.

3. Materials and methods

3.1. Analytical framework

For our analysis of farmers' adoption behavior we assume that the farm household is maximizing utility. For the decision whether or not to adopt, the expected utility of SRI is compared to the expected utility of conventional practices subject to individual resource endowments and other constraints (Feder et al., 1985). Agricultural technology adoption has been studied extensively in the literature (e.g., Feder et al., 1985; Byerlee and de Polanco, 1986). Often, adoption is not simply a yes/no decision. For instance, farmers may decide to adopt a certain innovation but only apply it on a part of their land, or, when several components are involved, they may decide to use only certain components but not others