Agricultural Systems 132 (2015) 157–166

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Review

On-farm impact of the System of Rice Intensification (SRI): Evidence and knowledge gaps

Ezra Berkhout [a,b,*,1], Dominic Glover [c,2], Arie Kuyvenhoven [a]

[a] *Development Economics Group, Department of Social Sciences, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands*
[b] *Centre for World Food Studies (SOW-VU), VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands*
[c] *Knowledge, Technology and Innovation Group, Department of Social Sciences, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands*

ARTICLE INFO

Article history:
Received 4 April 2013
Received in revised form 19 September 2014
Accepted 2 October 2014
Available online 31 October 2014

Keywords::
System of Rice Intensification (SRI)
Smallholder rice farming
Enhanced yields
Technology effect
Input productivity
Labour demand

ABSTRACT

The System of Rice Intensification (SRI) is being promoted worldwide, but relatively little is yet known about its impacts at farm level. This article reviews available evidence on the impact of SRI practices in terms of yield and productivity. Adoption of SRI practices necessarily changes the mix and allocation of inputs, in particular of water, seeds, fertiliser and labour. However, SRI impact studies have generally failed to distinguish between technological change – a more productive use of inputs, evidenced by a change in total factor productivity – increases in input use, or selection effects and their respective effects on yields. The studies reviewed point not only to modest increases in rice yields associated with SRI adoption, but also to concurrent increases in labour and fertiliser use. Often SRI is selectively practised on more fertile plots. As a result, no firm evidence on changes in total factor productivity can be discerned, while partial productivities of land and labour show mixed results. Though yields tend to be higher under SRI management, risk also seems to increase, which initially favours adoption by better-endowed farmers and on better soils. Evidence on SRI impact is further complicated by the large diversity of SRI practices associated with different biophysical, socio-economic and institutional circumstances. We conclude by identifying knowledge gaps surrounding the SRI phenomenon, encompassing agro-technical aspects, socio-economic issues and (dis)adoption behaviour.

Contents

* Corresponding author. Tel.: +31 6 55220189; fax: +31 30 2744479.
E-mail address: ezra.berkhout@pbl.nl (E. Berkhout).
[1] Present address: Netherlands Environmental Assessment Agency (PBL), Antonie van Leeuwenhoeklaan 9, 3721 MA, Bilthoven, The Netherlands.
[2] Present address: Institute of Development Studies at the University of Sussex, Library Road, Falmer, Brighton BN1 9RE, UK.

http://dx.doi.org/10.1016/j.agsy.2014.10.001

1. Introduction

The System of Rice Intensification (SRI) is a method of rice cultivation which, according to a diverse community of its supporters, promises to increase smallholder rice yields while using substantially less water and seed. SRI comprises a suite of recommendations for crop establishment, irrigation management, weed control and fertilisation, which diverge from conventional methods. SRI techniques are said to be based on close observation of the physiological characteristics of rice plants, thus exploiting the plants' innate genetic potential without depending heavily on costly external inputs. Promoters of SRI argue that the system is particularly appropriate, accessible and beneficial to poor and marginal farmers because it can produce higher grain yields without the need for costly improved seeds or expensive chemical fertilisers (Stoop et al., 2002; Uphoff, 2007).

These claims have provoked controversy among agronomists and rice scientists, particularly the assertion that SRI methods can produce dramatically higher and even record-breaking grain yields (see Surridge, 2004). In spite of those misgivings and the hostility of some rice scientists, smallholders in dozens of countries are reported to have adopted SRI methods (Kassam et al., 2011). In this article we address two major topics. First, we consider and evaluate the available evidence on the impact of SRI worldwide: what has been reported and what is the evidence base? Second, we identify remaining gaps in knowledge about the SRI phenomenon, encompassing agro-technical aspects, socio-economic issues and (dis)adoption dynamics.

1.1. History and background

SRI was first described in a technical journal in 1993 (de Laulanié, 1993). SRI is now typically understood to comprise five or six key cultivation practices: (1) raising seedlings in a carefully managed, garden-like nursery; (2) transplanting of very young seedlings (ideally 8–15 days old); (3) widely spaced, single seedlings, often planted in grid patterns (typically 25×25 cm and possibly wider); (4) water management to promote moist, aerated soil conditions, sometimes including dry periods of 3–6 days; (5) early and regular weeding, typically four times at regular intervals, ideally using a mechanical rotary weeder which churns and aerates the soil, or by hand; (6) fertilisation, preferably using organic sources (compost, farmyard manure and green manure) (Stoop et al., 2002, 252; Uphoff, 1999). These practices differ considerably from conventional methods, whereby seedlings are typically transplanted in closely spaced clumps of two to four or even more plants at a time, randomly distributed or in narrowly spaced rows, 20 to 60 days after sowing. Also, rice fields are often kept flooded continuously from transplanting to maturity, which suppresses weeds and curbs the need for regular weeding.

The compilation of the portfolio of SRI practices is attributed to a French agronomist and Jesuit missionary, Fr. Henri de Laulanié, who worked with rice farmers in the highlands of Madagascar from 1961 until his death in 1995. De Laulanié portrayed his methods as 'a system based on the physiology of rice' (de Laulanié, 2003, 59), and this notion is widely accepted by contemporary promoters of SRI. The idea is that SRI methods create conditions in which rice plants can achieve their full, innate potential to grow and flourish. The suite of SRI practices enumerated above is said to express three underlying principles, as summarised by Uphoff (2003, 39): the use of *healthy seedlings*, which accounts for the nursery management component as well as early, quick and gentle transplanting; *optimal plant density*, which explains the wide spacing of seedlings planted singly; and the promotion of *aerobic soil conditions*, which underpins the irrigation practices and soil disturbance.

SRI came to the attention of development workers and academics working in Madagascar during the second half of the 1990s (e.g. Association Tefy Saina and Uphoff, 2001; Stoop et al., 2002; Uphoff, 1999; Uphoff, 2002; Uphoff and Randriamiharisoa, 2002). An international conference in 2002 generated further attention (Uphoff and Randriamiharisoa, 2002; Uphoff et al., 2002) and SRI is now reported to have spread from Madagascar to nearly 50 countries across Asia, Africa and South America (CIIFAD, 2013).

1.2. Benefits and impact claimed for SRI

Many of the early reports about SRI were informal, anecdotal or derived from grey literature. The first systematic effort to document experiences with SRI agronomy was an international conference held in Sanya, China in 2002, which generated a body of papers from 14 different countries (Uphoff and Randriamiharisoa, 2002; Uphoff et al., 2002). Only in recent years has a larger volume of peer-reviewed literature become available.

Scientific support for the agronomic principles underlying SRI – namely, that substantial improvements in yield and productivity can be achieved through changes to crop management practices rather than improved rice varieties – has come from an analysis published by Horie et al. (2005). It is quite widely accepted that SRI techniques promote visible changes in the growth patterns and morphology of individual rice plants, specifically a vigorous production of numerous tillers (shoots with the potential to produce grain-bearing panicles). Some Chinese and Indian studies have confirmed that SRI methods produce physiological and morphological changes in rice plants that can lead to improved yields and higher factor productivity (e.g. Chen et al., 2006; Lu et al., 2005; Thakur et al., 2010; Vijayakumar et al., 2006). However, the relationship between tillering and grain production is not linear and vigorous tillering may not necessarily lead to high yields (Latif et al., 2005, 2009). It is also well established that rice yields can be sustained at existing levels while using significantly less water than in many conventionally managed, irrigated production systems (Bouman et al., 2002).

SRI techniques are reported to give rise to three key benefits. First, grain yields are reported to increase, delivering a direct benefit to both subsistence and (semi-) commercial farming households. Second, SRI methods are widely believed to increase the productivity of two key inputs, namely water and seed. Consequently the system is thought to be more accessible and affordable to poor and marginal communities and farmers facing water scarcity. A more controversial claim holds that the productivity of the system as a whole increases through positive synergetic interactions among the SRI practices; in other words the positive impacts of individual components of the system are multiplied when they are applied in concert (Stoop et al., 2002; Uphoff, 1999). Third, SRI is said to represent a more ecologically sustainable method of rice cultivation, primarily through water conservation but also (organic) soil husbandry and lower methane emissions (Uphoff, 2007).

According to some scholars (e.g., Kassam et al., 2011) these beneficial effects are encouraging many rice farmers to adopt SRI methods but rigorous studies assessing diffusion and adoption are scarce. A handful of published studies provide only localised snapshots (Anthofer, 2004; Moser and Barrett, 2003, 2006; Namara et al., 2008; Noltze et al., 2012; Palanisami, 2010; Palanisami et al., 2013; Sita Devi and Ponnarasi, 2009; Takahashi, 2013). Consequently it is impossible to answer the question exactly how widely SRI or its components have been adopted worldwide, nor to provide a consistent picture of the factors shaping adoption patterns across time and space. These studies do, however, reveal that patterns of adoption of SRI components differ substantially between sites, which suggests that some components fit better with particular types of farmers, households, rice plots or other specific characteristics, and that productivity changes associated with SRI are heterogeneous.

1.3. Research issues and method

In the light of the lack of robust information there is a clear need to assess the current state of adoption and impact of SRI techniques. In an effort to compile and synthesise the current state of evidence, we undertook an extensive literature review, paying specific attention to the most recent insights. The main aim of this review is to build an understanding of which production factors become more productive after (partial) SRI adoption and to identify the gaps in knowledge surrounding SRI impact.

Since much of the available literature and documentation on SRI was to be found in informal and grey sources, our search strategy was open-ended and included searches in academic databases including Scopus, Web of Knowledge and Google Scholar, as well as searches of the world-wide web through Google. In addition, we reviewed and downloaded materials from *SRI-Rice*, the web-portal on SRI maintained by staff linked to the Cornell International Institute for Food, Agriculture and Development (CIIFAD, 2013).

In view of their size and importance as rice producers and consumers, and as countries where SRI activities had been reported on a significant scale, we made a special effort to collect evidence from India and China. In India, we commissioned research assistants from Tamil Nadu Agricultural University to carry out a specific search of the Indian scientific literature for papers on SRI and/or its component practices. This search yielded a total of 28 additional papers. An assistant at the China National Rice Research Institute carried out a similar search of the Chinese scientific literature on SRI and, where necessary, translated the abstracts from Chinese into English. This search yielded a total of 60 documents published in 28 Chinese journals between 2001 and 2010. In total, we collected 345 documents including peer reviewed journal articles, draft scientific papers, consultants' reports, working papers, project documents, unpublished memos, and a few official documents. The full list of documents collected is provided in an online annex.

The resulting database was used to record, where applicable, (1) the definition or specification of SRI that was used in documents; (2) the control treatment or reference practice to which SRI was being compared, if any; (3) whether statistical methods were applied and if so, how this had been done; and (4) whether the statistical methods had been corrected for possible differences in inputs between SRI and non-SRI treatments (e.g. labour use, nutrient application or soil quality), and/or potential selection effects. Through these steps we identified the subset of papers which we used in our review in Section 3.

Our selection criteria placed strong emphasis on the sound use of statistical methods. As we explain later on, deriving firm conclusions from the studies reviewed is seriously hampered by methodological limitations, great diversity in SRI practices and extension and incompletely documented changes in relevant inputs. These limitations made it impossible to carry out a more extensive statistical analysis, such as a meta-analysis.

Given the importance of these methodological issues and the many potential pitfalls, we first discuss some methodological considerations in Section 2. Section 3, reviewing the on-farm impact of SRI, forms the core of this paper and we focus particularly on the productivities of seed, land, labour and water. Section 4 brings the empirical evidence on SRI practices together and identifies knowledge gaps.

2. Measuring impact: methodological considerations

If SRI methods have a positive impact on households adopting them, this should be evidenced by an increase in the partial productivity of one or more key inputs, i.e., land, labour, water, seeds, or fertilisers. However, positive impacts can only be truly understood when considering total factor productivity, i.e. an overall decrease in the net cost or use of inputs for a given level of output, rather than partial factor productivity. For example, farmers who adopt SRI components might increase or decrease the use of various inputs, directly or indirectly. This means that the change in technical practice and the change in inputs are connected, and this complicates comparisons with non-adopters.

Next to endogenous input changes, various other sources of both endogenous and exogenous variation need to be considered, including diversity in biophysical conditions and agro-ecological settings, macro- and micro-economic factors, and institutional contexts. Some relevant variables, such as farmer skills or motivation, are intrinsically unobservable. Such complexities make it difficult enough to assess the impact of simple changes in technology, for instance, a new seed variety. They greatly complicate matters when assessing a composite innovation like SRI, which involves a set of simultaneous adjustments in crop, soil, water and weed management methods, which are associated with changes in the allocation of inputs and the organisation of labour.

One particularly tricky analytical challenge arises from the way SRI has been conceptualised by many of its promoters as an intrinsically flexible and adaptable 'suite of principles' rather than a fixed blueprint for rice cultivation (Stoop et al., 2002; Uphoff et al., 2011). Analytical difficulty arises from the proposition that SRI is simultaneously an integrated system involving synergetic interactions, which must be understood and evaluated holistically, and a decomposable system whose individual elements may be adopted independently, producing substantial effects which, according to some advocates, should still be recognised as systemic effects of SRI (Uphoff, 1999; Uphoff et al., 2011). As other researchers have found (Noltze et al., 2012), even if SRI is considered a 'system innovation', for analytical purposes the only plausible approach is to disaggregate SRI into its component parts, which makes it possible to evaluate both the effects of individual SRI components as well as any possible synergetic effects.

Thus, in order to assess the impact of a new technology, all observable and unobservable characteristics that may influence production levels and the likelihood of adoption need to be included and corrected for. One of the best approaches to achieve this is to use randomised impact assessments (Gertler et al., 2011), but these have not yet been used in assessing impact of SRI. Another relatively straightforward methodology is to compare SRI management and a reference treatment managed by farm households that practised both methods at the same time on plots that are as similar as possible. In such a controlled evaluation, all the potentially confounding variables that help determine yield cancel one another out, and the outcome can be considered a robust measure of impact within the adopting household. Nevertheless, adoption patterns are usually not random, reflecting the fact that changes in input productivities do not materialise uniformly across farm households, and the observed impact can therefore not be generalised to non-adopters.

Taking all these considerations into account, we propose that the processes that shape SRI adoption and impact can only be fully appreciated if the various components that constitute the system are investigated separately yet jointly. They need to be investigated separately because the factors driving adoption of individual system components, as well as their impact, are distinct and context-dependent. They need to be investigated jointly because total factor productivity is the best test of whether the overall impact of a complex set of technical changes is positive or negative. Finally, a careful comparison of changes in total factor productivity for a diverse range of combinations of SRI components adopted serves to identify the potential existence of synergetic effects among them.

3. On-farm impact of SRI

To establish whether, and how, SRI impacts farm households, 26 studies were selected from our database. The following selection criteria were used: (1) studies should present primary empirical evidence and analysis; (2) the authors explicitly aim to compare changes in productivity between SRI and a reference treatment, in most cases 'conventional practice'; (3) studies provide a sufficient level of detail in the description of SRI and the reference treatment, allowing for analysis by third parties; and (4) studies were carried out in on-farm settings, providing insights based on actual farmer behaviour. The studies selected are shown in Table 1, which lists details on the methods used as well as the advantages and limitations of each study.

3.1. Changes in partial input productivity

Very few of the studies we reviewed provide a detailed and complete overview of changes in all relevant inputs while simultaneously controlling for various unobserved farmer and farm characteristics or differences in plot-level soil fertility. Only two very recent studies provided relatively more detail on changes in input costs while attempting to control for selection biases (Noltze et al., 2013; Takahashi and Barrett, 2013). Most of the studies were unable to identify a change in total factor productivity, uncover potential synergies between SRI components, or both. Nevertheless, as discussed below, some provided useful insights into changes in partial factor productivities.

Anthofer (2004) used pairwise observations of on-farm rice yields under SRI and non-SRI management in the same households spanning several seasons. In this way he was able to control for unobserved farmer characteristics such as skills and access to inputs. He found that SRI yields were around 30% higher than yields under conventional management. However, he also observed that SRI was generally applied on fertile plots which were also closer to the homestead. As a result it is not clear how much of the yield increase should be attributed to differences in inputs or soil fertility levels, changes in crop management practices, lower net labour costs due to reduced travel requirements, or a combination of these. In addition, Anthofer's study included only SRI adopters. This is an important qualification because Resurreccion and Sajor (2008) and Ly et al. (2012) observed that farmers practising SRI in Cambodia are typically better endowed than farmers using only conventional practice, as reflected by farm size and production level.

Barrett et al. (2004) carried out one of the most detailed analyses, which corrects for observed and unobserved farmer differences. They found a yield increase for SRI management of almost 2500 kg/ha. According to their estimations, about half of this increase could be attributed to SRI practices, and the remainder reflected pre-existing differences in farm characteristics and soil fertility. However, Chen and Yen (2006) showed that Barrett et al. (2004) incorrectly derived the equations they estimated, making it likely these findings are biased and inconsistent. Other studies only partially controlled for plot, farmer and household differences. While some studies carefully accounted for farmer- and plot-level differences, few reported or took account of changes in labour use, or in some cases detailed information about differences in fertiliser use. In Styger et al.'s (2011) study, all SRI adopting households increased the use of manure, making it impossible to separate the effects caused by increasing inputs from those caused by a change in management practice, such as transplanting.

In the following sections we look more closely at the productivities of seed, soil fertility, land and labour.

3.1.1. Seed and soil fertility

One of the attractive selling points of SRI is the potential saving in seed because of the significant decrease in planting density. Single-seedling transplanting at a spacing distance of 25 × 25 cm requires just 16 plants per square metre, as compared with 200 seedlings per square metre when planting two seedlings at a distance of 10 × 10 cm. If the yield per unit of area does not decrease, the implication is a dramatic increase in seed productivity, which could be particularly attractive in the case of expensive improved varieties and hybrids. Most of the studies reviewed report increases in seed productivity, which are sometimes substantial. For example, seed costs reported under SRI cultivation are about 10% to 33% of those in available alternatives (Adusumilli and Bhagya Laxmi, 2011; Anthofer, 2004; Latif et al., 2005; Noltze et al., 2013).

Various authors have observed a relationship between soil fertility differences and reported SRI yields. For example, Tsujimoto et al. (2009) found that high SRI yields of plots they studied in Madagascar were primarily related to soil fertility effects, in particular a greater nutrient-supplying ability. Also in Madagascar, Serpantié and Rakotondramanana (2013) found that SRI fields were typically more fertile and found closer to homesteads, probably due to the need for more frequent monitoring. They also found that use of manure is significantly higher on SRI plots, particularly on plots close to market areas.

Similarly, Schiller (2004) stated that in Laos SRI is only suitable under very fertile conditions, or when large quantities of nutrients were applied. Findings reported by Turmel et al. (2011) suggest that the marginal productivity of the stock of soil nutrients changes when switching the production method to SRI, implying a change in total and partial productivities in highly fertile plots only. When comparing SRI and non-SRI plots pairwise across different fertility strata, Serpantié and Rakotondramanana (2013) reached a similar conclusion. In summary, SRI methods appear slightly more productive on fertile and less drought-prone plots with higher organic and inorganic inputs. Under less favourable conditions alternative methods outperformed SRI.

3.1.2. Land

All but two of the studies reviewed showed higher land productivity for SRI than the corresponding reference practice (see Table 2). The magnitude of the differences varies from substantial, around twenty per cent, to huge, such as the range of very high SRI yields presented by Andrianaivo (2002). However, as noted above, direct comparisons between SRI and non-SRI yields may not highlight a causal effect of SRI, unless the effects of observed or unobserved farmer and plot characteristics are properly suppressed. When interpreting these results, it should be kept in mind that some of these land productivity studies involved very small sample sizes. Nine studies had sample sizes smaller than 100 observations, five even below 50, and sampling error could have had relatively large distorting effects in these studies. In sixteen studies detailed information on the sampling framework was lacking or samples were not constructed randomly.

3.1.3. Labour

Changes in labour productivity play an important role in shaping the dynamics and patterns of SRI adoption. Transplanting and weeding are two labour-intensive operations in rice farming that have attracted special attention in debates about the benefits and disadvantages of SRI (e.g., Latif et al., 2005; Senthilkumar et al., 2008). Two other SRI practices may lead to a higher demand for labour: (1) the increased collection, processing and application of organic manure or compost; and, somewhat trivially, (2) the time spent on crop harvest and post-harvest processes if yields increase.

Moser and Barrett (2003) published the first study that looked in detail at labour use in SRI, finding that labour use increased with SRI methods, mostly as a result of increased weeding requirements. The authors hypothesised that for many of the poorest farmers the opportunity cost of labour was higher than the

Table 1
Studies reviewed on input productivities and technology effects.

Study and location	Reference treatment	Sampling framework and size	Controlled for:	Not-controlled for:
Andrianaivo (2002), Madagascar	Traditional practice	- 50 farmers selected by agricultural development organisation in one province in Madagascar.	- The cost–benefit analysis compares inputs of conventional practice and SRI practice.	- Data on both systems are collected in different years, locations and circumstances for different farmers.
Yamah (2002), Sierra Leone	Farmers' techniques	- 8 farmer groups established for on-farm trials in Sierra Leone, each having 20 members.	- Unobserved farmer characteristics by comparing yield differences for farmers contemporaneously following SRI and conventional practice.	- Changes in labour use not reported; - Yields not corrected for plot level characteristics.
Ceesay (2002), The Gambia	Farmers' practice	- 10 participating farmers; - No information on sampling framework.	- Unobserved farmer characteristics by comparing yield differences for farmers contemporaneously following SRI and conventional practice.	- Changes in inputs (fertiliser, manure, labour) not reported; - Yields not corrected for plot level characteristics.
Anthofer (2004), Cambodia	Conventional practice	- Sample from five purposively selected provinces, from which four villages were selected randomly. In each village 20 SRI-farmers were selected and 10 non-SRI farmers were randomly selected; - This gives the overall sample of 400 SRI farmers and 100 non-SRI farmers.	- Unobserved farmer characteristics by comparing yield differences for farmers contemporaneously following SRI and conventional practice.	- Changes in labour use and some inputs such as green manure not reported. - It is reported that SRI is often cultivated on more fertile plots, no attempt is made to link this to yield differences.
Barrett et al. (2004), Madagascar	Conventional practice	- A random selection of 111 farmers from four sites in Madagascar, whereby the farmers contemporaneously practise SRI and traditional rice cultivation.	- Unobserved farmer characteristics by comparing yield differences for farmers contemporaneously following SRI and conventional practice; - Differences in plot level characteristics.	
Namara et al. (2008), Sri Lanka	Conventional practice	- Sampling from two districts with high SRI prevalence, yielding 60 SRI farmers and 60 non-SRI farmers; - Stratification methods differed between districts and adoption status, including factors (a.o.) as geographical location, membership of farmer organisation.	- Unobserved farmer characteristics may explain large difference in yield between adopters and non-adopters.	- Yields are not corrected for plot level characteristics; - Labour use is reported to increase substantially, but no attempt to link this to yield differences.
Schiller (2004), Laos	No clear comparison provided	- Not specified.		- Study does not present details on comparison.
Latif et al. (2005), Bangladesh	BMP and farmers' practice	- On-farm trials at 20 households; - No information on sampling framework.	- Unobserved farmer characteristics by comparing yield and input differences for farmers contemporaneously following SRI and conventional practice; - Cost–benefit analysis accounts for differences in all used inputs.	- Yields are not corrected for plot level characteristics.
Dhakal (2005), Nepal	Traditional methods	- Sampling framework and sample size not specified.		- Not clear how SRI and traditional methods are compared.
Kabir and Uphoff (2007), Myanmar	Practices before and after SRI extension	- A random selection of 612 farmers participating in 30 farmer field schools; - Selection of farmer field schools motivated by accessibility of researchers.	- Unobserved farmer characteristics by comparing yield and input differences for farmers contemporaneously following SRI and conventional practice.	- Yields are not corrected for plot level characteristics; - Changes in labour use.
Sato and Uphoff (2007), Indonesia	Conventional practice	- 12,133 farmers familiarised with SRI methods; - No clear description of sampling framework.		- SRI-yields compared with non-SRI yields for potentially different farmers, with different input and soil fertility levels; - SRI is reportedly more often cultivated with certified seeds, but no attempt to link this to yield differences.
Sinha and Talati (2007), West Bengal, India	Conventional practice	- Two districts (blocks) were selected in West Bengal based on the prevalence of SRI practice. In these blocks 110 farmers were selected from a list of SRI farmers provided by an NGO.	- Unobserved farmer characteristics by comparing yield and labour use for farmers contemporaneously following SRI and conventional practice, although in a non-random sample.	- No control for soil fertility or other inputs used.
Feuer (2008), Cambodia	Rice yield is explained in regression from various exogenous variables	- 70 randomly sampled SRI-adopters, of which 22 had disadopted; - No clear description of sampling framework.	- Yields are related to cultivation practices and adoption of SRI technology in regression analysis.	- Regression analysis does not include many variables describing input use.

(*continued on next page*)

Table 1 (*continued*)

Study and location	Reference treatment	Sampling framework and size	Controlled for:	Not-controlled for:
Sita Devi and Ponnarasi (2009), Tamil Nadu, India	Conventional practice	- Purposive selection of district and sub-districts, from which 50 SRI farmers and 50 conventional rice cultivators were randomly selected.	- Cost-benefit analysis shows differences in use of seeds, labour, machines and irrigation water.	- SRI-yields compared with non-SRI yields at different farmers, with different soil fertility levels.
Barah (2009), Tamil Nadu, India	SRI compared to non-SRI farmers	- A sample of 58 SRI farmers and 60 Non-SRI farmers taken in four districts in Tamil Nadu; - No details on sampling framework presented.	- Differences in input levels are reportedly included in statistical analysis, but not described in detail.	- No control for unobserved farmer and plot characteristics.
Thomas and Ramzi (2011), Afghanistan	Conventional practice	- Assessment based on 24 SRI plots and 42 conventional plots; - No specific information on sampling or selection framework provided.	- Unobserved farmer characteristics by comparing yield differences between farmers at the same time cultivating SRI and conventional practice.	- No control for soil fertility or input use.
Styger et al. (2011), Mali	Control and farmers practice	- Assessment in 12 villages in which NGO is active. In each village 5 farmers were selected by community members, giving a sample of 60 farmers implementing both SRI and a control.	- Unobserved farmer characteristics by comparing yield differences between farmers at the same time cultivating SRI and conventional practice.	- (Opportunity) costs of manure collection and application not included; - Use of labour and nutrients double under SRI as reported but no attempt to link this yield differences.
Turmel et al. (2011), Panama	Farmers' practice	- 10 collective farms, with a total of 46 farmers involved; - No information on sampling framework.	- Unobserved farmer characteristics by comparing yield differences between farmers at the same time cultivating SRI and conventional practice.	- No control for changes in labour use.
Adusumilli and Bhagya Laxmi (2011), Andhra Pradesh, India	Conventional practice	- An NGO provided a list of SRI-farmers within two subdistricts (mandals) in Andhra Pradesh. From the list, 55 SRI farmers were randomly selected. Another 55 farmers practising only a conventional system were randomly selected.	- Total use of inputs listed for both SRI and non-SRI farmers.	- No control for unobserved farmer and plot characteristics.
Barison and Uphoff (2011), Madagascar	Conventional practice	- Based on a list of SRI-farmers provided by an NGO, 109 farmers were selected who contemporaneously practised SRI and a conventional system.	- Unobserved farmer characteristics by comparing yield differences between farmers at the same time cultivating SRI and conventional practice.	- No control for differences in use of labour and fertiliser.
Ly et al. (2012), Cambodia	Conventional practice and direct seeded rice	- Spatial random sampling provided a sample of 207 households in two districts.	- Cost–benefit analysis shows differences in use of seeds, fertiliser and labour.	- No control for unobserved farmer and plot characteristics.
Noltze et al. (2013), East Timor	Conventional practice	- Stratified sampling within two districts that received SRI extension. Here, 1228 farmers received SRI training and 3220 did not; - 200 farmers were selected from each cohort. In the end 397 households and 475 paddy fields were surveyed.	- Observed farmer characteristics that influence the decision to adopt SRI.	- No control for unobserved farmer and plot characteristics.
Palanisami et al. (2013), India	Non-SRI fields	- 2234 farmers with SRI and non-SRI fields in 13 Indian states; - No information on sampling framework.	- Unobserved farmer characteristics by comparing yield differences for farmers contemporaneously following SRI and conventional practice.	- Differences in costs of production between SRI and non-SRI plots are assessed. Which production costs are included is not explained.
Takahashi and Barrett (2013), Indonesia	Non-SRI fields	- Random selection of 30 farmers from 24 randomly selected Water User Associations in South Sulawesi District; - Final sample: 864 households, 1202 rice plots.	- Selection effects due to observed farmer characteristics are contained by using Propensity Score Matching (PSM);	- Application of tests to check whether unobservable variables may influence outcomes, through selection effects.
Serpantié and Rakotondramanana (2013)	Non-SRI fields	- Random selection of 109 plots in Fianarantsoa district, Madagascar, whereby 43 were used to practise SRI.	- Controlled for differences in soil characteristics, fertility and fertiliser use.	- No control for unobserved farmer characteristics
Yokoyama and Zakari (no date), Indonesia	Conventional practice	- Not specified.	- Yields controlled for various cultivation practices increases in use of organic matter, and application of micro-organisms.	- No control for unobserved farmer and plot characteristics; - No control for differences in labour use.

Notes: Studies are presented in chronological order. 'Reference treatment' refers to the farming system to which SRI is compared. In describing the reference treatment and sampling framework and size, we use the original phrasing by the respective authors, adjusted to fit the table.

Table 2
Reported changes in land productivity.

Study and location	Yield from reference practice	Variation in yield of reference practice	Yield from SRI	Variation in yield of SRI practice
	t/ha		t/ha	
Andrianaivo (2002), Madagascar	2.0	–	6.0–20.0	–
Yamah (2002), Sierra Leone	2.5	Range: (1.9–3.2)	5.3	Range: (4.9–7.4)
Ceesay (2002), The Gambia	2.5	–	7.4	–
Namara et al. (2008), Sri Lanka	3.8	SD: 1.9	5.5	SD: 2.8
Barrett et al. (2004), Madagascar	3.4	SD: 0.5	6.3	SD: 1.8
Anthofer (2004), Cambodia	1.6	–	2.3	–
Dhakal (2005), Nepal	Various data	–	Various data	–
Latif et al. (2005), Bangladesh	6.8 (BMP); 5.0 (Farmers' practice)	–	5.9	–
Kabir and Uphoff (2007), Myanmar	2.1	SD: 0.5	6.5	SD: 2.6
Sinha and Talati (2007), West Bengal, India	4.0	–	5.3	–
Sato and Uphoff (2007), Indonesia	4.3	–	7.6	–
Feuer (2008), Cambodia	1.8	–	3.1 (Good SRI fields) 2.7 (Partial SRI fields)	–
Barah (2009), Tamil Nadu, India	–	Range: 4.0–6.2	–	Range: 5.1–7.0
Adusumilli and Bhagya Laxmi (2011), Andhra Pradesh, India	4.6	SD: 0.6	5.4	SD: 1.1
Barison and Uphoff (2011), Madagascar	3.4	SD: 0.5	6.4	SD: 1.8
Styger et al. (2011), Mali	5.5 (Control) 4.9 (Farmers' practice)	SD: 0.3 (Control) SD: 0.2 (Farmers' practice)	9.1	SD: 0.2
Thomas and Ramzi (2011), Afghanistan	5.6	SD: 1.5 Range: 2.0–9.0	9.3	SD: 3.4 Range: 4.0–20.0
Turmel et al. (2011), Panama	–	Range: 0.6–7.5	–	Range: 1.2–9.0
Noltze et al. (2013), East Timor	3.2	SD: 2.7	2.9	SD: 2.2
Serpantié and Rakotondramanana (2013)	4.2	–	5.2	–
Yokoyama and Zakari (no date), Indonesia	6.3	SD: 1.3	8.1	SD: 1.7

Notes: Variations in yield are presented as standard deviations (SD) or the range of crop yields observed (Range). Figures are reported yields (tons per hectare) per rice crop per cropping season.

potential gains, explaining why these farmers generally would not adopt SRI. In a different sample of SRI adopters in Madagascar, Barrett et al. (2004) noted that labour productivity under SRI increased for some, but decreased for a substantial number of farmers in the sample. More recently, Serpantié and Rakotondramanana (2013) observed that the small increases in SRI crop yield are negated by overall increases in labour use, with labour productivity remaining constant.

A frequently cited study by Sinha and Talati (2007) analysed labour use under SRI management in West Bengal, India. For a non-random sample of SRI adopters, the study reported that labour use on SRI plots was lower than on conventional plots. However, the authors did not specify the procedure employed to calculate labour use for their sample, in which not all farmers had adopted all the SRI components. Some of their findings are counterintuitive, such as the indication that labour use in harvesting operations decreased even while crop yield increased. Neither did they examine the actual variation in labour use between farmers or test the differences statistically.

Takahashi and Barrett (2013) investigated the impact of SRI on productivity and income, using a statistical approach to correct for much of the bias arising from selection effects. While SRI appeared to change the marginal productivity of land, they did not observe any discernible effect on labour productivity. Rather, overall labour use increased under SRI adoption, and farmers re-allocated labour away from off-farm activities. The net effect on income was negligible, which in turn begs the question, as the authors point out, why some farmers might take the trouble of adopting a new technology if it does not deliver a notable change in income.

Other studies also reported changes in labour use and productivity, but again with different magnitudes. These results should not be surprising. For instance, taking into account relative local input prices, it could make perfect sense for farmers in Madagascar to increase labour use, while farmers in India substitute relatively cheaper fertilisers for labour. Some studies also point to issues surrounding temporal allocation of labour over the course of a season or year, suggesting that the opportunity costs of labour vary not only across households but also across the cropping calendar.

Differences in opportunity costs as well as perceived comparative advantages in the performance of farming operations also shape the division of labour within households. In many regions, rice transplanting and weeding operations have typically been carried out by women (IRRI, 1985), while men have usually performed more physically demanding tasks such as land preparation. The adoption of SRI methods, especially weeding with a mechanical rotary hoe, often triggers a change in these task allocations between men and women. In Tamil Nadu, for example, many men have reportedly taken over weeding operations from women who used to weed by hand, freeing time for women to engage in other activities. On the whole, however, little evidence on SRI's impact on gender relations has been documented.

While SRI methods may increase labour requirements at first, it has been argued that farmers can economise on labour inputs after one or two seasons, when they become more skilful and confident in the use of the new methods, an argument put forward by Adusumilli and Bhagya Laxmi (2011), for example. Such a trend was indeed observed by Barrett et al. (2004), who reported that the median of labour productivity increased over time after SRI adoption. But the authors noted that this observation could also result from attrition bias, caused by farmers with the lowest rates of labour productivity disadopting SRI and dropping out of the sample. Ly et al. (2012) reported that labour use in SRI plots, particularly for transplanting, remained high over time.

3.1.4. Water

Although claims on the adoption of SRI-practices, reduced water use, and increasing water productivity, are frequent, there is a paucity of studies quantifying the magnitude of these changes under farmer conditions. We are aware of only one study doing so (Adusumilli and Bhagya Laxmi, 2011), whereby the authors found that the number of irrigations and pumping hours was reduced by 52%.

The studies reviewed here indicate that SRI improves several partial input productivities, but there is no firm consensus on the issue of labour productivity. The impact on the complete set of input productivities has rarely been addressed. Synthesising these findings is further complicated by the observed diversity in SRI adoption and practice, small and non-random samples, and a lack of control for various unobserved farm characteristics. These factors also make it impossible to identify the presence of synergetic effects among SRI components. Consequently, while the studies provide some valuable insights into local experiences with SRI methods, they cannot be used to make robust predictions on the impact of SRI elsewhere or in general.

3.2. Changes in marginal productivity and production variance

A few studies assessing the impact of SRI stand out because their methods offer scope to uncover changes in marginal productivity resulting either from the adoption of separate SRI components, or combinations of components. The latter approach, in particular, makes it possible to identify the presence of synergetic effects between components. Kabir and Uphoff (2007) and Palanisami (2010) both aimed to disentangle the various SRI components in order to identify the respective marginal contributions of these individual components to crop yields. The findings suggested that the complete SRI package has a larger marginal effect on yield than adopting improved seeds or varieties alone. In both studies, caveats apply regarding small sample sizes and a lack of control for observed and unobserved farmer characteristics.

With a similar objective in mind, Noltze et al. (2013) set out to identify whether the marginal effects of inputs on yield and income levels differ across SRI and non-SRI adopters. Their findings suggest significant yield and income gains, with small farmers benefiting more than larger ones. As the authors pointed out, many on-farm variables are likely to influence both the likelihood to adopt and the contribution to yield and income, and an instrumental variable approach was used. Unfortunately, the authors did not provide detailed information on the variable selected as an instrument, making it difficult to assess whether their method truly suppressed the estimation bias. More problematically, some of the supposedly exogenous variables, such as seed rate and labour use, are typically determined endogenously as a function of the technology selected. Both points imply that the presented regression results are biased, making it unlikely that the authors have really identified marginal effects on yield and income.

Barah (2009) investigated whether cultivation of SRI leads to a change in farmer efficiency levels, comparing adopters and non-adopters. He observed that yield under SRI was higher than conventional practice, a finding that also held across different wealth groups, and more importantly that SRI adopters were more efficient, both technically and economically. However, Barah's (2009) account of his method and variables makes it difficult to establish whether SRI adoption has a causal effect on efficiency, or whether SRI farmers were more efficient to begin with.

The data on yields presented in Table 2 suggests not only that land productivities are higher under SRI, but that the variation in land productivity is wider for SRI plots/farmers. Out of the 10 studies reporting variation in yields for both SRI and the reference practice, seven reported increased variation in SRI crop yield. This implies that adopting SRI practices could create a source of increased risk for farmers, and many smallholder farmers are justifiably risk-averse. A specific example of (perceived) heightened risk is the practice of transplanting very young, single seedlings. The mortality of young seedlings may be higher than that of older seedlings, necessitating a second transplanting to fill gaps in the field (Senthilkumar et al., 2008). Only one study documented the impact of risk aversion on adoption, which confirmed that a greater anxiety about risk reduces the propensity to adopt SRI practices (Takahashi, 2013). However, it is possible that once the adopter has fully mastered the new technology, the returns could become more stable over time, reducing risk.

In conclusion, evidence from the existing literature does not provide a definite test for the presence of technological change, i.e. a decrease in overall input costs for a given output, associated with increased partial productivities of one or more inputs. Nevertheless, several studies do provide a number of important leads for additional research, which we take up in the concluding section.

4. Conclusions and knowledge gaps

4.1. Major findings

Despite an increase in the number of publications describing SRI adoption and impact, the discussion makes clear that our understanding of what drives a farmer to adopt SRI components, and how this affects his or her livelihood, remains limited. It is also evident that there is substantial diversity in SRI extension and practice across sites, making it very difficult to draw general conclusions about the impact of "SRI" as a singular technological package. From our review several specific conclusions emerge:

(1). The overall effect of SRI adoption on total factor productivity remains unclear. Although reported yields under SRI cultivation methods are often higher than reference practices, the cause(s) of these increases remain obscure. Adoption of SRI methods is associated with fairly substantial changes in the allocation of inputs, especially labour, water and fertiliser. No studies have assessed the changes in all relevant inputs simultaneously, while sufficiently controlling for observed and unobserved farmer characteristics. For the same reason, possible synergetic effects among SRI components have not been demonstrated.

(2). A majority of the studies we analysed pointed to increased labour use on SRI plots, but there is no firm consensus on whether overall *labour productivity* increases or decreases. It is clear that the adoption of SRI transplanting and weeding methods leads to significant changes in the organisation of tasks, gender division of labour, and temporal distribution of labour demand, including the possibility of an increased labour requirement at harvest time. The available literature allows few firm conclusions regarding the impact of these changes, which theoretically may be positive or negative for different households or groups. There is a widely held view that SRI methods may increase labour demand in the short term, but that labour requirements can be reduced once the new methods have been mastered. Though this is plausible, we found no studies that explored this dynamic in detail.

(3). The nature and exact cause of increases in *land productivity* remain obscure, although differences in land productivity between SRI plots and non-SRI plots (or farmers) are likely to be a partial cause *or* an effect of improved results with SRI methods. Various studies suggest 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 fertiliser and labour to SRI plots.

(4). Available evidence does indicate that SRI practices can substantially improve the partial *productivity of seed and water*. Increases in seed and water productivity follow logically from reductions in the seed rate and irrigation, which can be achieved without adverse effects on output, and sometimes with an increase in yield. However, as noted in Section 1.2, water savings and improvements in water productivity can also be achieved by adopting water-saving management methods, without necessarily adopting the whole set of SRI practices.

(5). Yield variability under SRI management is often reported to be larger in comparison with conventional practice. This difference may stem from either unobserved farm characteristics, or truly represent a source of elevated risk associated with SRI management, making SRI less attractive for the most vulnerable farmers. The literature does discuss some sources of increased risk under SRI management, such as the hazard of seedling loss when the seedlings are very small due to pests, flooding or soil salinity. These factors, together with the physical difficulty involved in handling tiny seedlings, may explain why some farmers and SRI-promoting organisations have opted not to use extremely young seedlings.

4.2. Knowledge gaps

While SRI may potentially offer advantages, several socio-economic issues remain unresolved and deserve further research:

(1). There is a vital need to generate more detailed and reliable information about the spread and levels of adoption of SRI methods. In particular, it is very important to study the patterns of adoption and partial adoption, including the range and degrees of variation in the ways SRI guidelines are specified and practised by farmers.

(2). (Partial) adoption of SRI methods by farmers will potentially lead to changes in output and input productivity. As a result, different types of farmers are likely to re-allocate scarce production factors across on-farm, off-farm and non-farm activities in different ways. In addition, labour demand changes in rice production may have a profound impact on the income and well-being of landless labourers. In all these cases SRI methods may have a measurable impact on household income, food security status and health of household members. The magnitude and direction of this impact, and how it varies across different regions and types of households, has not yet been established, but can be addressed through the implementation of well-designed impact assessments, such as randomised controlled trials or natural experiments at farm household or village level.

(3). Studies investigating both partial and total factor productivities should make it possible to investigate the presence of synergetic effects among the SRI components. Such studies should focus on whether interaction effects can be detected between some or all of the SRI components, how and when these occur, and how they affect total factor productivity.

(4). An interesting question is whether the diversity in local and regional specifications of SRI is a systemic property, stemming from an inherent flexibility of the technical characteristics of the cultivation system, or simply a consequence of the natural diversity that characterises smallholder farming across diverse landscapes, cultures and institutional settings. Investigating this question would be an important step towards creating training and extension systems that can support specific kinds of farmers and communities to improve their rice cultivation practices in appropriate and locally valued ways.

References

Adusumilli, R., Bhagya Laxmi, S., 2011. Potential of the system of rice intensification for systemic improvement in rice production and water use: the case of Andhra Pradesh, India. Paddy Water Environ. 9, 89–97.

Andrianaivo, B., 2002. Evaluations of the System of Rice Intensification in Fianarantsoa Province of Madagascar. Paper presented at the International Conference on assessments of the System of Rice Intensification (SRI), Sanya, China, April 1–4, 2002.

Anthofer, J., 2004. Potential of the system of rice intensification (SRI) for Cambodia. *Consultancy Report* Phnom Penh/Spaichingen: GTZ.

Association Tefy Saina, Uphoff, N., 2001. More rice with less water. Approp. Technol. 28, 8–11.

Barah, B.C., 2009. Economic and ecological benefits of system of rice intensification (SRI) in Tamil Nadu. Agric. Econ. Res. Rev. 22, 2099–2214.

Barison, J., Uphoff, N., 2011. Rice yield and its relation to root growth and nutrient-use efficiency under sri and conventional cultivation: an evaluation in Madagascar. Paddy Water Environ. 9, 65–78.

Barrett, C.B., Moser, C.M., McHugh, O.V., Barison, J., 2004. Better technology, better plots, or better farmers? Identifying changes in productivity and risk among Malagasy rice farmers. Am. J. Agric. Econ. 86, 869–888.

Bouman, B.A.M., Hengsdijk, H., Hardy, B., Bindraban, P.S., Tuong, T.P., Ladha, J.K., 2002. Water-wise rice production. Paper presented at the Proceedings of the International Workshop on Water-wise Rice Production, Los Baños, Philippines, 8–11 April 2002.

Ceesay, M.M., 2002. Experiments with the System of Rice Intensification in the Gambia. Paper presented at the International Conference on assessments of the System of Rice Intensification (SRI), Sanya, China, April 1–4, 2002.

Chen, H., Zhu, D., Rao, L., Lin, X., Zhang, Y., 2006. Effects of SRI technique on population quality after heading stage and yield formation in rice. Jnl. of Huazhong Agric. Univ. 25, 483–487.

Chen, Z., Yen, S.T., 2006. Better technology, better plots, or better farmers? Identifying changes in productivity and risk among Malagasy rice farms: a comment. Am. J. Agric. Econ. 88, 763–766.

CIIFAD, 2013. The System of Rice Intensification (Sri) – SRI information by country. Cornell International Institute for Food, Agriculture and Development (CIIFAD), <http://sri.ciifad.cornell.edu/countries/index.html>.

de Laulanié, H., 1993. Le Système De Riziculture Intensive Malgache [The Malagasy system of intensive riziculture]. Tropicultura 1–19.

de Laulanié, H., 2003. Le Riz À Madagascar: Un Développment En Dialogue Avec Les Paysans. Editions Ambozontany/Editions Karthala, Antananarivo, MG.

Dhakal, M.P., 2005. Farmers' evaluation of the System of Rice Intensification in the middle mountains of Nepal. Consultant's report People and Resource Dynamics in Mountain Watersheds of the HKH (PARDYP) /International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Feuer, H.N., 2008. Sustainable Agricultural Techniques and Performance Oriented Empowerment: An Actor-Network Theory Approach to Cedac Agricultural and Empowerment Programmes in Cambodia. University of Oxford, United Kingdom.

Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B., Vermeersch, C.M., 2011. Impact Evaluation in Practice. World Bank Publications.

Horie, T., Shiraiwa, T., Homma, K., Katsura, K., Maeda, S., Yoshida, H., 2005. Can yields of lowland rice resume the increases that they showed in the 1980s? Plant Prod. Sci. 8, 259–274.

IRRI, 1985. Women in rice farming. Paper presented at the Women in Rice Farming Systems, Manila.

Kabir, H., Uphoff, N., 2007. Results of disseminating the system of rice intensification with farmer field school methods in Northern Myanmar. Exp. Agric. 43, 463–476.

Kassam, A., Stoop, W., Uphoff, N., 2011. Review of SRI modifications in rice crop and water management and research issues for making further improvements in agricultural and water productivity. Paddy Water Environ. 9, 163–180.

Latif, M.A., Islam, M.R., Ali, M.Y., Saleque, M.A., 2005. Validation of the system of rice intensification (SRI) in Bangladesh. Field Crops Res. 93, 281–292.

Latif, M.A., Ali, M.Y., Islam, M.R., Badshah, M.A., Hasan, M.S., 2009. Evaluation of management principles and performance of the System of Rice Intensification (SRI) in Bangladesh. Field Crops Res. 114, 255–262.

Lu, Y., Li, J., Wang, J., Tang, Y., Yu, G., 2005. Effects of SRI on dry matter production and grain yield of Yuyou 11. Xi Nan Nong Ye Xue Bao 18, 79–83.

Ly, P., Jensen, L.S., Bruun, T.B., Rutz, D., de Neergaard, A., 2012. The system of rice intensification: adapted practices, reported outcomes and their relevance in Cambodia. Agric. Syst. 113, 16–27.

Moser, C.M., Barrett, C.B., 2003. The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. Agric. Syst. 76, 1085–1100.

Moser, C.M., Barrett, C.B., 2006. The complex dynamics of smallholder technology adoption: the case of SRI in Madagascar. Agric. Econ. 35, 373–388.

Namara, R.E., Bossio, D., Weligamage, P., Herath, I., 2008. The practice and effects of the system of rice intensification (SRI) in Sri Lanka. Q. J. Int. Agric. 47, 5–23.

Noltze, M., Schwarze, S., Qaim, M., 2012. Understanding the adoption of system technologies in smallholder agriculture: the system of rice intensification (SRI) in Timor Leste. Agric. Syst. 108, 64–73.

Noltze, M., Schwarze, S., Qaim, M., 2013. Impacts of natural resource management technologies on agricultural yield and household income: the System of Rice Intensification in Timor Leste. Ecol. Econ. 85, 59–68.

Palanisami, K., 2010. Adoption of SRI under Different Irrigation Sources and Farm Size Categories in Tamil Nadu, India. International Water Management Institute (IWMI).

Palanisami, K., Karunakaran, K.R., Amarasinghe, U., Ranganathan, C.R., 2013. Doing different things or doing it differently? Econ. Polit. Wkly XLVIII, 51–58.

Resurreccion, B.P., Sajor, E.E., 2008. Gender dimensions of the adoption of the system of rice intensification (SRI) in Cambodia. Research Report. Phnom Penh: Asian Institute of Technology and Royal University of Phnom Penh.

Sato, S., Uphoff, N., 2007. A review of on-farm evaluations of System of Rice Intensification methods in eastern Indonesia. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2.

Schiller, J.M., 2004. System of Rice Intensification – SRI - suitability for lowland rice production in the Lao PDR. Consultant's report, Food and Agricultural Organisation (FAO), Lao PDR.

Senthilkumar, K., Bindraban, P.S., Thiyagarajan, T.M., de Ridder, N., Giller, K.E., 2008. Modified rice cultivation in Tamil Nadu, India: yield gains and farmers' (lack of) acceptance. Agric. Syst. 98, 82–94.

Serpantié, G., Rakotondramanana, M., 2013. L'intensification De La Riziculture Malgache, En Pratiques. Cahiers Agricultures 22, 401–410.

Sinha, S.K., Talati, J., 2007. Productivity impacts of the System of Rice Intensification (SRI): a case study in West Bengal, India. Agric. Water Manag. 87, 55–60.

Sita Devi, K., Ponnarasi, T., 2009. An economic analysis of modern rice production technology and its adoption behaviour in Tamil Nadu. Agric. Econ. Res. Rev. 22, 341–347.

Stoop, W., Uphoff, N., Kassam, A., 2002. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. Agric. Syst. 71, 249–274.

Styger, E., Attaher, M., Guindo, H., Ibrahim, H., Diaty, M., Abba, I., et al., 2011. Application of system of rice intensification practices in the arid environment of the Timbuktu region in Mali. Paddy Water Environ. 9, 137–144.

Surridge, C., 2004. Feast or famine? Nature 428, 360–361.

Takahashi, K., 2013. The roles of risk and ambiguity in the adoption of the System of Rice Intensification (SRI): evidence from Indonesia. Food Secur. 5, 513–524.

Takahashi, K., Barrett, C.B., 2013. The System of Rice Intensification and its impacts on household income and child schooling: evidence from rural Indonesia. Am. J. Agr. Econ. doi:10.1093/ajae/aat086.

Thakur, A.K., Uphoff, N., Antony, E., 2010. An assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practices in India. Exp. Agric. 46, 77–98.

Thomas, V., Ramzi, A., 2011. SRI contributions to rice production dealing with water management constraints in northeastern Afghanistan. Paddy Water Environ. 9, 101–109.

Tsujimoto, Y., Horie, T., Randriamihary, H., Shiraiwa, T., Homma, K., 2009. Soil management: the key factors for higher productivity in the fields utilizing the system of rice intensification (SRI) in the central highland of Madagascar. Agric. Syst. 100, 61–71.

Turmel, M.S., Espinosa, J., Franco, L., Perez, C., Hernandez, H., Gonzalez, E., et al., 2011. On-farm evaluation of a low-input rice production system in Panama. Paddy Water Environ. 9, 155–161.

Uphoff, N., 1999. Agroecological implications of the System of Rice Intensification (SRI) in Madagascar. Environ. Dev. Sust. 1, 297–313.

Uphoff, N., 2002. Opportunities for raising yields by changing management practices: the System of Rice Intensification in Madagascar. In: Uphoff, N. (Ed.), Agroecological Innovations. Earthscan, London, UK, pp. 145–161.

Uphoff, N., 2003. Higher yields with fewer external inputs? The System of Rice Intensification and potential contributions to agricultural sustainability. Int. J. Agric. Sust. 1, 38–50.

Uphoff, N., 2007. Agroecological alternatives: capitalising on existing genetic potentials. J. Dev. Stud. 43, 218–236.

Uphoff, N., Randriamiharisoa, R., 2002. Reducing water use in irrigated rice production and the Madagascar System of Rice Intensification. In: Bouman, B.A.M., Hengsdijk, H., Hardy, B., et al. (Eds.), Water-Wise Rice Production. IRRI, Los Baños, the Philippines, pp. 71–87.

Uphoff, N., Fernandez, E., Yuan, L.-P., Jiming, P., Sebastien, R., Rabenandrasana, J., 2002. Assessment of the System for Rice Intensification (Sri). Proceedings of an International Conference, Sanya, China, April 1–4, 2002. Cornell International Institute for Food, Agriculture and Development (CIIFAD), Ithaca, NY, USA.

Uphoff, N., Kassam, A., Harwood, R., 2011. SRI as a methodology for raising crop and water productivity: productive adaptations in rice agronomy and irrigation water management. Paddy Water Environ. 9, 3–11.

Vijayakumar, M., Ramesh, S., Chandrasekaran, B., Thiyagarajan, G., 2006. Effect of System of Rice Intensification (SRI) practices on yield attributes, yield and water productivity of rice (Oryza Sativa L.). Res. J. Agric. Biol. Sci. 2, 236–242.

Yamah, A., 2002. The practice of the System of Rice Intensification (SRI) in Sierra Leone. Paper presented at the International Conference on assessments of the System of Rice Intensification (SRI), Sanya, China, April 1–4, 2002.

Yokoyama, S., Zakari, A.K., no date. Technological characteristics of organic-SRI (System of Rice Intensification): case in West Java, Indonesia. Draft.