Knowledge-Based Agricultural Innovations in Asia: The System of Rice Intensification (SRI) in Timor Leste

Martin Noltze, Stefan Schwarze, Matin Qaim

Abstract: Growing concerns about the downturn of productivity growth and environmental problems associated with intensive paddy systems call for innovative practices in rice cultivation. Improved technologies have to increase productivity by simultaneously addressing land, labour, and capital constraints. The so-called System of Rice Intensification (SRI) may increase productivity in a sustainable way. Nevertheless, SRI adoption is still limited, and there are knowledge gaps as to what determines adoption by smallholder farmers under different conditions. Using survey data from Timorese rice producers collected in late 2009, this study analyzes adoption patterns in the local context. Proper extension training helps to increase adoption, although at this stage partial adoption of the SRI package is commonplace. Moreover, significant differences in farm and household characteristics can be observed between adopters and non-adopters. The findings help to identify opportunities and constraints related to the dissemination of knowledge-intensive innovations in smallholder farming communities.

Key Words: System of Rice Intensification (SRI); Technology Adoption; Rural Development; Timor Leste

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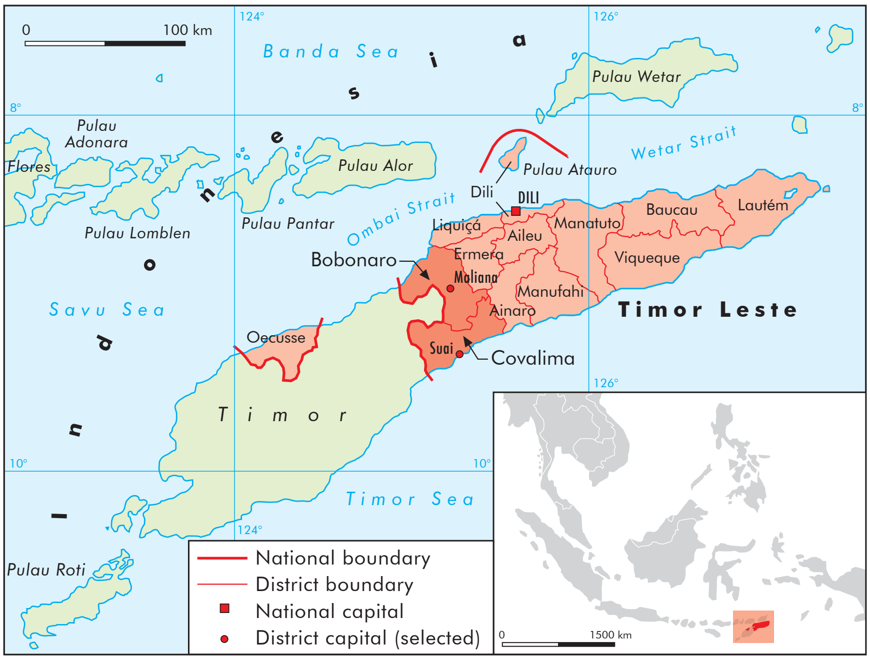
In the aftermath of the recent economic turmoil, the Food and Agriculture Organization (FAO, 2009) estimates that more than one billion people are food insecure and undernourished worldwide. Many of the poor and vulnerable depend largely on the production of rice as the main staple food, but also as an opportunity for employment and an income source. It is estimated that current paddy production needs to be increased by more than 50% to meet the rising food demand over the next few decades (Mishra & Salokhe, 2010). Although rice production has increased substantially since the Green Revolution, annual growth rates are now facing a remarkable downturn (Spielman & Pandya-Lorch, 2009). In some regions, stagnating yields can be observed. High-input rice farming often involves mono-cropping, modern varieties, fertilizer, and pesticide use. There are concerns that the stagnating yields reflect the deterioration of the crop-growing environment as a result of soil degradation in intensive paddy systems. While in some regions overuse of chemical inputs has caused negative externalities, in many low-income countries limited resources still hinder the implementation of high-input systems. Accordingly, post-Green Revolution perspectives call for innovative strategies that are resource conserving and technically feasible, addressing livelihoods in an economically and socially acceptable way. The System of Rice Intensification (SRI), a knowledge-based low-external input technology, promises higher yields with no deleterious impact on natural resources at affordable costs for poor smallholder farmers.

Motivation of the study

SRI is already raising factor productivity and incomes for more than one million smallholders around the world on more than one million hectares (Meyer, 2009). Today it is applied in various agroecosystems in Africa and Asia: from tropical and coastal to semi-arid and mountainous regions. Experiences suggest that crop yields under SRI can be doubled, and even in some cases, quadrupled (Anthofer, 2004; Sato & Uphoff, 2007). Furthermore, several studies found a significant reduction in the total amount of water needed (Ceesay, Reid, Fernandes, & Uphoff, 2006; Uphoff, 2001). Poor water management often leads to land degradation through salinisation or water logging. Additionally, inappropriate use of pesticides causes groundwater pollution and loss of biodiversity. Low external input use (water and fertilizer, etc) marks SRI as an environmentally friendly technology for small-scale farmers in developing countries. However, Alagesan and Budhar (2009) found that farmers faced difficulties in the large-scale adoption of SRI in Tamil Nadul, India, due to knowledge deficits and labour shortages. Non-adoption and dis-adoption was examined by Moser and Barrett (2002) in Madagascar; they also cited problems relating to the higher labour needs of SRI. A study by Barrett et al. (2004) found that half of the gains from SRI adoption are based on farm and farmer characteristics rather than the technology itself.

Obviously, SRI is the subject of considerable controversy in the agricultural development debate. Concrete empirical evidence about the adoption performance of SRI under different agroecological and socioeconomic conditions remains limited. This article aims to contribute to the ongoing discussion by describing SRI adoption patterns among smallholder rice producers in Timor Leste and to explore differences between adopters and non-adopters. The research builds on primary farm survey data. Adequate definitions of knowledge-based land management practices need to consider the complexity of non-fixed technology packages. We do so by specifically accounting for partial adoption, that is, farmers adopting only certain components of the package but not others. The article is structured as follows. Firstly, a general overview of SRI will be provided. Secondly, the introduction of SRI in Timor Leste will be outlined. SRI adoption is defined at the farm household level using a two-group cluster approach, differences between adopters and non-adopters in terms of farm and household characteristics will be presented. In order to assure that key components of the technology are relevant among the derived group of adopters, principal component analysis (PCA) identifies defining factors determining SRI adoption in the given context. Finally, some conclusions will be discussed.



Map of Timor Leste (survey areas of Bobonaro and Covalima districts are highlighted)

SRI in practise

SRI relies mainly on changing farmers' agronomic practices for managing rice plants, soil, water, and nutrients. In the context of sustainable land management practices, SRI can be described as a complex agricultural production system, leading to higher agroecological and biological productivity without necessarily increasing external key inputs such as mineral fertilizer and pesticides, labour or capital (Meyer, 2009). The concept of SRI was developed by a French priest, Fr. Henri de Laulanié, in the mid 1980s in Madagascar, to enable small-scale farmers increase rice yields using less water and seeds.

The main practices in the field include (i) carefully managed nurseries, (ii) application of compost, (iii) transplanting of young seedlings (10-15 days old), (iv) row planting (v) cultivation of single seedlings (vi) using a planting distance of at least 20x20 cm, (vii) intermittent flooding and (viii) regular weeding of plots (Table 1). Early transplanting of single seedlings and modified water management are the most prominent characteristics of SRI (Meyer, 2009). Together with row planting in high distance square patterns these principles support roots growth and tillering. A strong root system has positive impacts on plants' vegetative and reproductive phases via advanced nutrient uptake. The raising and selection of strong seedlings can

Components		Description	Adopted (%)	Factor loadings
i	Nursery	carefully managed mat or tray nurseries	39.8	0,7319
ii	Compost	application of compost in nurseries and on plots	12.3	0,3918
iii	Transplanting	planting young seedlings < 15 days	57.9	0,7400
iv	Row planting	square pattern row planting on plot	65.7	0,9023
v	Single seedlings	only one seedling per hill	54.2	0,8917
vi	Distance	distance of seedlings from 20x20 to 50x50cm	63.5	0,8964
vii	Re-irrigation	alternate flooding and drying on plots	54.2	0,3637
viii	Weeding	multiple weedings preferably with hand weeders	91.9	0,3578

Source: Own survey data

Table 1: Adoption of components per household (N=397)


Extension Training Maliana, Bobonaro

be supported by carefully managed nurseries. Additionally, improved water management supports soil aeration and reduces overall water input. Uphoff and Randriamiharisoa (2002) found that continuously flooded soils constrain root growth and limit anaerobic microbial populations. Advantageously, SRI is able to reduce the total amount of water needed where water shortages occur. The water management practises are not primarily meant to be recommendations for rice cultivation in permanent flooded locations. However, if water levels are reduced to moist soil conditions, weeds are likely to grow. Thus, weeding is seen as another important SRI element to control for pests. Furthermore, organic input is added to enhance soil fertility by simultaneously facilitating soil aeration. Square pattern planting in high distances enables the use of mechanical weeders to reduce labour inputs. And finally, the incorporation of organic manure into the soil supports root activities by stimulating growth-promoting bacteria (Mishra, Whitten, Ketelaar, & Salokhe 2007).

Globally, the introduction of SRI differs slightly according to location-specific, agronomic and socioeconomic characteristics of target groups and program objectives. Accordingly, there is no common definition available capturing the complexity of this novel rice production management system. Finally, SRI was never meant to be a fixed technology package; it can rather be described as an expandable menu which is constantly modified through researchers' and farmers' experimentation. Farmers are encouraged to participate in the adaptation of SRI to specific socioeconomic and agroecological conditions (Meyer, 2009). Therefore the adoption decision is strongly based on knowledge. Firstly, farmers have to collect information about the different components before deciding for each component separately to adopt or not to adopt, and if yes, how to adapt each technique to local conditions: the number of weedings per season, the quantity and quality of compost or the optimum distance between seedlings, and so on. Thus the knowledge character of SRI is simply not defined by 'knowledge on how to use the technology'; rather, it is the incorporation of a comprehensive 'knowledge of the effects of all eight components and the interactions among them'.

SRI in Timor Leste

The young nation-state of Timor Leste, which is located in the Southeast of the Indonesian archipelago, is among the poorest countries in SE Asia. The country's economy depends largely on agricultural production, which sums up to one third of the national GDP, providing income to more than 80% of the population (Correia, Janes, Rola-Rubzen, Freitas, & Gomes, 2009). Rice is one of the main crops grown by Timorese farmers both as a staple food for home-consumption and as a source of cash income. However, average production levels of 2 tons per ha cannot meet local demand, so the country relies on rice imports which costs an estimated average of US$ 58.5 million annually (Ministry of Agriculture and Fisheries, 2008). The domestic production is subsidized as the government is buying rice at a guaranteed price of US$ 0.30 per kg of paddy, which is usually higher than the price of imported rice. This import substitution strategy aims to cover higher production costs of relatively inefficient Timorese rice producers of today. Nevertheless, rising food prices and export limitations of important rice producing countries have intensified the risks of import dependencies. Hence, the government emphasizes strategies to increase levels of domestic rice production.

Since 2007, the Second Rural Development Programme for Timor Leste (RDPII), jointly implemented by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and the Timorese Ministry of Agriculture and Fisheries (MAF), promotes SRI for an increase in domestic rice production so as to meet the rising food demands of the fast growing Timorese population. The agricultural extension component of RDPII works through an advisory service approach with farmer groups. The focus is particularly on knowledge-based technologies, because levels of mechanization are low and farmers' access to external inputs is limited. Especially in the two western boarder districts of Bobonaro and Covalima, SRI has become the main component of extension services.

Empirical Approach

In order to examine adoption patterns of SRI among small-scale rice producers in Timor Leste, a farm survey was carried out between August and December 2009. The survey covered the two districts of Bobonaro and Covalima (see map). Complete household lists had been generated, after which stratified random sampling was used to select 200 households from both participants (N=1,228) and non-participants (N=3,220) of SRI extension trainings. This sampling procedure allows for causal conclusions in an impact analysis but has no such implications in the given investigation. A total of 397 households were finally visited and interviewed, including 199 training participants and 198 non-participants. All six relevant lowland rice producing sub-districts are represented in the sample. For the interviews, a structured questionnaire was used to collect comprehensive information from all household members, including wealth indices, agricultural and non agricultural income generating activities, social capital with respect to exposure to institutions and detailed information concerning rice cultivation practices.

Results & Discussion

It cannot simply be assumed that participants in SRI training would be SRI adopters and non-participants would be non-adopters. The reason is that some participants may not have adopted, or that some non-participants may have adopted due to information and knowledge spill-overs. Moreover, adoption is not a simple 0-1 decision, because SRI involves different components, of which some may be adopted by farmers and others not. Against this background, an SRI component count system, or so-called 'adoption scores', which provide detailed information on the number of SRI components applied by each household was developed. The adoption of each component counts as one adoption score. High adoption rates of more than 50% for individual components suggest that these components are applied also beyond the group of training program participants (Table 1). Adoption rates of more than 60% are observed for weeding, row planting, and distance recommendations. This is not surprising as these components were already part of a former rice extension service known as Integrated Crop Management (ICM) and were seen as a stepping stone towards the introduction of SRI in Timor Leste (Deichert, Barros, & Noltze, 2009). In contrast, newer components such as composting or the use of mat or tray nurseries were only adopted by fewer farmers. The application of carefully managed nurseries is a practice that was particularly unknown to Timorese rice farmers until recently, but adoption rates might potentially increase with more experience becoming available. A lagged uptake can be expected for composting, too, as its controlled production takes months even under subtropical climatic conditions.

Harvest in Covalima

In order to classify farmers into SRI adopters and non-adopters, a two-group clustering approach was applied using Stata's partition-clustering method. This method allows group formation based on statistical principles, reducing the dispersion of data within a selected number of clusters to a minimum. Based on this procedure, adoption scores of <5 and >=5 identify non-adopters and adopters, respectively (Figure 1). As a result, 227 farm households were classified as adopters. 22% of these adopter households apply SRI on only some part of their rice areas next to traditional practices on the remaining parts. Highlighting the influence of SRI training indicates that among the training program participants, only 5% had an adoption score of less than 5, meaning that they were non-adopters (Figure 2). On the other hand, 19% of the non-training participants were classified as adopters. Not surprisingly, 79% of the non-training participants who have an adoption score of >=5 take part in the government-promoted hybrid rice program, which has a number of components that are similar to those in SRI. Based on the utilization of hybrid seeds, differences include later transplanting (>15 days), two seedlings per hill instead of one, flooded water conditions and specific recommendations on fertilizer use. In contrast to other rice intensification technologies, varieties are not part of SRI technology; as such, SRI can be fully applied taking hybrid seeds or other improved varieties.

Even though the introduced adoption scores give insights towards the intensity of the technology package adopted, it remains unclear which components determine SRI adoption in the given study. As each component is assumed to be relevant for SRI in the Timorese context, principal component analysis (factor analysis) allows for the establishment of an index representing the dimensionality of SRI

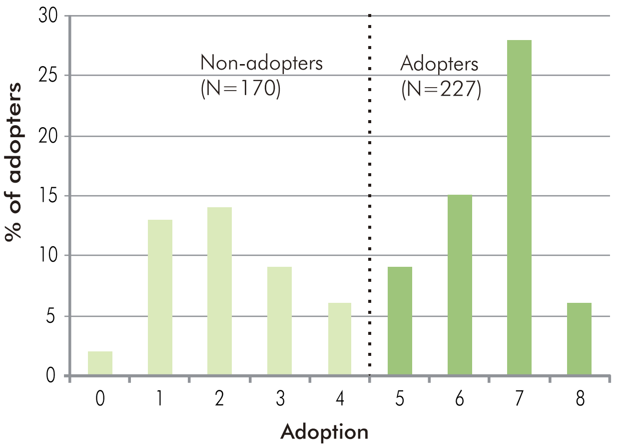


Figure 1: SRI adopters and non-adopters by adoption scores (%)

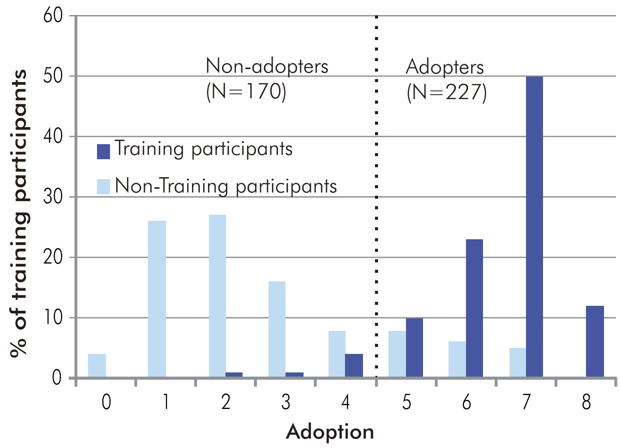


Figure 2: SRI training participants & non-participants by adoption scores (%)

Source all figures: Own survey data

in the Timorese context. Factor loadings are the correlations among the variable and the factor (Table 1). The higher the loading the more powerful is the variable in defining the factor's dimensionality. Results indicate that row planting, distance and single seedlings are the main defining factors for this SRI index, followed by transplanting young seedlings and the use of nurseries. Accordingly, weeding seems to be less specific to SRI as it is applied by most of the households (92%). However, the total number of weedings in one season is significantly different and 1.25 times higher compared to non-SRI plots. Circular re-irrigation and compost application do not have high impacts on defining the index. The components row planting, distance and single seedlings are applied by 100%, 98% and 93% of all adopter households, respectively. 92% of adopter households practise these three components in combination. 81% apply additionally transplanting of young seedlings. 78% of the adopters follow row planting, distance and single seedlings together with weeding and re-irrigation recommendations.

Farm and location characteristics	All		Non-SRI household		SRI household		Sig. diff.
Total land area (hectare)	1,88	(1.78)	1,66	(0.95)	2,05	(1.29)	**
Total rice area (hectare)	1,27	(0.83)	1,13	(0.71)	1,38	(0.89)	**
HH living in Bobonaro (%)	48,86	(50.05)	34,71	(48.74)	59,47	(49.20)	**
Household and contextual characteristics							
HH size (number of HH members)	6,64	(2.27)	6,52	(2.29)	6,73	(2.27)	
HH head years of schooling (years)	4,09	(4.56)	4,05	(4.63)	4,12	(4.52)	
HH having nonfarm income (yes/no)	46,09	(49.91)	40,00	(49.13)	50,66	(50.10)	*
Access to formal credit sources (%)	11,33	(31.74)	7,64	(26.65)	14,09	(34.87)	*
Participation in SRI training (%)	50,12	(50.06)	5,88	(23.59)	83,25	(37.41)	**
Participation in hybrid programme (%)	16,12	(36.81)	4,11	(19.92)	25,11	(43.46)	**
SRI training participants in village (%)	36,55	(29.42)	23,27	(23.31)	46,50	(29.64)	**

Notes: Means (SD), ** and * denote statistical significance at the 1% and 5% level respectively.

Source: Own survey data

Table 2: Summary statistics by household (HH) adoption status

Most farmers in the sample are primarily rice farmers who cultivate additional crops for home-consumption such as cassava, sweet potatoes, and vegetables. Maize is the main secondary cash crop cultivated on the harvested paddy fields which is done by 51% of all interviewed households. Few households cultivate also cash crops like mung beans, soy beans or peanuts. Additionally, nearly all households keep livestock, mainly pigs (89%) and chicken (81%), but also buffaloes and cows (67%) or goats (38%). Except for chicken, livestock is seldom sold but it rather represents an asset which is used for festivities, ceremonies and dowry. Moreover, 46% of the households are at least seasonally involved in non-farm income activities such as construction work, home production, small-scale trading or work as off-farm hired labourers.

Adopting and non-adopting households differ by farm, household, and contextual characteristics (Table 2). On average, households own 1.88 hectares of land, of which 1.27 hectares are cultivated with rice. SRI adopters own significantly more land and cultivate significantly more rice. It can be assumed that larger farms tend to concentrate more than small farms on lucrative wet rice production, so that they are more eager to adopt innovative intensification strategies. SRI farmers are likely to be located in the district of Bobonaro (59%) as SRI was first introduced in the Maliana valley before extension recently spilled over to the southern district of Covalima. However, besides the starting time of large-scale promotion of SRI and the fact that SRI farms in Bobonaro tend to be slightly larger compared to Covalima, no fundamental differences can be detected among the two target districts with regard to adoption. Even though no significant differences can be found between the groups, overall, low levels of schooling can be considered as a challenge for the diffusion of knowledge-based technologies. On average, the household heads went to school for just about four years, only 36% completed primary school.

The share of SRI adopters, who have nonfarm income and access to formal credit sources such as banks, government programs or credit groups, is also significantly larger than the share of non-adopters. SRI as a low-input system promises to reduce input costs compared to conventional practices. However, SRI components are labour intensive and the costs of hired labour needed on top of the family labour could be an obstacle for adoption. Furthermore, adopters have significantly higher rates of participation in extension programs such as SRI or the hybrid rice training program. The percentage of adopters is also higher in villages with a larger share of SRI training participants, suggesting that there are spill-over effects, for instance through indirect farmer-to-farmer extension.

Analyzing plot level data, 2009 average yield levels in both districts were 3.6 and 3.5 tons per hectare on SRI and non-SRI plots, respectively. It can be assumed that the uptake of knowledge intensive and laborious technologies can take several years until full effects occur. A comparative view indicates that SRI produces equal yields using less water and seeds. However, the extent of input reduction requires further analysis, which is beyond the scope of this article

Conclusion

SRI is a knowledge-based technology, which consists of different components. In the case considered here it consists of eight components, not all of which are widely adopted yet. Whereas well-known techniques such as row planting and weeding are widely applied in the research area, components that have previously been unknown to farmers, like the use of compost and nurseries, lack widespread implementation. However, compost enriched soils combined with carefully managed seedlings are two key elements for the success of SRI as an integrated sustainable agricultural system. Accordingly, extension training should concentrate especially on these newer components.

Taking empirical data from two districts of Timor Leste the study found high adoption rates among SRI training participants in the selected sample. This supports the assumption that – with proper extension – knowledge-intensive agricultural production systems can be implemented in the Timorese context, which is characterized by low productivity levels and limited availability of high-input technologies. However, land and household characteristics seem to play a role in the adoption decision and thus can be assumed as important influencing factors for large-scale promotion. Owners of larger farms, located in villages where training participation is high, are more likely to adopt the new system. Accordingly, extension services have to find mechanisms on how to encourage small farmers in remote areas to adopt the innovative technology. It can be expected that a successful introduction of knowledge-intensive technologies needs several years until its full implementation.

Further research should focus on the influence of farm and farmer characteristics on the adoption of SRI components. The analysis presented here will be extended by multivariate regression analysis. Furthermore, yield differences and other outcomes may potentially be due to systematic differences among groups and should not be hastily attributed to SRI technology. Based on the data collected, proper assessment will be carried out in order to estimate the impact of adoption.

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