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Annex 3

Case study
System of Rice Intensification

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STOA Project "Agricultural Technologies for Developing Countries"

THE SYSTEM OF RICE INTENSIFICATION (SRI)

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EXECUTIVE SUMMARY

INTRODUCTION

The System of Rice Intensification (SRI) is an innovation in rice production systems that is still evolving and ramifying, but already it is raising factor productivity and incomes for more than 1 million small farmers producing rice around the world on over 1 million hectares. SRI addresses the major constraints affecting the livelihoods of small and poor farmers: their limited resources of land, labour, water and cash, as well as losses from pests and diseases and adverse climatic conditions. SRI does not require rice farmers to purchase and use any external inputs, since its benefits derive from changes in the ways that their existing resources are used for rice production.

Because SRI is a biologically-driven innovation, rather than being based on introducing certain genotypes or increasing purchased external inputs, there can be wide variability in results. Averages are thus not very meaningful, but generally speaking, SRI methods are seen to have the following impacts compared to their conventional counterparts:

- Depending on current yield levels, *output per hectare* is increased usually by 50% or more, with increases of at least 20%, and sometimes 200% or more.
- Since SRI fields are not kept continuously flooded, *water requirements* are reduced, generally by 25-50%.
- The system does not require purchase of new varieties of seed, chemical fertilizer, or agrochemical inputs, although commercial inputs can be used with SRI methods.
- The minimal capital costs make SRI methods *more accessible to poor farmers,* who do not need to borrow money or go into debt, unlike many other innovations.
- *Costs of production* are usually reduced, usually by 10-20%, although this percentage varies according to the input-intensity of farmers' current production.
- With increased output and reduced costs, *farmers' net income* is increased by more than their augmentation of yield.

All this sounds 'too good to be true,' but these various effects have been documented in a diverse set of countries, now up to 35 across Asia, Africa and Latin America. Over the past decade, SRI has been spreading rapidly beyond its country of origin, Madagascar, despite relatively little donor support. Farmer uptake of SRI in some rice-producing areas, including areas of severe poverty such as eastern and northern India and northern Myanmar, is proceeding at unprecedented rates. Although SRI was developed for improving production of *irrigated rice*, its concepts and methods are now being extended to *rainfed* rice production and also to *other crops* such as wheat, finger millet and sugar cane. Thus, the eventual impact on the agricultural sector of SRI ways of thinking and cultivating could become quite broad.

SRI AS A PRODUCTION SYSTEM

SRI is basically a set of modified practices for managing rice plants and the soil, water and nutrients that support their growth. These changes in often age-old cultural practices were assembled and integrated by Fr. Henri de Laulanié, S.J., who spent half a lifetime in Madagascar working with small and poor farmers there to improve their rice productivity and output so as to alleviate their families' hunger and poverty. The crop husbandry methodology that he developed inductively can be justified in terms of principles that are well-grounded in agronomic science.

Key Elements of SRI: In practical terms, SRI involves the transplanting of young seedlings, one per hill instead of a clump of several seedlings and 8-12 days old instead of the usual 3-4 weeks; very carefully but quickly, taking special care to protect the young roots; with wider spacing and in a square pattern to give both roots and canopy more room to grow, for taking up nutrients and capturing sunlight; maintaining the soil in mostly aerobic condition, not suffocating the plant roots or beneficial soil organisms; controlling weeds with a simple mechanical hand weeder that also actively aerates the soil; and enhancing the soil organic matter as much as possible with compost or mulch to 'feed the soil' so that the life within it will help feed and protect the growing plants.

SRI can be fully organic since resulting plants are more resistant to pests and diseases; but if not enough biomass or labour is available to supply the soil with organic matter, mineral fertilizers can be used. Also, agrochemicals can be used for pest control but are usually not needed or uneconomic. Generally the best yields and highest incomes with SRI methods come from organic crop management. The methods are successful with both traditional, local varieties and with new, improved varieties and hybrids, so they can be used within the full range of subsistence to 'modern' agricultural production systems. [most of this is said below; best to keep an executive summary as short as possible]

Complementary Elements: The SRI recommended practices are modifications of irrigated rice cropping systems, not the whole system, so there are a number of other activities involved, having some modifications to suit the core practices: land preparation including possibly raised beds and/or zero-till; nursery management under unflooded conditions; seed selection and priming; soil solarisation where pathogens are a problem; and soil enrichment with microorganisms as an innovation still being evaluated. SRI is still evolving, so innovations and modifications like direct-seeding or mechanical transplanting are being introduced by farmers. Also, possibilities exist for increasing organic matter from biomass produced from within the rice-based cropping system using high-biomass cover crops and crop rotations as is the case with Conservation Agriculture systems.

Defining SRI: Not being a conventional standardized 'technology' and being still 'a work in progress,' no fixed or narrow definition is possible or desirable. SRI concepts and practices are being extended to other crops so 'SRI' is not even just for rice. Essentially, SRI is a suite of practices, based on sound scientific principles, for enhancing the growth and performance of both plant roots and soil biota, to produce more healthy and productive plant phenotypes (phenomena) from any genotype (initial genetic potential). The result is more profuse growth of tillers (stems), leaves, panicles (ears of grain), and grains themselves.

SRI is better understood as a matter of degree than of kind, and it is better regarded as a 'menu' rather than a 'recipe.' Rather than try to decide what is or what is not SRI, we suggest considering to what *extent*, and how *well*, the recommended practices were used, and with what *results*. SRI practices such as timing and spacing, how much soil disturbance, water management, and biomass production within the rice cropping system, are always to be adapted to local conditions and cropping systems.

Knowledge Involved: SRI is an innovation based on new knowledge, or rediscovery of old knowledge, rather than on purchased material inputs, utilizing available land, labour, water, natural resources and cash more productively. The specific knowledge involved is discussed in the full chapter.

Key Actors: From its inception, SRI has been a farmer-centered innovation. Its success depends gretly upon farmers' motivation and skill for using the insights originating in Fr.

Laulanié's work but that are being continuously expanded and ramified. SRI has been extended by a full range of institutions, from national to local levels, working with farmers in the dissemination and application of SRI concepts and practices: government agencies, non-governmental organization (NGOs – initially the most active on behalf of SRI), universities and research institutions, also private sector organizations (e.g., Syngenta in Bangladesh, Nippon Koei in Indonesia). In general, SRI can be characterized as a 'civil society' innovation.

International Actors: There has been some donor agency support in a number of countries, but so far most of the initiative has occurred at national, intermediate and local levels, with communication and coordination support coming particularly from Cornell University in the U.S. The international community generally has been slow to respond to SRI opportunities, and there has been some controversy surrounding SRI. But the evidence of SRI's benefits and wide applicability is increasing season by season, and country by country, so SRI is becoming more and more of an international phenomenon and an opportunity to be harnessed for poverty alleviation and strengthening food security and sustainability.

Potentials for Sustainability: Because SRI reduces the demand for water in agricultural production and also the use of agrochemical inputs, it has benign environmental impacts. By raising the agronomic and economic productivity of land, labour, water and capital all at the same time, it enables farmers to produce more with less, by mobilizing the services and benefits of soil biota. While not exactly a 'free lunch' (see listing of costs and constraints below), it points the way to greater sustainability of agricultural production in general, and of production intensification. Producing more outputs with less inputs is unique and uniquely appropriate for sustainability.

CURRENT RELEVANCE AND APPLICATIONS

As reviewed in the full chapter, SRI is now demonstrated and spreading in all world regions except Europe and North America, and its methods have proved to be productive in a wide variety of agroecosystems: from the tropical coastal regions of West Africa to the interior, arid climate of the Timbuktu region in Mali, on the edge of the Sahara Desert; from 100 meters asl in the *terai* region of Nepal up to 2,700 meters in that country. Although developed for the benefit of small farmers in Madagascar, SRI as a biologically-based innovation is scale-neutral. In Sichuan and Zhejiang provinces of China, extension services report that SRI methods are being taken up most quickly by larger farmers, because these help them save labour as well as seed, water and money.

LIMITATIONS AND CONSTRAINTS

The main requirement is improved if not necessarily perfect *water control* so farmers can apply smaller but reliable amounts of water; where fields are inundated, the main benefits of SRI will not be achieved because plant roots will die back and only anaerobic soil organisms can survive. *Labour availability* is essential because initially the methods require more time while these are being mastered; over time, however, SRI can become labour-saving. *Biomass availability* to enrich the soil organic matter content and/or make compost is important, although if there are limitations of biomass as a source of nutrients or a shortage of labour time to produce compost, mineral fertilizers can be used with the other methods. *Crop protection* is sometimes needed, although SRI plants have considerable natural resistance against pests and diseases. *Farmer skill and motivation* is the most important requirement since SRI involves more intensive and knowledgeable management, while reducing the intensity of other purchased inputs. Then there are *other factors* include access to simple, reasonably inexpensive implements that enhance labour and soil productivity; market development where increases in supply may exceed local demand; and appropriate land tenure arrangements.

POTENTIALS FOR IMPROVEMENT AND EFFECTS FOR SMALL FARMERS

SRI is being continually improved, particularly at farmer initiative, although the scientific community has growing interest in and involvement with SRI. The benefits obtainable for small farmers as well as for the environment are driving this continuous innovation. Potential for further improvement exists in minimizing puddling or doing away with it altogether, introducing direct seeding, increasing biomass production within the cropping system through high-biomass mulch and cover crops, and transforming the total rice-based cropping system to Conservation Agriculture. There are opportunities for development-oriented research to improve equipment and practices for direct seeding, for weed management, for residue and soil cover management, for nutrient and water management and for cropping pattern management.

In irrigated rice, there are potentials for significant water savings through SRI, and in case of irrigation expansion for rice production, SRI-based systems offer higher return to investment to the farmers and at the scheme level to governments. Policy support to promote SRI has been slow in coming, but this is beginning to change. Policy and institutional changes can be accelerated if the scientific and donor community can be made aware of the full potential of SRI methods for sustainable production intensification, reducing energy and production costs, responding to climate change, saving water, and reducing the consumer price of rice.

FAVOURABLE CONDITIONS FOR PROMOTING AND SUSTAINING SRI

Climate of opinion is very important for promotion and sustainability of any innovation in agriculture. 'Modern agriculture' has proceeded from the paradigm of the Green Revolution, which specifies that productivity improvements will be best achieved by making genetic improvements in crops, and then making appropriate increases in the application of external inputs. SRI operates from a different paradigm, positing that existing genetic potentials can produce more agronomic output and economic returns by modifying growing environments, specifically improving soil health, root growth and performance, and inducing greater abundance, diversity and activity of soil biota. Getting these differences in paradigms understood, providing scientific evidence and explanations for their acceptance, reducing reliance on the preceding paradigm and gaining adherence to the newer one, are all part of the process for creating 'favourable conditions' for SRI spread, with both short-term and long-term impact.

AREAS AND OPTIONS FOR ACTION

In conclusion, the full chapter reviews areas where research, experimentation and policy can be supportive of the further exploitation of SRI potentials to enhance factor productivity in agriculture with a pro-poor orientation and with regard for the quality and preservation of environmental resources. Improvements are needed in water control, simple mechanization, and biomass production and processing, also possibly in crop protection. Creating convergence with Conservation Agriculture practices should make both areas of innovation more beneficial to farmers and to the environment. Farmer-to-farmer extension and Farmer Field Schools (FFS) offer the most effective means for disseminating knowledge and practice of SRI, supplemented with certain incentives. Since SRI is fully compatible with the objectives of European development cooperation policy, it should be easy and beneficial to integrate the new knowledge and opportunities which SRI is providing into EC programmes and projects both for rice development in Europe and in the developing regions.

THE SYSTEM OF RICE INTENSIFICATION (SRI)

1. SRI AS A PRODUCTION SYSTEM

SRI is better understood as a knowledge-based system of rice production rather than as a technology because it is basically *a set of insights* into how to grow better rice plants, not requiring new machinery, chemicals or improved seeds. These ideas can be stated succinctly in terms of *a number of principles* which explain and justify *a set of specific practices* that change many current rice-growing practices, some of them age-old. Actually, the practices preceded the principles, rather than the principles coming first, because SRI was developed through decades of observations and experiments to determine what kind of growing environment (above- and especially below-ground) could elicit more fully the genetic potentials of both old and new varieties of rice. SRI was created inductively by Henri de Laulanié, a French Jesuit priest who spent much of his adult life in Madagascar, assembling practices that would be most advantageous for small farmers and for their poor, vulnerable households (Uphoff, 2006).

The changes which are recommended for SRI appear *counterintuitive* at first, because getting ‘more from less’ appears illogical, but all of them can be justified with scientific explanations. Also, although they may at first appear to farmers to be somewhat *risky*, in general their effect is to reduce risk (Uphoff, 2007). To consider SRI as a technology directs attention toward *what* is done more than to *how* it is done -- appreciating that qualitative factors are important for nurturing best plant performance -- and *why* -- knowing the reasons for changing plant, soil, water and nutrient management.

1.1 Key Elements of SRI

The main operational elements of SRI, each having good agronomic rationales, are:

1. Young seedlings. If establishing the rice crop by transplanting, start by using single seedlings preferably 8 to 12 days old, and certainly less than 15 days, i.e., before the start of the 4th phyllochron.[1] The objective is to preserve the plants’ vigour and growth potential for

[1] Unless seasonal temperatures are low, in which case somewhat older seedlings are still ‘young’ in terms of biological age. To underscore that SRI is not a fixed technology, we want to note that farmers in some countries have modified this first practice to reduce their labour requirements. Instead of transplanting young seedings, they establish their crop by *direct seeding*, one plant per hill and in a square pattern, or by *broadcasting* more

tillering and root development which is forfeited by using older seedlings beyond their 4th phyllochron of growth (Stoop *et al.*, 2002).

2. Careful transplanting of single seedlings. The transplanting of *single seedlings*, instead of a clump of several seedlings, should be done *quickly*, within 30 minutes after the seedlings are removed from the nursery, and *carefully*, keeping soil and seed sac attached to the root, putting the roots in very *shallow* (1-2 cm), without inverting the root tips by pushing them straight down into the soil as this will set back their resumption of growth. Careful handling of seedlings avoids desiccation and trauma to the roots, with little or no interruption of plant growth and no 'transplant shock'.

3. Wider square spacing. This is important for better growth of roots and canopy. We noted above the recommendation of *one plant per hill* established in a *square pattern*, starting out usually with 25x25 cm distances between rows and hills. If the soil is not very fertile, for the first year or two, farmers can get somewhat higher yield with two plants per hill and perhaps 20x20 cm spacing. But as SRI practices build up soil fertility, through root exudation and additions of organic matter to the soil, sparser planting will give higher productivity (per square meter as well as per plant). It is counterintuitive that reducing plant populations by as much as 80-90% can give higher yield, but this is the result, provided that the other SRI practices are also followed. The higher yield with reduce population results from the increase in panicle-bearing primary tillers per unit area, and also more spikelets and filled grains per panicle, as well as usually higher grain weight.

4. Aerobic soil conditions. Using very young seedling has been shown in factorial trials to be the single most important contributor to higher SRI yields (Randriamiharisoa and Uphoff, 2002), but the second most important is keeping the paddy soil *moist but not continuously saturated*. This avoids the suffocation and degeneration of rice plant roots (Kar *et al.*, 1974) and also supports more abundant and diverse populations of aerobic soil organisms that provide multiple benefits to the plants (Randrimiharisoa *et al.*, 2006). This can be done by applying small amounts of water daily, with several periods when the field is allowed to dry for 3-6 days during the vegetative growth stage, or by alternate wetting and drying (AWD) with cycles ranging from 6 to 14 days.

The original advice of Fr. Laulanié was to maintain 1-2 cm of standing water on the field after panicle initiation until 10-15 days before harvesting -- when the field would be

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seed on a muddy field than would be used with transplanted SRI and then *thinning* the new-growing crop when they weed the field to create a square pattern of plants. Some farmers are also experimenting with *raised beds* and *zero-till* to enhance soil fertility and save labour, converging SRI practice with conservation agriculture (CA). All of these variants in practice reflect the principles of (1) greatly reducing plant populations, and (2) ensuring good environments for root growth which contribute to better crop performance.

drained. But some farmers now continue minimum or alternating water applications also through the reproductive phase, after panicle initiation. The operative principle is to provide both roots and soil biota with optimizing amounts of both water and oxygen. The result is larger and deeper root growth which gives rice plants more resilience to adverse climatic conditions, such as drought, storms or extreme temperatures.

5. Active soil aeration. Not flooding fields is conducive to passive soil aeration, letting biological processes improve soil structure and functioning. Beyond this, SRI promotes mechanical measures to aerate the soil. When paddy fields are not kept continuously flooded, weed growth becomes a greater problem. While weeds can be controlled by manual weeding or chemical herbicides, neither gives as good results with SRI practices as the *use of a soil-aerating hand weeder* which breaks up the surface soil as it turns weeds into mulch, conserving their nutrients as they decompose in the soil. This practice, especially if done several times, can add 1 to 3 tons/hectare to yield without other soil amendments, by inducing better soil health and more nutrient cycling and solubilization through microbial activity.

Mechanical weeding should begin about 10-12 days after transplanting, moving preemptively against weeds. We recommend an additional 2-4 weedings at 10-12 day intervals until the canopy closes, whether or not weeds are an evident problem, because soil aeration is a benefit in itself. Weeding is the most labour-intensive part of the SRI methodology. Some farmers dislike this work, while others embrace it, as preferable to hand weeding. It is important to have well-designed, well-built weeders to have best results and least onerous work. Once motorized weeders become widely available and used, SRI will become even more attractive to farmers.

SRI results depend substantially on maintaining mostly aerobic soil conditions, and good soil porosity is an essential element in this. So far, SRI practice has not moved away from the standard intensive 'puddling' which destroys soil porosity. There are indications that puddling can be done away with in SRI and substituted with no-till practices as recommended for Conservation Agriculture (CA). Good soil aeration can be obtained through biological means through the activity of the soil biota. Also, no-till practice causes the weed seed bank in the soil to decay over time, contributing to effective weed management. These new developments are being tested with promising results.

6. Enhanced soil organic matter. Initially, SRI was developed in the 1980s with mineral fertilizer being used to boost soil fertility, because this was thought necessary to improve yields on the very poor soils in Madagascar. At the time, government subsidies made fertilizer affordable to poor farmers. But when these subsidies were eliminated, SRI practice was shifted to rely on ***compost*** made from rice straw and any other available biomass. It turned out that what was considered second-best gave even better results, with less out-of-pocket cost. This has been confirmed by factorial trials (Randriamiharisoa and Uphoff, 2002).

Mineral fertilizer can be used with the other SRI practices if farmers do not produce or have access to enough biomass to enhance soil organic matter, or do not have enough labour to convert biomass into compost. But the other SRI practices give better results to the extent that the soil is well-supplied with organic matter. Compost contributes more than just the plant nutrients that it contains. It mobilizes the soil biota; improves the soil‘s structure and water-holding capacity; and enhances soil biodiversity and biological activity.[2]

It is possible to increase organic matter production and N fixation in a SRI-based cropping system through the use of high-biomass legumes as cover crops in rotation, also returning as much of the crop residue as possible to cover the soil surface and/or add organic matter into the soil. This practice has been an integral part of Conservation Agriculture, and it is believed that SRI systems could also benefit from it.

These six domains in which the management of plants, soil, water and nutrients is altered constitute the core of the SRI methodology, reflecting but not ending with the work and analysis of Fr. Laulanié. The first three practice areas listed above stimulate the overall growth of ***plants***, while the latter three are important particularly for enhancing the growth and health of their ***roots*** and of the ***soil biota***.

All of these practices have impacts on, and in turn benefit from, the *other* recommended practices, with each having more effect when used together with the others. There is a positive feedback loop between root and canopy growth, as root systems with increased capacity can support a larger canopy, while a larger canopy can help nourish through its photosynthesis an expanded root system. Indeed, phytohormones produced in the canopy induce greater growth in the roots, and *vice versa*.

[2] In SRI experience, while farmyard manure makes for better-quality compost, we find that any decomposed biomass will enhance soil fertility and structure enough to justify the effort. In India, some farmers are using various preparations to enhance SRI productivity, some of which stem from Vedic times, e.g., *panchagavya*, a blend of five products from cattle: dung, urine, milk, ghee and curd, plus other ingredients. There is no prescription of what kind of organic matter should be used with SRI, or how much; only the principle of enhancing soil endowments of organic material to benefit plant nutrition and soil biodiversity and activity.

1.2 Complementary Elements

These practices are not all that should be known and done for successful rice production, however. There are a number of associated practices in other domains of rice growing:

1. Land preparation. This is done similarly to conventionally-grown rice; however, particular care should be given to *land leveling*, so that water can be very efficiently distributed in small amounts across the entire surface. Where rainfall is heavy, water control can be improved by putting *drainage channels* around the inside of the field and across the field at intervals of 3-4 meters. Also, as indicated above, there is scope for reducing soil disturbance once adequate land leveling has been achieved, and Conservation Agriculture practices of no-till, organic-matter soil cover, and rotation with legumes can offer additional means to optimize resource use in SRI-based rice production.

2. Nursery management. SRI nurseries should be garden-like, e.g., on raised beds, and unflooded, as this will improve the root growth and vigor of the seedlings (Mishra and Salokhe, 2008). Farmers have many different techniques for raising seedlings, e.g., in a thin layer of soil on trays or pans or on banana leaves, or in plastic trays/cups. This makes it easy to transport seedlings to the field and to handle them gently. Some grow seedlings in a fibrous mat that can be rolled up and carried, a method also used for raising seedlings to be used in a mechanical transplanter.

3. Seed selection and priming. Using a salt-water solution to separate the more viable seeds (which sink to the bottom of a container) from lighter, less developed seeds (which float) can add 10-20% to yield just by having more vigorous seedlings resulting. A process known as seed priming can improve germination rates and enhance seedlings' early growth (http://priming.bangor.ac.uk//public/on_farm/on_farm.htm).

4. Soil solarization. This can produce more healthy seedlings where there are problems with soil pathogens and has been shown to enhance SRI practices, and *vice versa* (http://research.cals.cornell.edu/impact/individual/vivo/individual16667).

5. Soil enrichment with microorganisms. To enhance the biological activity of the soil, some farmers add preparations such as commercially-available Effective Microorganisms or home-made 'indigenous microorganisms'(IMO).[3] There is no consensus among SRI practitioners about the merits of these materials, but they are consistent with the approach.

[3] See, for example: http://newfarm.rodaleinstitute.org/features/0404/microorgs/index.shtml Similar effects are attributed to panchagavya soil amendment mentioned in previous footnote.

These various associated practices that expand upon the original set of recommended practices are noted in part to indicate that SRI is eclectic, not dogmatic; inclusive and empirical rather than exclusive and fixed. SRI continues to ramify as a production system as farmer experience expands, and as more researchers having innovative inclinations get involved with working out the implications of the insights that gave original impetus to SRI.

1.3 Defining SRI

Being empirically developed and still 'a work in progress,' constructing definitions of SRI has not been a priority nor very fruitful. Drawing a line between 'what is SRI' and 'what is not SRI' is not very meaningful, although exploring these questions in a general way can be useful.[4]

Historically, SRI refers to the changes in management of irrigated rice production that were recommended by Fr. Laulanié based on his 34 years of work with farmers and with rice systems in Madagascar (Laulanié, 1993, 2003). He would be the first to insist that his ideas are not final and that they should be subject to further elaboration and revision, particularly by farmers. Thus today there is such a thing as *rainfed SRI*, developed successfully in Philippines (Gasparillo, 2003), northern Myanmar (Kabir and Uphoff, 2007), Cambodia (Anthofer, 2004), and eastern India (PRADAN, 2006, 2008). Farmers there and the NGOs working with them have gotten ideas and inspiration from the results of Fr. Laulanié's work with irrigated rice, adapting his concepts to unirrigated rice production. Rainfed rice yields averaged 7 ton/ha in

[4] Philosophers distinguish between definitions by *extension* and definitions by *intention*. The first employs terms and criteria to denote *everything that can be subsumed* under a particular definition; everything else *not included* under a definition is *excluded* – literally by definition. This binary way of looking at the world focuses on matters of *kind* and is not interested in matters of *degree*.

Definitions-by-extension are primarily concerned with setting *boundaries* that delimit a specified domain, implying that everything within certain boundaries is homogeneous, or at least similar to a significant extent, because all share some specified trait(s).

Definitions-by-intention are concerned less with boundaries than with specifiable *qualities* or *characteristics*. They acknowledge that particular traits and properties can be possessed *to varying extents*, and these extents are themselves of considerable interest.

The main impetus for definitions-by-extension is *classification*, whereas definitions-by-intention are more concerned with understanding *relationships*. A definitions-by-intention is most interested in what are the central, core or essential characteristics which differentiate things that share these descriptors from other things that lack them -- or that exhibit these qualities to a lesser degree. They focus more on the *connections* between certain qualities or properties and on their correlated *outcomes or effects*, not just on *the things themselves*.

Persons concerned with definitions-by-intention attach less weight to the way that things can be *categorized* because they appreciate that in the real world *a multiplicity of contingent causal factors* are operative. The *names* that are given to things through definitions-by-extension are therefore of less intrinsic interest for definitions-by-intention, who are more concerned with the *purposes* that are or can be served by the phenomena subsumed by a particular definition -- and with the *consequences* of entailed relationships.

carefully controlled trials in the Philippines and are now averaging this level for tens of thousands of poor farmers in India.

Transplanting young plants was at first the most innovative part of SRI practice, contributing the most to yield improvement. But farmers and researchers in several countries have been working with ***direct seeding*** of rice in association with the other practices: wider, square spacing, enrichment of soil organic matter, aeration of the soil, etc. Direct-seeding is consistent with the SRI principle that we should avoid trauma to rice plant roots. Highest SRI yields have come with very careful transplanting according to the original recommendations, rather than from direct seeding, so possibly there is some merit in having a mini 'shock' to stimulate the plant's growth, a hypothesis yet to be properly tested. The point here is that SRI is not *defined* by transplanting young seedlings, but rather by a set of principles and practices that are meant to be adapted and applied, with appropriate modifications, to concrete circumstances. Direct-seeded SRI can still qualify as SRI without transplanting any young seedlings.

The most distinctive *features* of plants grown according to SRI management are:

- *More profuse tillering*, starting about a month after transplanting,
- *More and larger panicles of grain*, often but not always with higher grain weight,
- *Much larger and healthier root systems* that remain functioning throughout the crop cycle,
- *Soil that is biologically more active*.

The first two features listed are easy to see and to measure, while the third is visible but only if plants are uprooted, which is not often done by farmers or by researchers. The fourth feature is difficult to observe and measure, but it is the basic source of SRI productivity, as it is for all agricultural production. Functionally, SRI can be defined as *those practices which can contribute to these four outcomes of rice cultivation*. Other results such as resistance to biotic and abiotic stresses and better grain quality are derivative from these features.

SRI can be defined technically by the key elements listed in 1.1. But none of these elements is, by itself, necessary or sufficient. It is *the complex of practices* that cumulatively, although usually used imperfectly or incompletely, will give better crop results. A farmer could use herbicides instead of doing soil-aerating weeding, but by following the other practices, he or she would be utilizing SRI precepts in a functional way. He or she could use mineral fertilizer instead of compost with young seedlings widely spaced and no flooding of the fields, and this could be regarded as SRI. Above we have characterized 'ideal SRI,' based not only on Fr. Laulanié's original recommendations but also on factorial-trial confirmations. In practice, we find that there are many 'SRIs,' not attaining the ideal practices or results but still worth supporting and giving net benefits to the farmers.

Actual adaptations of SRI concepts could be ranked along a continuum in terms of the ***degree*** to which they approximate the ideal, 25%, 50% or 75%. SRI methods are not a *package* but rather they offer a *menu*. We encourage farmers to be *adapters*, rather than adopters, making discoveries and decisions rather than following instructions, since SRI is seen as contributing to human development as well as food security (Laulanié, 2003).

If pressed to say whether or not a particular rice production system qualifies as 'SRI,' a simple definition could be that *more than half* of the key practices used are consistent with SRI recommendations, meaning at least 4 of the 6 listed above. Even within such an operationalization, there is some flexibility. With less fertile soil, using 2 plants per hill will give higher yield than single plants (until the soil fertility has been built up by continuing SRI use); or spacing with less fertile soil could be 20x20 cm instead of 25x25 cm, or wider. These practices will reduce the plant population even if not by as much as with 'ideal SRI.' There is little point in getting embroiled in definitional arguments. The SRI experience represents empirical relationships and results that should be continually re-examined and critiqued, so as to improve both scientific and practical understanding of how to create a better environment for growing rice plants (and other crops), with the effect of improving the productivity of the land, labour, water and capital invested in rice production.

1.4 Knowledge Involved

SRI is an innovation that is constituted entirely of knowledge. It is knowledge-centered and knowledge-intensive. It helps to have a simple soil-aerating mechanical weeder as this can improve yields without the use of fertilizer. But there are many designs for weeders, and one of the most important improvements for making SRI more attractive will be to have motorized weeders that are suitable for SRI practice, that are not too expensive, and that are easy to operate. This will save labour time and reduce drudgery. Other material inputs are optional -- compost, mulch, green manures, mineral fertilizers or biofertilizers, also biocontrols against pests or diseases, insect traps or bird perches, chemical spray. Some are more effective and more cost-effective than others. Weed control (more serious with SRI) and pest and disease control (less serious) are both important for good SRI results, but exactly which material inputs are best will depend on many factors, best evaluated by farmers themselves. Outside agencies should help to ensure that menus of appropriate choices are available.

SRI knowledge comes from a number of sources. It does not represent a triumph or vindication of traditional/indigenous knowledge because in fact, it alters, sometimes greatly, what rice-growing farmers have been doing for generations, even millennia – transplanting older seedlings, 3 to 4 weeks old, even 6 to 7 weeks; planting them together in clumps of 3 to 4 seedlings, even 7 to 10; closely spaced to have high plant populations; and keeping paddies continuously flooded, appreciating the weed control benefits that this confers but also considering standing water as a requisite for rice production when in fact it is an inhibition. By proposing use of young seedlings, widely spaced, in unflooded fields, Father Laulanié was contradicting centuries of farmer practice and was derogating the 'ways of the ancestors,' which are revered in traditional culture. His own special contribution to SRI was planting single seedlings in a square pattern coupled with the use of the rotating hoe (*houe rotative*) to control weeds made more numerous by no flooding; in the process he discovered the benefits of active soil aeration.

No farmer on his or her own would have started transplanting tiny, feeble seedlings, cutting plant populations by 80-90%, and stopping the flooding of rice paddies, as this would appear to jeopardize the food security of his or her household. A newly-transplanted SRI field looks miserable and unpromising (Figure 1). First-time SRI farmers during their first month are prone to self-doubt until rapid SRI tillering begins after about four weeks. Over and over we hear about how neighbours mocked the SRI farmers during that first month, but then began admiring the prospering field, asking how this impressive crop growth was obtained, often mistakenly thinking that this was due to some new and better variety rather than just to changes in practices. A few SRI farmers have even lost some of their crop to thieving neighbours at night who believed that the crop improvement was a varietal effect, not yet understanding that the effect was due to changes in crop management. How SRI plants can move from tiny seedlings to large, productive plants is seen in a series of pictures from Afghanistan, where a natural resource management project supported by EU funding introduced SRI in 2007 (Figures 2, 3 and 4).

Figure 1: Newly transplanted SRI field in Bali, Indonesia. Here, SRI rice has been nicknamed *Sim-sim-sala-bim* (disappearing) rice because the newly-transplanted SRI seedings are almost invisible. *Sim-sim-sala-bim* is word used by traditional magicians when performing disappearing tricks. (Picture courtesy of Made Setiawan)

Figure 2: Afghan farmers planting 11-day seedlings with 30x30 spacing in Baghlan Province at 1,700 meters, May 2008. (Picture courtesy of Ali Mohammed Ramzi, Aga Khan Foundation-Afghanistan)

Figure 3: Elderly Afghan farmer observing his SRI field 30 days after transplanting.
(Picture courtesy of Ali Mohammed Ramzi, Aga Khan Foundation-Afghanistan)

Figure 4: SRI plant with 133 tillers in field of Juma Gul, Baghlan province, 72 days after transplanting. AKF project staff calculated the yield from Gul's yield as 11.56 tons/ha. His yield with conventional methods on the same soil was 5.83 tons/ha.
(Picture courtesy of Ali Mohammed Ramzi, Aga Khan Foundation-Afghanistan)

It can be fairly easily explained and demonstrated that the observed improvements depend on gaining and utilizing new but simple knowledge on how to use existing resources more productively. The principles behind SRI – such a reduced plant population or use of compost to 'feed the soil, so that the soil can feed the plant' – are all supported by scientific knowledge. It can be explained to farmers, for example, how *crowding* rice plants reduces their lower leaves' exposure to sunlight and the capacity of these leaves for photosynthesis. As a result, these lower leaves of crowded plants end up taking from the supply of energy (photosynthate) rather than contributing to it, and this especially reduces the supply of energy to the roots (Mishra *et al.*, 2006). Or it can be explained to farmers how applying compost or organic matter, rather than mineral fertilizer, supports more abundant and diverse populations of soil organisms, and how these in turn render many services to rice plants – fixing nitrogen (diazotrophic bacteria), solubilising phosphorus (phosphobacteria), cycling nutrients(protozoa and nematodes), expanding the volume of soil from which water and nutrients can be acquired (mycorrhizal fungi), producing phytohormones (many aerobic bacteria and fungi), and also inducing systemic resistance to pests and pathogens (contributed by various microorganisms) (Randriamiharisoa *et al.*, 2006).

Farmers do not need to know all the scientific reasons for the efficacy of SRI practices, but the principles can be explained and communicated without much formal educational requirements. Some of the knowledge which undergirds SRI is not even well known among agricultural scientists – such as that *soil* microorganisms that inhabit the leaves of rice plants can enhance the plants' chlorophyll levels, rates of photosynthesis, and resulting yield (Feng *et al.*, 2005). SRI is an innovation where the knowledge base is itself not neatly defined or entirely agreed upon, but that does not prevent it from benefiting farmers willing to try out the recommended practices.

It should be noted that some of the practices involved in SRI were known and used in the past by farmers. Farmers who won the national rice-yield competitions in Japan after World War II used many SRI practices, according to Horie *et al.* (2005). Indeed, some of the ancient rice-growing practices used in China had definite similarities with what is now known as SRI (Yuan Long-ping, pers. comm.). SRI was not a discovery or creation of anything new, but rather an assemblage and synthesis of practices that capitalize upon existing productive potentials within the genome of plants in the rice genus (*Oryza*). Happily, these practices also are conducive to better performance of other plants in the grass family (*Gramineae*) and even for plants in other botanical families. Although SRI knowledge has been developed inductively, as noted above, it is linked to a wider body of knowledge and practice that has both scientific and farmer-based foundations.

1.5 Key Actors

SRI can be characterized as *a civil society innovation* (Lines and Uphoff, 2006), but the methodology has evolved to include now a variety of institutional agents. When Fr. Laulanié began working on rice in Madagascar in the early 1960s, there were few institutional partners with scientific knowledge to work with, so his main collaborators were necessarily farmers. Once he and local friends were confident that they had learned how to capitalize on productive potentials in the rice plant, they formed a non-governmental organization (NGO) in 1990, *Association Tefy Saina* (www.tefysaina.org), to spread this and other innovations The Malagasy name *Tefy Saina* does not mean 'grow more rice' but rather 'improve the mind/mentality' because the priest and his local colleagues were concerned not only with people's economic development, but also with the social, cultural and even spiritual dimensions of human progress (Laulanié, 2003). Thus from the start there was a humanistic vision for SRI, not just a technical agronomic conception. This could be one reason why there has been resistance to SRI from some quarters of the rice science community even though *Tefy Saina* itself is a secular service organization.

The initial consortium that conducted research on SRI in Madagascar, starting in 1999 with a small grant from the Rockefeller Foundation, was institutionally pluralistic. The partners were, along with *Tefy Saina*, researchers from the University of Antananarivo and FOFIFA, the government's agency for agricultural and rural development research, assisted by the Cornell International Institute for Food, Agriculture and Development (CIIFAD), which facilitated and managed the grant.

Such a multi-sectoral 'alliance' is typical of the way that SRI work has proceeded, country by country, with different combinations of government and non-governmental actors along with university, research institution and private sector participants taking initiative and responsibility together with a variety of farmer and community-based organizations (see Figure 4 in Uphoff, 2007). The partnerships have each evolved according to the institutional capacities in a country and reflect the personal interests and engagement of individuals who are attracted by the potential of SRI methods to benefit simultaneously farmers, consumers and the environment, and who want to support the realization of this potential.

The concept of comparative advantage guides the division of labour that evolves in each country setting, with different institutions and individuals taking the lead or sharing responsibility according to capacities, interest, and time availability. There has been more concern for learning and results than with authority and status, exemplified by the 'learning alliance' model developed in Orissa and given support by the Sir Dorabji Tata Trust to be established in other states of India (Shambu Prasad e*t al.*, 2007; Shambu Prasad, 2007). Some examples of how leadership for SRI evaluation and extension has been given by different kinds of institutions – governmental, NGOs, university, private sector, etc. – are given in section 2.0 with reference to the spread of SRI and impact.

SRI is an innovation which nobody can 'own' or 'monopolize'. There are no intellectual property rights to be claimed for SRI, which has been in the public domain for 15 years (Laulanié, 1993), and it cannot be patented. SRI practices like timing or spacing could hardly be controlled or regulated for purposes of collecting royalties of licensing fees. So although SRI can produce immense benefits, these are cannot be privately appropriated and controlled like a new seed variety, or agrochemicals, or farm implements. This has some drawbacks, to be sure. There are no commercial interests spending money to promote SRI because they can profit from the sale of 'SRI inputs', indeed, input sales are reduced. No business representatives get commissions from SRI adoption.

This said, there has been significant support from the private sector in a number of countries where there are convergent interests.

- A technical assistance team for the private Japanese consulting firm Nippon Koei has given effective leadership for introducing SRI in eastern Indonesia (Sato and Uphoff, 2007). It recognized that a methodology which reduces water requirements while raising the yields and profitability from rice production could make the irrigation management project being implemented more successful, both for the farmers participating in it and in terms of the economic rates of return which would satisfy the government and donor agency (JBIC).
- Syngenta Bangladesh Ltd. has been a member of the SRI National Steering Committee in Bangladesh since 2002. It had demonstrated to its own satisfaction that SRI methods could

make its seed-multiplication operations more profitable, so it has helped evaluate and publicize SRI more broadly (Hussain *et al.*, 2004).

- The largest processor and exporter of basmati rice in India, Tilda Riceland Pvt. Ltd, is promoting SRI practices among the farmers with whom it works because these practices are giving improved grain quality: increased head rice (unbroken grain) recovery from milling; reduced chalkiness; and fewer damaged, discoloured or immature grains.
- The Andhra Pradesh State Rice Millers' Association began producing and circulating calendars and brochures to promote SRI use in 2004, having learned that SRI paddy rice gives higher milling outturn (more kg of polished rice per bushel/bag of unmilled rice).

So while government, NGO and university partners have been the main actors in the diffusion of SRI, there have been private-sector actors as well.

1.6 International Actors

The main international role has been played by the Cornell International Institute for Food, Agriculture and Development (CIIFAD), which learned about SRI from *Association Tefy Saina* in Madagascar in 1993. Because the benefits from SRI management appeared 'too good to be true,' CIIFAD made no effort to promote SRI until 1997, after three years of trials and demonstrations had been conducted on farmers' fields under a USAID-funded conservation and development project which it was helping to implement. The farmers whom *Tefy Saina* leaders and field agents persuaded to try the culturally-strange methods got average yields of >8 tons/ha -- without planting new varieties, without relying on mineral fertilizer, and with less requirements for irrigation water -- on very poor soils (Johnston, 1994) where paddy yields had previously averaged 2 tons/ha. Only after 1997 did CIIFAD begin trying to get the methods evaluated in other countries.

It took two years for CIIFAD to get any rice scientists outside of Madagascar to evaluate these 'incredible' methods. But trials at Nanjing Agricultural University in China in 1999 and then at the Sukamandi rice research station of the Agency for Agricultural Research and Development in Indonesia in 1999/2000 confirmed the kind of improvements in factor productivity that were being seen in Madagascar. International efforts to get SRI more widely evaluated and, where results justified this, extended began only after 1999.

A major step forward was the convening of an international SRI conference in China in 2002, with participation from NGOs, government agencies, research institutes and other organizations from 15 countries. The meeting, made possible by a small grant from the Rockefeller Foundation, was co-sponsored by the China National Hybrid Rice Research and Development Center, the China National Rice Research Center, *Association Tefy Saina* and CIIFAD. It was hosted by Prof. Yuan Long-ping, director of the National Hybrid Rice Center and known worldwide as 'the father of hybrid rice.' He reported a yield of 16 tons/ha the previous year at his seed multiplication farm in Sichuan Province (Yuan, 2002).

Most of the reports from the 15 countries, but not all (Nepal and Thailand were exceptions), indicated that SRI methods could greatly improve rice productivity in a wide variety of agroecosystems (Uphoff *et al.*, 2002). The Sri Lanka delegation which included a Deputy Minister of Agriculture, a Senior Assistant Secretary of Agriculture, and an innovative organic SRI farmer represented the range of persons involved with SRI as well as some of the outstanding results. The farmer had gotten yields of 10-15 tons/ha from his first year of SRI trials, and the Deputy Minister reported SRI yields as high as 16 tons/ha on his own paddy farm using an improved variety, and 13 tons/ha with a popular local variety.

Unfortunately, such reports were dismissed by most rice scientists, not so much those in national agricultural research systems as in international organizations (and at Cornell University), as being 'anecdotal' or not properly documented. A number of articles critical of SRI were published following the Sanya conference (Dobermann, 2004; Sheehy *et al.*, 2004; Sinclair and Cassman, 2004; Sinclair, 2004; McDonald *et al.*, 2006), but not by persons who had themselves worked with SRI or who had talked with farmers who had used the methods. The rejections relied on secondary data or questionable models, or on results from a few small trial plots on which SRI protocols had not been properly followed (Stoop and Kassam, 2006; Uphoff *et al.*, 2008).

Why SRI should have been received in some agronomic circles with so much vehemence rather than curiosity is beyond the scope of this chapter. The national rice research institutions in the three largest rice-producing countries, China, India and Indonesia, have validated the methods and recommended them to their governments (e.g., Gani *et al.*, 2002; Swaminathan Sub-Committee, 2006; Yuan, 2002; Zhu, 2006). We simply note here that SRI methods have been more controversial at the international level that at national levels, and they have seldom been controversial at local levels once the methods have been tried out.

1.7 Potentials for Sustainability

No definitive conclusions can be drawn in the present about the sustainability of an innovation in the future, because nobody can know all of the conditions or pressures that could arise. It is more feasible to conclude what innovations are *not* likely to be sustainable by looking at the demands they make on natural ecosystems, on stocks of non-renewable resources, on social organization, etc.

Given the very high yields being obtained with SRI methods, many soil scientists are sceptical that these levels can be sustained. Since SRI is a rather new innovation, there are no time-series data more than about 10 years, but where yields have been tracked over time, in almost all cases, yields have been sustained or even increased – provided (and this is a major provision) that the soil systems have been continually supplied with organic matter, to sustain sufficient substrate for the soil biota. SRI is not necessarily ‘organic,’ so if at some point in the future there are specific nutrient deficits encountered that could be redressed, such as phosphorus or zinc, nothing in SRI restricts making such amendments.

What SRI experience has shown is that trying to raise yields by amplifying the concentrations of inorganic sources of nutrients in anaerobic soil is less successful than mobilizing elements within the atmosphere (nitrogen, carbon, oxygen) and nutrients within the soil (phosphorus, potassium, and myriad micronutrients) in ‘demand-led’ rather than ‘supply-driven’ processes that link plants and soil components, particularly the soil microorganisms (Uphoff *et al.*, 2006). The latter regulate and literally animate endogenous soil processes and potentials to an extent that is greatly understated in conventional soil science. Its body of literature is heavily based upon soil analyses that assess soil under *axenic* conditions, i.e., where all life in the soil has been eliminated by sterilization or fumigation so that there is no biological activity to create variance or ‘noise’ in the results that would make replication of results difficult. This is like conducting medical research only on cadavers.

SRI methods enhance, rather than detract from, soil fertility and hence they improve soil health and productive capacity. They involve adding organic matter to the soil, of course, but they also induce much greater root growth, both reaching greater depths in the soil (Table 2) and having more complex, branched root systems that are reflected in the resistance to uprooting which can be measured as a proxy for total root system development (Ekanayake *et al.*, 1986) (Table 3). The larger, deeper, more articulated root systems, supported by the greater photosynthesis occurring in the larger SRI canopies, put greater volumes of organic matter into the soil through the exudation of carbohydrates, amino acids, organic acids and other compounds from plant roots into the rhizosphere, the soil around the roots. When soil systems are not kept continually flooded (i.e., when they are aerobic) and the top horizon is frequently mechanically aerated, with a greater supply of organic matter for the soil biota, such soils can increase fertility and productive capacity through biological activity: fixing nitrogen, solubilising phosphorus, cycling nutrients, accessing more micronutrients, etc.

Table 2: Root length density (cm cm^{-3}) under SRI, SRA and conventional systems

Treatments	Soil layers (cm)					
	0-5	5-10	10-20	20-30	30-40	40-50
SRI with compost	3.65	0.75	0.61	0.33	0.30	0.23
SRI without compost	3.33	0.71	0.57	0.32	0.25	0.20
SRA with NPK and urea*	3.73	0.99	0.65	0.34	0.18	0.09
SRA without fertilization*	3.24	0.85	0.55	0.31	0.15	0.07
Conventional system	4.11	1.28	1.19	0.36	0.13	0.06

* SRA is the Système du Riziculture Ameliorèe, system of improved rice cultivation promoted by the Madagascar government based on best management practices, including use of chemical fertilizer, plus higher plant populations than with SRI and continuous flooding. Source: Barison (2003).

Everyone needs to be concerned with sustainability of all agricultural production systems as we begin this 21st century, when conditions are or are becoming different from those of the preceding decades. We have less and less arable land available per capita, so land must be used as productively as possible, making the ‘extensive’ agriculture of the 20th century less economic than previously. Water resources are becoming scarcer and more unreliable as climate change begins to affect rainfall patterns and ambient temperatures; so getting ‘more crop per drop’ is an urgent need. Energy prices have risen considerably from those under which Green Revolution technologies were developed and large-scale mechanized production flourished. So the economics of agricultural technology need to be reconsidered.

Table 3: Comparison of root-pulling resistance (RPR), in kg, at different stages

Treatments*	RPR at panicle initiation	RPR at anthesis	RPR at maturity	Decrease of RPR between anthesis and maturity (%)
SRI with compost	53.00	77.67	55.19	28.69
SRI without compost	61.67	68.67	49.67	28.29
SRA with NPK and urea	44.00	55.33	34.11	38.30
SRA without fertilization	36.33	49.67	30.00	39.40
Conventional system	22.00	35.00	20.67	40.95

* Note that the SRI hills for which RPR was measured contained 1 rice plant; the SRI hills contained rice plants; and the conventional-system hills contained 3 rice plants. So the per-plant RPR was more than 3 times greater for SRI plants vs. SRA plants, and more than 8 times greater for conventionally-grown plants.
Source: Barison (2003).

Many features of SRI make it a much better candidate for sustainability than the currently-favoured agricultural technologies.

- Most are 'thirsty' technologies, whereas SRI reduces the water requirements for rice production and makes it financially attractive for farmers to stop flooding their paddies.
- Most depend on purchased inputs, the majority of which are derived from petrochemical sources, whereas SRI reduces such dependence; this is important as the relation between supply of and demand for petroleum becomes more strained in the future.
- Most of these other technologies are reducing biodiversity, whereas SRI can make greater biodiversity in the rice sector more profitable.

In general, SRI enables farmers to produce *more outputs with reduced inputs*. This should in itself contribute to making production more sustainable, especially in comparison to other current technologies which are land-extensive, water-using, chemical-dependent, and energy-intensive. We cannot and do not want to make any broad claims about SRI sustainability because experience with it is limited in time. But there are many reasons to regard it as inherently more sustainable than other methods for food production because it moves away from the technology strategy of creating artificial conditions with heavy inputs of energy and other exogenous materials, toward relying more upon existing potentials within plants and the natural ecosystems in which they can thrive.

SRI is not necessarily a stand-alone innovation. Some of its principles, such as the enhancement of soil organic matter and soil aeration, wider spacing for greater root and shoot growth, and reduced soil disturbance, are relevant to almost all crop production. As discussed below, its practices and thinking are being extrapolated to other crops already, such as wheat and sugar cane with good results (e.g., Mahalakshmi, 2006; Prasad, 2008). In China, the China Academy of Agricultural Sciences has begun introducing SRI concepts and practices into the rice-wheat rotational cropping system, a system that covers 22 million hectares at present in China and South Asia, not just for yield improvement but for reductions in water requirements and in agrochemical applications (Dr. Zhai Huqu, CAAS president, personal communication, 1/15/09).

Focusing on the enhancement of soil fertility and its productive capacity through revisions in the management of plants, soil, water and nutrients, seeking to mobilize and benefit from the soil biota, is a different approach for agricultural development than most current approaches. It is one that we believe should be pursued as much for its sustainability potentials and its positive impacts on the environment as for the productivity increases that it can accomplish.

It is not proposed as a total strategy, to replace all other methodologies, but as an augmentation and refocusing of present agricultural development efforts. Given objective changes in the context of agricultural production – less land and water per capita, rising energy prices, climate change, and greater concern for protecting the quality of soil, water and air – an alternative approach acquires more logic and justification, especially as decision-makers pay more attention to the probabilities of sustainability.

2. CURRENT RELEVANCE AND APPLICATIONS

Thus far, SRI has not had the kind of resource investments in its dissemination that match the large and expensive efforts made to promote Green Revolution technologies. Moreover, the spread has occurred in the face of opposition and criticism from various quarters. Even so, the diffusion has been unprecedented, because the results can be so compelling. Four years ago, there were probably less than 30,000 hectares of SRI use outside of Madagascar, whereas today this area is over 1 million hectares. Where government agencies have gotten involved in SRI dissemination or where NGOs have had sufficient resources for their extension activities, the spread has been quite rapid as seen in Table 1 (at the end of the study).

Much of the spread of SRI methods has been farmer-to-farmer, for example:

- Following from Farmer Field School training as in northern Myanmar where once one-third of the farmers in a village had learned the methods, within three years there was almost full-village adoption (Kabir and Uphoff, 2007). With training of less than 10,000 farmers, SRI use has spread to over 50,000.
- In Cambodia, a survey of 120 farmers who had practiced SRI for three years found that they had promoted SRI to an average of 16 persons each, to a total of 969 farmers within their respective villages and to 967 farmers outside (Tech, 2004).

The data on SRI adoption are fragmentary and often not comparable, because there has been no funding for tracking SRI use. The spread of SRI has occurred through a completely decentralized process, country-by-country. Moreover, monitoring is made more difficult because this innovation is not like the adoption of an improved-variety seed or the purchase and use of an external input, but rather it involved the utilization of new practices. Most farmers who say that they are practicing SRI, or who are counted as such, are probably not using all of the recommended practices, or are not using all as fully or carefully as recommended. Even so, they are achieving impressive yield and factor productivity improvements even with partial utilization of the system. This means that there are still further yield and productivity gains to be achieved with better use of SRI methodology, judging by results from where the practices have been well and fully used.[5]

[5] This difference can be seen in data from northern Myanmar in Table 1 on farmers' yields in Farmer Field School demonstration plots, where there was more complete use of SRI practices, compared to their results on their own farms were use was more partial. Note also that SRI yields increased as farmers and FFS instructors became more knowledgeable about and comfortable with the new methods, using them more effectively. An economic analysis showed that even *incomplete* use of SRI methods increased farmers' net incomes from rice production increased almost eight-fold because yields increased with some reduction in costs of production (Kabir and Uphoff, 2007). Kachin and Shan State farmers were previously operating with very little profit from their rainfed rice production.

2.1 Distribution by World Regions

1. Asia: Most of the uptake of SRI methods has been, not surprisingly, in Asia, where 90% of the world's rice is produced. The countries reported on in Table 1, where SRI is getting well-established, represent two-thirds of the world's rice production. While SRI is still not covering large areas in total, the Department of Agriculture in Tamil Nadu state of India estimates that the methods are used on about 750,000 hectares, one-third of its rice area, and in Zhejiang province in China, extension personnel in Jia Xing township report that 80% of the rice area there was under SRI management already in 2007.

Given that SRI spread really began only about four years ago, more significant than the total SRI area or number of farmers at present are the rapid rates of uptake where the validity and value of SRI methods have been demonstrated to farmers and researchers' satisfaction. SRI has gotten started in all rice-producing countries of South, Southeast and East Asia except for Malaysia, the Republic of Korea, and the Democratic People's Republic of Korea; and all three are expected to begin their own evaluations in 2009.

2. Africa: Except for Madagascar, the country of SRI origin, there has been no major spread of the new methods in this region. The Minister of Agriculture in Madagascar estimated in 2006 that over 200,000 farmers were using SRI methods in his country (H.E. Randriarimanana, pers. comm.) That the methods can raise yields with lower water and other input requirements has been shown in many countries -- Benin, Burkina Faso, Democratic Republic of Congo, Gambia, Guinea, Mali, Mozambique, Rwanda, Senegal, Sierra Leone, and Zambia (http://ciifad.cornell.edu/sri/). This indicates that SRI dissemination could address food security needs across much of the continent.

3. Latin America: The country in this region which was first to take up SRI methods was Cuba where the methodology is known as SICA (*Sistema Intensivo de Cultivo Arrocero*). The validity of SRI practices has also been demonstrated in Brazil, Ecuador, Peru, and Costa Rica, although there has been little uptake so far. The main obstacle to adoption in this region seems to be the reluctance of rice farmers in Latin America to transplant rice by hand, favouring mechanized methods, given the costs and availability of agricultural labour. However, recently a farmer in Costa Rica has adapted a Chinese implement to transplant young single seedlings in a square pattern with an SRI spacing (22 x 30 cm), obtaining a yield of 8 t/ha vs. the national average yield of 4.2 t/ha (http://ciifad.cornell.edu/sri/countries/costarica/index.html). This could make it easier for the productivity benefits from SRI practices to be adapted to larger-scale production in Latin America than is common in Asia.

4. Middle East and North Africa: The rice research institutes in Iraq, Iran and Egypt have all demonstrated the efficacy of SRI management methods (Figure 5). In the first season of on-farm trials in Baghlan Province of Afghanistan, supervised in 2007 by the Aga Khan Foundation with EU funding, there was vigorous tillering but insufficient grain filling. The SRI trial plots gave only 3 t/ha compared with 6.5 t/ha using usual methods; but the planting was done one month later than normal, and at an altitude of 1700 m elevation, where the growing season is short (see Figure 2). Fortunately, farmers were not deterred by the initial results, having been impressed by the tillering they saw. In 2008, with better timing, SRI plots averaged 10.13 t/ha while farmers' control plots cultivated with regular methods on the same farms yielded 5.41 t/ha (http://ciifad.cornell.edu/sri/countries/afghanistan/AfgAKFfinalrpt08.pdf).

Figure 5: Varietal trials comparing SRI with conventional methods at Al-Mishkhab Rice Research Station, Najaf, Iraq. (Picture courtesy of Dr. Khidhir Hameed, MRRS)

SRI trials supported in Morocco in 2008 by WWF gave no satisfactory results. The farmers in the Gharb region, not accustomed to 'intensive' methods, did not manage water as recommended. The results were not good enough, as in Afghanistan, to encourage a second year of trials. This is the least successful demonstration that we know of, confirming that SRI methods can fail under certain biophysical or socio-economic conditions. However, in general, the methodology has remarkable versatility and robustness.

2.2 Distribution by Agroecosystems

SRI methods have been successful in a wide range of environments. In China, they have given benefits from tropical Hainan province in the south, to the northern province of Heilongjiong near Manchuria (Jin *et al.*, 2005). In South Asia, SRI methods have produced good results from low-lying Bangladesh (http://ciifad.cornell.edu/sri/countries/bangladesh/index.html) to mountainous Bhutan (http://ciifad.cornell.edu/sri/countries/bhutan/index.html). In Nepal the practices have been beneficial from 70 meters above sea level in the *terai* up to 2,700 meters.

Within India, probably the most diverse country in Asia, a survey by WWF has determined that SRI is started already in 218 of the country's 564 rice-growing districts, from Tamil Nadu in the south to Himachal Pradesh and Jammu in the north, from Tripura in the east to Gujarat in the west (http://sri-india.110mb.com/documents/SRI_INDIA_A4.pdf). The initial evaluation of SRI done in Andhra Pradesh state in 2003 encompassed all of its 22 districts with a wide variety of soils and climatic conditions. Side-by-side comparison plots, each 0.2 ha, supervised by the state agricultural university and extension service, showed a yield advantage for SRI methods across the whole state. This ranged from 1.8 t/ha in the low-lying coastal areas with their heavy, moist clay soils, to 4.8 t/ha in the interior Rayalseema region with lighter, well-drained soils and much lower rainfall (Satyanarayana *et al.*, 2006).

In Africa, the country where SRI was developed (Madagascar) has diverse soils and climates ranging from warm coastal areas to cooler higher elevations on the central plateau. While factorial trials have shown better results in the latter, the same pattern is seen at both extremes. When all-SRI practices are used, 100-200% increases resulted compared with conventional practices of older seedlings, 3 per hill, continuous flooding, and NPK fertilization (Randriamiharisoa and Uphoff, 2002). In West Africa, SRI benefits have been documented in the sub-humid lowlands of The Gambia (Ceesay *et al.*, 2006) as well as in the Timbuktu region of Mali which is on the edge of the Sahara Desert (http://www.erikastyger.com/SRI_Timbuktu_Blog/SRI_Timbuktu_Blog.html). This confirms that alternative management practices that focus on improving soil biological processes while also enhancing root growth can improve agricultural productivity significantly (e.g., Figures 6 and 7).

[Figures 6 and 7 about here]

Figure 6: Bourema, first farmer in Burkina Faso to use the new methods effectively, showing root growth on single SRI plant that led to a paddy yield of 7 t/ha in 2006. (Picture courtesy of Timothy Krupnik)

Figure 7: Malian farmer in Timbuktu region comparing SRI rice plant on right with plant grown conventionally on left. Trials in 2007 and 2008 gave yield of 9 tons/ha with SRI practices compared to 6.7 tons/ha with best management practices. (Picture courtesy of Dr. Erika Styger)

2.3 Distribution by Farm Types

SRI methods were developed explicitly to benefit smaller, resource-limited farmers in Madagascar, but because the innovation is based on biological processes more than on exogenous inputs, it has proved to be essentially scale-neutral. To the extent that SRI methods can be more *labour-intensive*, at least during the first year or two while farmers are gaining experience and skills with the new methods, this can favour smallholders. However, labour-intensity can be a barrier to adoption for very poor households that do not have sufficient income flows or reserves to be able to afford investing more labour in SRI, even if this investment would yield higher returns and they know this (Moser and Barrett, 2003). Such a constraint lies in the socio-economic and institutional context, however, rather than in the innovation itself. While it is recognized that the poor could benefit (most) from the innovation, unless imperfections in the credit market can be overcome, poor farmers can be prevented from taking up SRI. Further evaluation of SRI use in Madagascar have documented that the initial labour-intensity of SRI use can be converted to labour-saving once experience with the methods is gained (Barrett *et al.*, 2004).

In other evaluations, it has been found that SRI methods can be labour-neutral or labour-saving from the beginning, and that adoption rates may not vary between economic strata. A study by researchers with the International Water Management Institute in Sri Lanka, based on random samples of SRI and non-SRI farmers in two districts, found no significant difference in adoption rates between poor and rich farmers (Namara *et al.*, 2008). A socio-economic evaluation of a village in Sichuan province of China, where SRI use had gone from 7 farmers in 2003 to 398 farmers in 2004, did a wealth-ranking analysis of these adopting farmers (N=398) compared to all the households in the village (N=612). No real difference was found between well-off, medium and poor farming households (Li *et al.*, 2005). Further, SRI adopters ranked *labour-saving* as their most important reason for their adopting SRI, even in their first year.

On the other hand, because SRI is based on more intensive and careful management of the crop itself, smaller farmers do have some inherent advantage with SRI methods. They are better able to monitor the crop and address its needs than can larger farmers who cultivate more extensively. However, that SRI is not necessarily a labour-intensive methodology is seen from a number of studies that have shown SRI to be labour-saving or at least labour-neutral on average (Sinha and Talati, 2007; Sato and Uphoff, 2007; Anthofer *et al.*, 2004; Thiyagarajan, 2004). The rapid spread of SRI use in Zhejiang province of China is attributed by the extension service there to SRI methods being labour-saving -- in addition to being seed-saving, water-saving, and cost-reducing (Gao Song Lin, director of Technology Extension Center, Xia Zhou county, pers. comm.).

In India, large farmers have cultivated as many as 80 hectares of rice with SRI methods, so these are not limited to small farmers, and with the introduction of mechanization for transplanting and weeding (see reference to Costa Rican innovation above), adaptation of SRI insights and practices will be increasingly extended to larger-scale production. This will not deprive small farmers of the benefits they can get from the methods, however, and the increased production of rice with lower costs of production should reduce market prices while still enhancing farmer incomes, so that urban poor can also gain from the new methodology.

3. LIMITATIONS AND CONSTRAINTS

While SRI ideas and practices can be adapted to a wide range of conditions, they should not be regarded as applicable and beneficial for all farmers and all areas. Any biological process is bound to have limitations, although some of these may be malleable, altered by further innovation or by learning and experience. There are a number of constraints that need to be considered with respect to SRI;

3.1 Water Control

Unless the paddy soil can be kept in mostly aerobic condition, neither the rice plant roots nor the soil organisms needed to obtain more productive phenotypes will thrive, so this is the most important and objective constraint for SRI utilization. There can be benefit from using the other SRI practices, but given the centrality of aerobic soil to the synergy among the practices, we flag this requirement as most important for capitalizing on SRI opportunities. SRI will be most feasible and profitable where there is good water control, such as with tubewell irrigation, and farmers pay for the water used and have an incentive to curtail use, unlike in most gravity-flow systems.

In most situations where there is little capacity to maintain moist but not saturated soil, some combination of *hardware* (modified infrastructure for water application such a field channels to replace field-to-field, cascade water distribution; plus soil drainage facilities where needed) and *software* (water user organizations and better administrative structures and operation) can achieve greater capacity to apply smaller amounts of water regularly and reliably, or to replenish field water supply periodically. The greater economic returns that SRI methods can give should provide farmers with strong incentives to cooperate, and they can justify considerable investment by government and donor agencies since water is becoming ever scarcer and more valuable.

It is likely that direct-seeded rice using SRI principles with Conservation Agriculture practices will provide a more robust system to cope with poor water control, but more research needs to be done in this area. In situations where rainfed wetland or flooded rice is grown, it can be difficult to create the appropriate SRI soil-moisture conditions unless some form of drainage can be installed. In some situations such as in the monsoon season in Bangladesh when it is not possible to drain inundated fields sufficiently to maintain aerobic soil conditions, SRI methods will not achieve their usual improvements in productivity.

3.2 Labour Availability

As noted already, at least during initial use of SRI methods, when new techniques are being learned, there are greater labour requirements. This can be a constraint or deterrent to farmers for changing rice-growing practices, especially very poor ones who need to invest most or all of their labour in immediate income-earning opportunities (Moser and Barrett, 2003). At first it appeared that labour-intensity was the ‘price’ to be paid for getting the many benefits of SRI, accepting that there had to be some tradeoff. But evidence has accumulated that, because plant populations are reduced so radically, by 80-90%, SRI does or can become labour-saving, especially as farmers develop labour-saving implements, such as rake-markers and roller-markers that can reduce transplanting time.

Most farmers now report labour-saving in their transplanting operations, but weed control requires more labour when their rice fields are not kept continuously flooded, and weed growth is greater. The development of better manual weeders has reduced this constraint, and now motorized weeders are being developed that will cut labour requirements for weeding significantly. Even simple tools can reduce labour constraints (e.g., Figure 8). So can modifications of SRI practices that optimize returns to labour, such as alternate wetting and drying (AWD) of fields rather than careful water management. AWD can enhance farmers’ net incomes even if it does not maximize yield.

Figure 8: Simple SRI weeder developed by Govind Dhakal, Indrapur, Nepal, costing 20 cents to make. With this tool, 1 hectare can be weeded in 4 person-days compared to 25-30 person-days with usual hand weeding methods. (Picture courtesy of Rajendra Uprety, District Agricultural Development Office, Biratnagar, Nepal)

3.3 Biomass Availability

SRI is not necessarily an ‘organic’ production practice although as much application of organic matter to SRI fields is recommended. Fr. Laulanié used mineral fertilizer when developing SRI in the 1980s; however, when fertilizer subsidies were ended at the end of the decade, compost was used instead and he found out that when the other SRI methods are used with compost, best results could be obtained (also farmers’ costs of production could be reduced) by relying fully on organic matter for soil fertilization. As important as the nutrients that compost supplies to the soil is the *improvement in soil structure and functioning* that organic matter can induce through its support of soil biota. Also, as explained earlier, SRI methods can increase the production of biomass within the cropping system and sequester more of its carbon through minimizing soil tillage and puddling, and by introducing high-biomass cover crops and legumes into the rotation, including the release of cropping time due to earlier sowing and maturation of SRI rice.

For SRI rice production, it is not necessary to have livestock and to use farmyard manure. Good results can be achieved with any decomposed biomass (rice straw, grass cuttings, weeds, shrub material, household waste, etc.). Further, farmers who do not have access to enough biomass to practice ‘organic SRI’ can get benefit from using the other SRI practices with mineral fertilizer. We note and regret that very little investment has ever been made in research and development for improving the production, collection, transport, processing and application of biomass for improving soil fertility. The science and practice of organic fertilization has languished for decades because it has been so convenient (and cheap, if mineral fertilizer was subsidized) to rely on inorganic fertilization. However, the cost of mineral fertilizers has been rising as energy prices increase, and as governments are increasingly unwilling or unable to maintain input subsidies. So the relative attractiveness of and access to mineral fertilizer is changing. The productivity of SRI makes investments in the production and use of organic fertilizers more profitable. It also justifies more research and development activity on the growing and utilization of appropriate plant materials, including ferns like azolla, and on labour-saving techniques and implements for managing organic material.

3.4 Crop Protection

Usually, SRI rice crops are more resistant or less vulnerable to damage from pests and diseases, as seen from Table 4. The National IPM Programme in Vietnam assessed the incidence of four major diseases and pests for rice crops in that country across 8 provinces in spring and summer seasons. Its evaluation showed 55-70% lower rates of disease and pest prevalence with SRI vs. conventionally-grown rice plants of the same variety in adjacent plots. Similar reductions have been documented in evaluations by Tamil Nadu Agricultural University in India (Thiyagarajan, 2004).

Table 4: Disease and pest incidence with SRI vs. standard farmer crop management in Vietnam, for two growing seasons in 2005-06 averaged across trials in 8 provinces

	Spring season			Summer season		
Disease/pest	SRI Methods	Farmer Methods	Difference (%)	SRI Methods	Farmer Methods	Difference (%)
Sheath blight (%)	6.7	18.1	63.0	5.2	19.8	73.7
Leaf blight (%)	--	--	--	8.6	36.3	76.5
Small leaf folder*	63.4	107.7	41.1	61.8	122.3	49.5
Brown plant hopper*	542	1,440	62.4	545	3,214	83.0
AVERAGE			55.5			70.7

* Insects/m^2 Source: National IPM Programme (2007).

One explanation for the reduced susceptibility to biotic stresses, although no research has been done on this, could be that the basically organic and biotic practices of SRI contribute to natural resistance, consistent with the theory of trophobiosis (Chaboussou, 2004). This theory deals with crop losses from microbial, viral and invertebrate sources, although it does not cover vertebrate pests such as birds and rats). Farmer reports on losses from these latter sources show no consistent pattern, with some reporting more loss, others less loss, and still others saying no difference.

Even if there is less overall incidence of damage, farmers need always to be vigilant and possibly to take protective action against pests and diseases. SRI being agroecologically-oriented favours integrated pest management (IPM) practices, including crop diversification, soil organic matter enhancement to support food-web pathways for natural pest control, and providing a balanced supply of required plant nutrients. Another reason why biotic stresses may have less impact is because SRI plants, with their bigger and longer-lived root systems in soils that have higher moisture-holding capacity, are also more resistant to abiotic stresses – particularly drought and extreme temperatures. There is not much that farmers can do to protect against these other than to grow plants that are more 'climate-proof,' which is often the case with SRI-based rice crops.

3.5 Farmer Attitudes and Psychology

The largest and most pervasive constraint for SRI adoption is a subjective one: farmers' thinking and willingness to change. Farmers need a certain amount of skill and motivation to use SRI techniques successfully. A newly-planted SRI field looks very unpromising for the first month or so (Figure 1), but by the fifth week or so the plants can be seen to start tillering vigorously. What is not seen, unless farmers inspect them, is the profuse growth of roots as well. Overcoming scepticism and mental resistance usually requires physical demonstration, or visits to see SRI fields that are growing as explained. Visiting demonstration plots and farmer-to-farmer communication are usually the most effective way to overcome resistance, although illustrated materials and visual displays, e.g., DVDs, can also be effective.

Farmers are concerned about what they perceive as the riskiness of the methods, even though evaluations and experience show economic and weather risks to be reduced by SRI methods (Uphoff, 2007). The confidence of those communicating about SRI is a key element in gaining acceptance. When researchers and extension personnel are uncertain about or – as is sometimes the case --are opposed to SRI methods, farmer apprehensions are reinforced and magnified. It can be hard to compete with input-dependent agricultural improvement because of convictions that this is the only or the best path, or because there are financial stakes in this strategy.

With good visual materials, opportunities for field visits, and persuasive reports of farmers who have already made the methods succeed, extension can be quite rapid. Table 1 gives data on SRI adoption from the Indian state of Tripura, where the government has given full backing and financial support to SRI extension, and from the states of Himachal Pradesh and Uttarakhand, where within three seasons use has expanded from 40 farmers to >12,000 farmers, thanks to effective NGO work and beneficial results. In these states, there has been no problem of ‘disadoption.’ But getting trials and demonstrations started required considerable effort to enlist farmer cooperation in getting the process going. Farmers usually are unwilling, for understandable reasons, to commit their entire rice-growing area to the new methods in their first year with SRI, but that is fine because it is advisable for them to gain skills and confidence in the new methods on a smaller areas before using them on a larger scale.

3.6 Other Factors

1. Capital requirements. SRI can spread farmer-to-farmer based on the diffusion of knowledge about the new methods, but this is likely to be slow. SRI does not entail major capital expenditures because purchased inputs are not required (although making markers and weeders available to farmers, possibly with some subsidy or even given free as an inducement, can speed up acceptance). However, any extension effort will require some expenditure for personnel, transportation, materials, etc. The Indian government has allocated $40 million for extension of SRI methods to 5 million ha of rice-growing areas in targeted districts with high incidence of poverty under its National Food Security Mission (mofpi.nic.in/nfsm/Presentations/NFSM_SRI.ppt). Eight dollars per hectare is actually a rather a modest expenditure for an innovation that can, using TNAU data, generate >$200 per hectare the first year, a benefit-cost ratio of >25:1. So while some financial investment is needed for an accelerated programme, the resources invested should be very cost-effective.

2. Market development. General development of markets is not an issue with SRI because markets for rice are well-established all around the world. If SRI rice is grown organically, it should be eligible for a premium price because of its higher quality. But markets may not exist that segment rice in terms of quality, so that producers would get remunerated for the full value of their product. Having such market development could enhance both farmer income and consumer benefits. However, the higher price is not a requirement for SRI adoption, only a justifiable reward for quality, because ‘organic SRI rice’ usually has a higher yield, with lower costs of production, than ‘regular rice.’

It was noted already that SRI paddy rice is of higher quality because milling outturn is about 15% higher, due to less chaff (fewer unfilled grains) and less breaking of grains in the milling process. In some places, millers have voluntarily paid 10% more per bushel of SRI paddy, competing with each other to obtain the benefit of higher outturn. If it would be the norm that SRI paddy receives a 10% premium price, this could be the greatest stimulus for farmer adoption because this would be a ‘bonus’ on top of the higher harvests of SRI paddy rice per hectare. This would cost the government nothing and would ensure that the productivity gains achieved with SRI methods are more fully shared in by farmers.

3. Access for the poor. Many innovations are not readily accessible to the poor because of high capital costs. SRI is different in that it is a knowledge-based innovation, not requiring capital expenditure. While there can be barriers to adoption by the very poorest agricultural producers (Moser and Barrett, 2003), these can be overcome by correcting for institutional failures, given that the innovation itself is ‘friendly’ to poorer households who are relatively better-endowed with labour than with land or capital. Perceptions of ‘riskiness’ may constitute a constraint initially, but evaluations have shown them to be incorrect (Uphoff, 2007), and as SRI use spreads more widely, these inhibiting perceptions should become altered.

4. Land tenure. Land rights and land ownership are a factor in SRI spread in that owner-operators, using family labour, have usually had more success with the methods than sharecroppers or agricultural labourers, who have less or no stake in the outcome of their crop management and thus manage the transplanting, weeding and watering less carefully than if the crop were their own. Measures to give land rights or ownership to agricultural producers lacking these would give a boost to SRI spread, because then all rice growers would more reason to undertake careful and intensive management and to manage their plants, soil, water and nutrients to as to build up the fertility of their soils, something that labourers lack. But there are other good reasons to make land more widely available to agricultural producers for the sake of equity and productivity. Smaller holdings, more intensively and better-managed, are invariably more productive per unit of land, and in a world where there is less arable land available per capita, aggregate land productivity is becoming more and more important.

5. Infrastructure. One of the reasons for promoting widespread use of SRI is that this can reduce the agricultural sector's water requirements, which would reduce the need for more irrigation infrastructure such as the construction of large-scale dams or reservoirs. Having irrigation management facilities that can apply reduced amounts of water on a reliable basis is one infrastructure requisite for SRI where farmers are dependent on currently unreliable irrigation systems, or having drainage facilities within irrigation systems where now they are missing and needed. Where electricity is needed for pumping water, from underground stores or from surface-flow channels, having reliable supply can also be a requisite for more widespread uptake of SRI, since irregularity or unpredictability will be a disincentive for farmers to change their production system. Most will prefer to continue wasteful use of water if they cannot be certain of having the small amounted needed for SRI cultivation in a reliable and timely manner.

6. Political factors. Practically all political and administrative leaderships welcome gains in productivity, i.e., being able to produce more output with less material inputs, SRI is regime-neutral as it is scale-neutral in economic terms. An example of what can be accomplished with active political support is seen in Tripura state of India, where full governmental backing plus technical-administrative leadership expanded SRI use from <1,000 in 2005 to >160,000 two years later (Table 1).

Among the 35 countries where SRI has gotten started, there is wide variation in political systems, ethics, and commitment to development. Where influential persons are benefiting financially from the current fertilizer- or seed-dependent systems of rice production, there can be covert resistance. We understand that one Director of Agriculture in a Northern Nigerian state was removed after his blockage of SRI demonstrations became known to a state governor. The resistance apparently stemmed from an apprehension that SRI would reduce officials' (under-the-table) income from fertilizer procurement. Such relationships are seldom amenable to documentation and proof, but we need to bear in mind that such constraints can exist and be operative behind the scenes.

4. POTENTIALS FOR IMPROVEMENT AND EFFECTS FOR SMALL FARMERS

SRI has been successful and has progressed in part because it is understood and presented as ‘a work in progress,’ something which is not to be simply adopted as a set package or fixed technology, but always to be experimented with and adapted to local conditions. Farmers are encouraged to take and feel ownership for the system, as something amenable to improvement based on their own experience and innovation.

Already we have seen some major changes within SRI as farmers, researchers and NGO personnel take ownership. SRI was developed to raise the productivity of irrigated rice production, but as noted already, ‘rainfed SRI’ is being practiced on a large scale in Cambodia, India and Myanmar, with yields that can average 7 tons/ha. In China and Cambodia, there are farmer experiments with raised-beds, no-till SRI which focuses on building up soil fertility and reducing labour requirements. We have noted also that SRI concepts and principles are being extrapolated to other crops, and not just to cereal crops like wheat and finger millet, but to sugar cane, mustard, even kidney beans. Farmers (N=113) working with the People’s Science Institute in Dehradun, India, have achieved a 67% increase by applying SRI concepts to *rajma*, a legume food crop, boosting average yield from 1.8 tons/ha to 3.0 tons/ha (Sen, 2007).

Certainly there are potentials for further improvement. The basic concepts and insights developed by Father Laulanié from his three decades of observation and experimentation have proved to be very robust, but they were developed entirely inductively, with the basic objective of enabling small farmers to improve the productivity of their land, labour, water and capital. The majority of the world’s farmers are not as constrained in terms of land area as are Malagasy farmers nor are they able to invest as much labour in their production activities. Thus, SRI practices need to be adjusted to different factor endowments as the innovation moves around the world. But this is happening, with labour-saving implements and even mechanization of key operations, including no-till and direct seeding, being introduced as noted above.

SRI is particularly relevant for and accessible to small-scale farmers, but its use is not limited to them. Moreover, the application of SRI principles is not limited to rice cropping. SRI is part of a broader movement within the agricultural sector to establish production methods that are more agroecologically-oriented. It capitalizes on the interactions among plants and myriad species of soil organisms, mobilizing currently underutilized genetic potentials through changes in management that modify and improve growing environments.

Small-scale farmers who have the time, knowledge and skill to manage growing environments more carefully and beneficially can get the most from these modifications in management. They need to get the most productivity possible from their limited resources of land, labour, water and capital. They cannot afford to pursue the same kind of ‘extensive’ management practices that large farmers benefit from, which economize on labour (for them a relatively expensive resource) by substituting capital or purchased energy for labour. In extensive agriculture, each unit of land is not exploited to its maximum productivity but rather output is optimized across the whole set of resources, economizing as much as possible on labour inputs and management time since this is considered very costly.

With arable land resources and water available for agricultural production becoming scarcer and more expensive year by year as populations grow, alternative uses increase, and climatic pressures have more impact, the logic of production will more and more favour ‘intensive’ management of the resources employed in agriculture. Risks need to be carefully assessed and minimized, particularly by small farmers who have little margin for failure, but for reasons discussed already, an agroecologically-based production strategy has more capacity to mitigate risks, economic and environmental, than do conventional practices.

5. FAVOURABLE CONDITIONS FOR PROMOTING AND SUSTAINING SRI

Climate of opinion is very important for promotion and sustainability of any innovation in agriculture. ‘Modern agriculture’ has been proceeding from the paradigm of the Green Revolution, which posits that yield and productivity improvement will be best achieved through genetic improvements and modifications in crops, through conventional plant breeding or now transgenic interventions, and that certain increases in the application of external inputs will be profitable, maximizing the spread between benefits and costs. SRI operates from a different paradigm, positing that existing genetic potentials of adapted cultivars, traditional and modern, can produce considerably more agronomic output and with economic returns by modifying growing environments, specifically improving soil health, root growth and performance, and by inducing greater abundance, diversity and activity of (aerobic) soil biota. Getting these differences in paradigms better understood, providing scientific evidence and explanations for their acceptance, and reducing reliance on the preceding paradigm, gaining adherence to the newer one, are all part of the process for creating ‘favourable conditions’ for SRI spread, with both short-term and long-term impact.

Because acceptance requires overcoming preconceptions and resistance, it is very important the persons – farmers, researchers, extension personnel, government decision-makers – be able to ***see*** SRI results for themselves, and to talk with persons like themselves who have validated the methods through hands-on practice. Thus, networks for sharing information, cross-visitation among farmers, end-of-season workshops to share and consolidate experience, and documentation and dissemination of improvements in the standard recommendations, reflecting local conditions, are all important. We have seen in the eight years since SRI methods were first validated outside Madagascar an acceleration in their acceptance. This creates a more favourable climate of opinion for still others now to undertake their own evaluations and reach their own conclusions. Thus, we anticipate that the resistance seen to date will begin dissipating more rapidly. Also, farmers as advocates for SRI, based on their own experience, are likely to become more active and outspoken, amplifying the effects of whatever governments and NGOs do to promote SRI. Further, private-sector entities are getting involved in SRI promotion, finding profitable uses or niches, so a more diverse set of institutions is engaging with farmers to help change production practices.

6. AREAS AND OPTIONS FOR ACTION

As the previous section suggests, the most important arena for enabling more producers around the world to utilize and benefit from SRI methods and techniques is cognitive, overcoming the skepticism and disbelief that have hindered the process of acceptance so far. More concrete things that could most facilitate the uptake of SRI mirror the discussion in section 3. above.

6.1 Water Control

Being able to maintain soil conditions that are mostly moist but also aerobic requires a combination of hardware (facilities for acquiring, distributing and, if necessary, draining water) and software (management capability for operating these structures). Given the growing scarcity and/or unreliability of water supply for agriculture, being able to enhance production with *less* water should be attractive to everyone: farmers, engineers, politicians, administrators, and citizen-environmentalists. Investments in gaining better control over water for the purpose of economizing on its use and making it more productive can be well justified.

6.2 Simple Mechanization

While some persons welcome labour-intensive production as a strategy for increasing employment opportunities, increased requirements for labour can be a deterrent to farmer adoption, and can make SRI less accessible to poor households (Moser and Barrett, 2003). The poor are likely to benefit most widely and consistently by utilizing opportunities to raise the efficiency of staple-food production, so as to ensure abundant supply and to reduce market prices. This will enhance the incomes of all the poor. Thus if SRI will be more widely adopted by farmers of all sizes, not just by small, food-deficit households but also by those producing surpluses for the market, this will have a major poverty-reduction impact. Efforts are underway to mechanize transplanting and weeding, the two 'bottlenecks' for SRI use. These should be expanded, with financing mechanisms such as time-payment, hire-purchase or subsidization schemes in place to ensure easy and widespread access to these implements or machines.

6.3 Biomass Production and Processing

If even 5% as many resources were put into improving the agronomic-effectiveness and labour-efficiency of producing and applying organic matter to improve the soil's fertility and its productive capacity as has gone into the development of mineral fertilizers, not only SRI but the whole agricultural sector would benefit, as Conservation Agriculture aptly demonstrates. This would help food production contribute more to environmental as well as human health. We need tools and implements for cutting and collecting biomass, transporting it, shredding it to accelerate microbial decomposition, processing it into high-quality compost or mulch, and applying it. The designs of many cutters, carts, etc. used now in biomass acquisition and handling are decades, even centuries old. There has been negligible ergonometric or other evaluation to arrive at more labour-efficient methods for getting biomass, an abundantly renewable resource in most environments, into the soil in forms that are agronomically efficient and produce as much as possible within the rice-based cropping system itself.

6.4 Crop Protection

With climate change creating conditions that will increase abiotic stresses and in turn biotic stresses on all crops, not just rice, more attention needs to be paid to crop protection, including the relationship between insect dynamics and crop nutrient and soil organic matter management. Specifically we would suggest that the theory of trophobiosis (Chaboussou, 2004) be more systematically evaluated from a multidisciplinary perspective, because if it bears up under empirical examination, its implications for improving all crop production, not just rice, are very significant, contributing to increase yields with reduced reliance on mineral fertilizers and agrochemical crop protection, enhancing food supply with cost savings and environmental-quality enhancement.

6.5 Conservation Agriculture

We believe that the three key elements of Conservation Agriculture (CA) -- no-till/minimum soil disturbance; soil cover with organic matter; and crop rotation -- would enhance the performance of SRI methods. This is because the ecological underpinnings of CA – soil organic matter build-up, soil biota promotion, and soil porosity enhancement – apply also to SRI systems. Systematic research is required to evaluate and adapt SRI systems for CA so that soil puddling can be minimized or done away with, and direct-seeded rice without puddling can be promoted. Work in North Korea indicates that this is possible and can offer further cost reductions and environmental benefits. CA-based SRI cropping systems would offer robust sustainable production systems that would harness the advantages of both SRI and CA systems.

6.6 Farmer-to-Farmer Extension and Farmer Field Schools

Governments, NGOs and donor agencies should, as a matter of effectiveness as well as reinforcing the values of participation and democratic self-governance, be facilitating exchanges of ideas and experience among farmers, enabling them to make further improvements upon any innovation introduced to or by them. Already we have seen individual farmers expend their own time and money to spread knowledge of SRI to hundreds, even several thousand farmers, because they wanted others like themselves to be able to have the benefits of higher yield and income as well as to enhance both human and environmental health through SRI. Support for travel and communication among farmers would greatly accelerate SRI spread and use and would also improve it year by year. Where SRI has been promoted through Farmer Field Schools (FFS), as in Cambodia, Myanmar, Philippines, Thailand and Vietnam, this has been a very good 'fit' as documented from Myanmar (Kabir and Uphoff, 2007).

6.7 Incentives

No major expenditures are needed to promote SRI, but investments in the above areas could be well justified in terms of their economic returns. The biggest incentive for SRI uptake, which would entail no cost to any government, would be to introduce a price premium for SRI paddy, e.g., 10%, to be paid by millers or anyone who purchases paddy rice, justified by the fact (to be documented and monitored with some precision) that this unmilled rice (purchased by volume) produces about 15% more milled rice (by weight). There is no justification for millers pocketing this windfall which derives from the productivity of SRI methods and farmers' management efforts. Farmers should get most of this gain as an incentive and a reward, thereby following practices that reduce water demand and agrochemical use, contributing to a cleaner and less-stressed environment as well as to healthier food products.

The nutritional value of SRI rice (the same variety, but grown with different methods) should be evaluated objectively. There is already fragmentary evidence that SRI rice contains more protein and more micronutrients. To the extent that this can be clearly established, the value of rice as a staple food would be demonstrated, further justifying a higher price for farmers. In any case, SRI grown in a fully organic manner should have market channels that remunerate farmers for this higher-quality food product. Such market incentives would make it more attractive for farmers to modify their production methods to become ‘greener’ and ‘cleaner.’

6.8 European Cooperation Policy

The stake that EU members have in helping agricultural sectors in developing countries, as well as their own agricultural sectors, move away from narrow-based Green Revolution technologies should be clear from the above. The world can be a better place to the extent that more of this most basic staple food can be produced, probably in more nutritious form and better for human health, with less input of arable land, fresh water, human labour, and capital funds. These are all resources with opportunity costs, and producing more with less has broad implications – which are even broader to the extent that other food production can be similarly restructured with similar if not necessarily as great effects, which we have more and more reason to expect is possible. No large reorientation should be proposed or implemented without more systematic and scientific studies. But there is more than enough evidence to make a *prima facie* case that there are now some promising opportunities to increase factor productivity, and to enhance human and environmental health, by pursuing the insights and conclusions of Father Laulanié. This should be followed up with thorough, objective and open-minded evaluations. It would be helpful if resources could be made available for monitoring, evaluating, synthesizing and communicating what is being learned from both scientific research and farmer experience about SRI methods.

Green Revolution technologies are not wrong and indeed have made important contributions to meeting world food needs during the 20th century. But they are not the only, or necessarily always the best, means for increasing agricultural productivity under the economic and environmental conditions of the 21st century. It is increasingly clear these measures have large and rising financial and ecological costs. To the extent empirically justified, it will be beneficial for reasons of poverty reduction, food security, environmental quality, and human health for European countries and the European Union to move away from currently prevailing, energy-intensive and input-dependent presumptions and to make agricultural policy and practice more agroecologically-informed. SRI concepts and methods were developed for very specific purposes of alleviating poverty and hunger in Madagascar, but the remarkable results of SRI practice have broad-ranging implications for agricultural technology and development in the decades ahead.

Rice production is an important agricultural activity in the Mediterranean EU member countries, but this is still carried out with Green Revolution scientific assumptions and agronomic practices that have many unsustainable characteristics and negative externalities. There is an opportunity now for the EU to take a serious look at the extent to which rice production in Europe can benefit from SRI principles and practices. In the same vein, where EU development assistance aims to boost rice- and irrigation-based food security and economic growth in developing countries, it would be appropriate, where applicable, to align investments in irrigated rice development according to SRI (and CA) practices so that poverty alleviation and food security goals of agricultural development can be combined profitably with sustainability goals.

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ABBREVIATIONS

AWD	Alternate Wetting and Drying
CA	Conservation Agriculture
CAAS	China Academy of Agricultural Sciences
CIIFAD	Cornell International Institute for Food Agriculture and Development
EU	European Union
FFS	Farmer Field Schools
FOFIFA	Centre National de la Recherche Appliquée au Développemnt
IPM	Integrated Pest Management
IMO	Indigenous Microorganisms
NGO	Non-Governmental Organization
SICA	Sistema Intensivo de Cultivo Arrocero
SRA	Système du Riziculture Ameliorèe
SRI	System of Rice Intensification
USAID	Unites States Agency for International Development
WWF	World Wildlife Fund

Table 1: Spread of SRI practice since 2000, in hectares (number of farmers shown in parentheses)

COUNTRY **State/Province**	**2001/ 2001-02**	**2002/ 2002-03**	**2003/ 2003-04**	**2004/ 2004-05**	**2005/ 2005-06**	**2006/ 2006-07**	**2007/ 2007-08**	**2008/ 2008-09**
CAMBODIA	28.7 (500)	900 (3,000)	4,700 (10,000)	4,786* (17,092)	11,200 (40,000)	16,386 (60,000)	47,039 (82,236)	*60,000* (>*100,000*)
SRI yield Natl. yield	3.20 2.07	3.50 1.91	3.57 2.10	3.66 1.97	4.00 2.47	3.70 2.48	3.56 2.40	*NA* *NA*
CEDAC introduced SRI to 28 farmers in 2000. In 2005, a Joint SRI Secretariat was established in the Ministry of Agriculture, Forestry and Fisheries (MAFF), with co-directors from MAFF and CEDAC, and with support from GTZ and Oxfam, to promote SRI as part of the National Development Plan. It also collects and reports SRI statistics on a comprehensive basis. Figures are from the 2007 report of the SRI Secretariat. **Note that 2004 was a drought year in Cambodia, which discouraged many farmers from taking up SRI. However, those farmers who used SRI methods were able to get a harvest where most conventional rice farmers did not, which gave impetus to the dissemination of the new methods.*								
CHINA								
Sichuan	TR	TR	TR	1,120	7,290	57,500	116,667	204,000
	SRI yield Prov. yield	NA	NA	9.10 NA	9.44 NA	8.82* NA	8.97 7.50	9.41 7.71
Sichuan Academy of Agricultural Sciences and Sichuan Agricultural University began SRI trials in 2001, as did China National Hybrid Rice R&D Center experimental farm at Meishan. Popularization began in 2004. Figures are reported from the Sichuan Provincial Dept. of Agriculture. **Note that 2006 was a drought year, but SRI yields were relatively better than conventional rice results, which gave impetus to the uptake of SRI.*								
Zhejiang	TR	TR	TR	NA	NA	NA	NA	130,000
Jia Xing Township	SRI area SRI yield	--	--	39.1 10.0	237.5 9.25	1,875 10.62	5,333 NA	NA NA
China National Rice Research Institute based in Hangzhou began trials in 2001 and started working with Zhejiang Provincial Dept. of Agriculture on SRI extension in 2004. Jia XIng Township has been the most receptive and by 2007 had about 80% of its rice area under SRI management. Figures reported here are from the Jia Xing Municipal Bureau of Agriculture and the Zhejiang Provincial Dept. of Agriculture.								

Note: Already in 2004, the Chinese Ministry of Agriculture recommended to Provincial Depts. of Agriculture that SRI be promoted as a beneficial technology, especially with hybrid rice. However, no systematic data on SRI area and yield have been gathered and reported as far as we know.								
INDIA								
Tamil Nadu State	TR	TR	Demos (ha): Area (ha)	2,287 NA	949 NA	4,648 NA	11,690 421,700	40,350 466,000 (as of 12/08)
						State ave.: Prev. ave:.	7.5 5.4	750,000 (08-09 target)
SRI trials and evaluations were begun at Tamil Nadu Agricultural University in 2000; by 2004, it began recommending SRI adoption through the state extension service. Figures for 2007-08 are from Tamil Nadu State Dept. of Agriculture. State average for that year was reported as 7.5 tons/ha *with SRI* -- compared to previous highest average yield *without SRI* as 5.4 tons/ha (*Financial Express*, 10/2/08). SRI was used on *one-third* of area.								
Andhra Pradesh State	--	--	1,530 trials (2003&2004)	NA	NA	NA	NA	NA
	SRI yield Conv. yield	--	8.73 6.31					
SRI evaluations were begun at the state agricultural university (ANGRAU) in 2003. With average increase in yield of 2.5 tons/ha in trials conducted across all 22 districts (Satyanarayana et al., 2007), the state's extension service began supporting SRI after 2004, although with less support than in Tamil Nadu. No aggregate figures are available for Andhra Pradesh that have used clear criteria for what constitutes SRI use (i.e., were all of the recommended practices used, and were they applied as recommended).								
Tripura State	TR	8.8 (44)	17.6 (88)	176 (440)	352 (880)	14,678 (73,390)	32,497 (162,485)	50,000 (250,000)
	SRI yield State yield	NA NA	5.36 2.40	5.03 2.35	4.69 2.38	4.27 2.50	4.32 2.55	NA
A senior researcher in the State Dept. of Agriculture began trials in 2000 and began on-farm trials/demonstrations in 2002-03. In 2005, the state government began supporting SRI expansion through its Extension Service, providing funding and authority to accelerate the spread of SRI. Data are from the Tripura State Dept. of Agriculture.								
Uttarakhand	--	--	--	--	--	0.95	15	238.7

& Himchal Pradesh States						(40)	(591)	(12,009)
	SRI yield Conv. yield	--	--	--	--	5.3 3.2	5.4 2.9	5.45 3.60

The NGO People Science Institute (PSI) began SRI demonstrations in 2006, and based on good results expanded 15-fold the next year, 2007. In 2008, wth support from the Sir Dorabji Tata Trust and WWF, SRI use expanded 20-fold in these two states. Data are from PSI.

West Bengal Purulia District	 SRI yield Conv. yield	 --	TR (4)	NA (150) 5.33 4.04	NA (2,000) 7.7 2.2	632 NA NA NA	1,080 NA 7.14 5.43*	2,351 (5,400) Not yet harvested

In Eastern India, the NGO PRADAN began SRI trials in Purulia district of West Bengal in 2003, working with poor farmers, most lacking irrigation. This experience has been evaluated by an IWMI-India programme team (Sinha and Talati, 2007). Recent data from PRADAN reports.

**2007 comparison data are for the same SRI farmers when using conventional practices on the same farm; they are probably using some SRI practices in their conventional production as the average paddy yield in the district is 2.5 tons/ha.* (asterisk printed at start)

Eastern India, incl. W. Bengal	--	--	TR (4)	NA (150)	NA (2,000)	NA NA	1,080 (10,423)	2,351 (23,303)

Given the results achieved in Purulia District, PRADAN teams began extending SRI in other poverty areas in the states of Eastern India from 2005. The following use of SRI among poor households in this region is reported by PRADAN teams as of 2008-09:

- **Assam**: 80 families with 10.7 ha of SRI cultivation; other NGOs are also working on SRI in Assam with support from Sir Dorabji Tata Trust.
- **Bihar**: 8,028 families with 1,633 ha of SRI cultivation --sample analysis of yield data from Gaya district showed 75% of SRI farmers harvested about 8 tons/ha; if there had not been drought conditions for most, farmers expected to have average SRI yields of 10 tons/ha.
- **Chhattisgarh**: 672 families with 235.6 ha of SRI cultivation -- analysis of data from 76 farmers showed that 96% of them were able to harvest yields of >5 tons/ha.
- **Orissa**: 1,761 families with 165 ha of SRI cultivation -- sample analysis of data from 425 families showed that 40% got 5-6 tons/ha, and another 30% got 4-5 tons/ha; average local yields have been 2.5-3 tons/ha.
- **Jharkhand**: 6,639 families with 623.65 ha of SRI cultivation -- analysis of sample data from 364 farmers in Khunti district showed

90% of households harvested yields of >5 tons/ha, and 77% had yields of 6-8 tons/ha. Improved practices with improved seed have yielded 4-5 tons/ha in these areas. • **Madhya Pradesh**: 723 families with 100.8 ha of SRI cultivation -- no yield data yet available for 2008-09 season.								
INDONESIA	TR	TR	NA	NA	NA	NA	NA	12,773 (22,981)
Eastern Indonesia	 SRI yield Conv. yield	3.5 (13) 7.29 4.59	15.3	364.5	981.9	4,245 (5,258)	NA	8,670 (13,786)
			Total for seven seasons (2003-06) SRI average yield 7.61 9,425.7 ha (12,120 farmers) Conv. average yield 4.27					
The Nippon Koei technical assistance team advising the Decentralized Irrigation System Management improvement Project (DISIMP) began trials in 2002. Within 9 seasons, it had data from 12,133 on-farm comparison trials (9,429.1 ha). Records documented 78% higher average yield, with 40% reduction in water applications, 50% reduction in use of chemical fertilizer, and 20% lower costs of production per ha (Sato & Uphoff, 2007).								
West Java	 SRI yield Conv. yield	TR (3) 6.85 4.50	NA	NA	NA	NA	NA	2,284 (7,650)
The National IPM Programme of the Ministry of Agriculture conducted a first trial in Ciamis in 2001. As there was little initial interest within the Ministry, the agronomist supervising the trials began promoting SRI individually. In 2006 together with the Nippon Koei team leader, he set up an NGO (Aliksa) to promote and train for organic SRI. The next year, Aliksa began receiving Ministry support to expand SRI training country-wide.								
West Sumatra	SRI demos SRI area	--	--	--	--	1 382	11 1,172	2,080 25,000 target
The Provincial Dept. of Agriculture in West Sumatra started demonstrations of organic SRI in 2006. Based on the promising results, it has planned to expand the SRI area substantially in this province starting in 2008-09 season, expanding its SRI demonstrations from 11 to >2,000. *Note: In 2002, the Ministry of Agriculture's Agency for Agricultural Research and Development, after 2 years of evaluations, recommended incorporating SRI practices into its Integrated Crop Management (ICM) strategy (Gani et al., 2002). However, there was little support for SRI from the Ministry until 2007, at which time the Ministry's Directorate of Land and Water Resources began*								

funding Aliksa training in 29 districts throughout Indonesia. The Ministry of Agriculture is now supporting SRI spread, with the explicit endorsement of President S.B. Yudhoyono. (http://www.srivideo.zoomshare.com/)								
VIETNAM	--	--	TR [3 prov.]	TR [5 prov.]	TR [12 prov.]	TR [17 prov.] (3,450)	NA	70,542 2 seasons (230,809)
Ha Tay Province	--	--	--	--	--	NA	3,000 (9,000) 1 season	68,894 (226,090) 2 seasons
SRI trials started in 2003 by the National IPM Programme in the Ministry of Agricultural and Rural Development and also by faculty at Hanoi Agricultural University and Thai Nguyen University, but the data here are only from MARD. In 2007, Oxfam America began assisting the National IPM programme to spread SRI use through Farmer Field School methods. Ha Tay province was the pilot area. In 2008, FFS programmes for SRI following the Ha Tay model were established in 20 other provinces by the National IPM Programme with Oxfam support, to expand use in 2009.								
MYANMAR								
Kachin and Shan States	TR	438 (584)	831 (1,108)	2,632 (3,510)	15,000 (20,000)	NA	21,750 (29,000)	37,500 (50,000)
	FFS yields Farmer SRI Conv. yields	5.58 4.27 2.22	6.77 4.08 1.89	7.13 4.76 2.25	NA NA NA	-- 4.3 2.9	-- 4.4 3.0	-- 4.4 3.0
Metta Development Foundation began introducing rainfed SRI methods in Kachin and Shan states in 2001 through Farmer Field School training. FFS training lasted through 2006, but spread continued as monitoring showed that once a third of farmers in a village had received SRI training, within three years, almost all farmers would be using SRI. FFS data thus understate total use from 2002 onward. SRI practices have to some extent also been incorporated in conventional practice. Metta Development Foundation is now introducing SRI in the Delta rice-growing areas, and a French NGO (GRET) has been introducing SRI in Rakhine State (Kabir and Uphoff, 2007).								

TR = Trials: area not recorded; relatively small area
NA = Not available
-- = No known SRI activity