Climate Change

Vulnerability & Adaptation Experiences from Rajasthan & Andhra Pradesh

SRI The System of Rice Intensification

Case Study
INDIA

V&A

Climate Change

Vulnerability reduction and adaptation to climate change in semi-arid India - The System of Rice Intensification

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ACRONYMS

ANGRAU	Acharya N.G. Ranga Agricultural University, Hyderabad
CSO	Civil Society Organisations
FFS	Farmer Field Schools
FYM	Farm Yard Manure
GHG	Green House Gases
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IPCC	Intergovernmental Panel on Climate Change
NFSM	National Food Security Mission
NSKE	Neem Seed Kernel Extract
RKVY	Rashtriya Krishi Vikas Yojana
SDTT	Sir Dorabji Tata Trust
SHGs	Self Help Groups
SRI	System of Rice Intensification
TNAU	Tamil Nadu Agricultural University
WASSAN	Watershed Support Service and Activities Network
WWF	World Wildlife Fund

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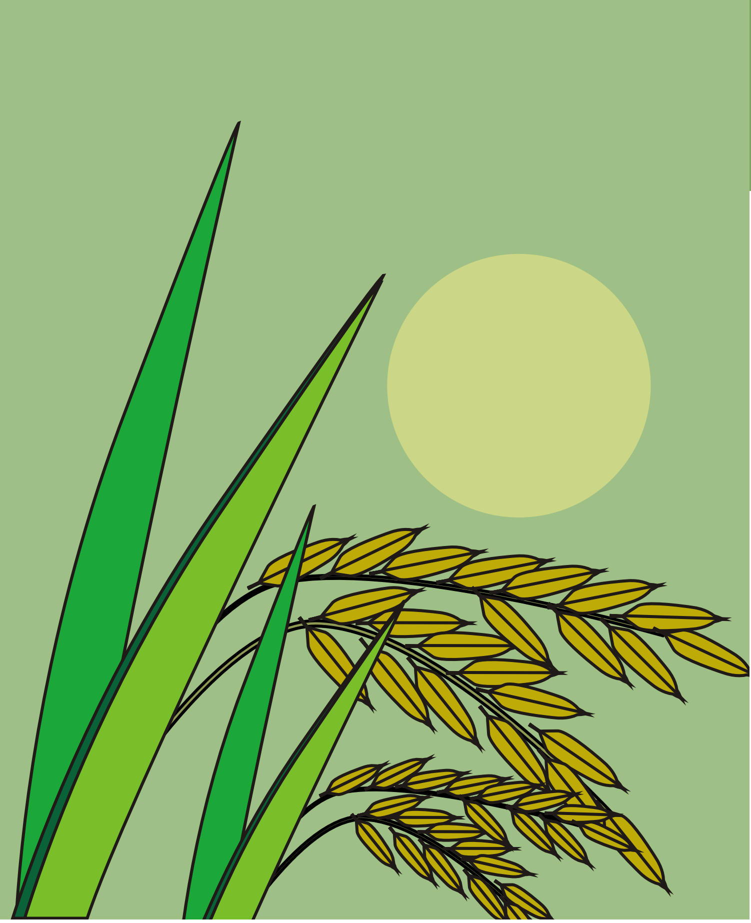
Executive Summary

Climate change is expected to aggravate stresses on natural systems, including on hydrological systems and on already scarce groundwater resources in semi-arid areas in India. New challenges for agriculture based livelihoods and food security will likely arise from increased climate variability and change. These challenges call for new technologies which help to enhance water use efficiency in agriculture, in particular in rice cultivation, which is a highly water intensive crop under conventional production. The System of Rice Intensification (SRI) offers a valuable option in this context: It is a package of practices which reduce water requirements in rice cultivation while at the same time increasing yields and reducing the need for input of seeds, chemical fertilizers and pesticides. Therefore, the SDC supported *Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi-Arid India (V&A)* pilot programme has promoted the adoption of SRI among farmers in two villages in Mahabubnagar district in Andhra Pradesh, where paddy cultivation accounts for the largest share of total irrigation water requirements, which are met mainly from already scarce groundwater resources.

The programme found that SRI offers multiple benefits for reducing the vulnerability of agricultural systems and livelihoods to climate variability and change. First, it helps to reduce pressures on vulnerable ecological systems by cutting irrigation water requirements and need of pesticide inputs and chemical fertilizer. Second, it enhances the resilience of rice cultivation systems against climate risks as it generates healthier and more robust rice plants with deeper and more vigorous root systems. Third, it improves farmers' overall livelihood situation by increasing yields and profitability; the substantial savings in seeds are particularly relevant in the context of food security. Finally, it builds adaptive capacity in farmers' communities as they are encouraged to experiment, evaluate, innovate and share experiences. In addition, SRI also has a potential for climate change mitigation, through avoiding flooded conditions on rice fields which brings down methane emissions from rice cultivation, through reduced energy consumption for operation of water pumps and through the reduced need for application of chemical fertilizers, the production of which is associated with significant energy and process related GHG emissions.



1. Introduction

Rice is the most important staple food grown in India. It accounts for nearly 42.5 per cent of total food grain production and occupies around one quarter of the total cropped area in the country. Of India's total irrigated area, nearly 23 per cent is used for rice cultivation.

Production of rice has increased considerably in India over the last few decades. In 2006, it reached almost 140 million tons, which was 4.5 times the level of 1950. Appreciable productivity gains have been achieved during the "Green Revolution" through the development and spread of high-yielding crop varieties. These high-yielding varieties tend to be highly responsive to key inputs such as fertilizers, agrochemicals and, notably, irrigation water. However, the downside of the Green Revolution is that it has made the Indian agriculture system, including rice cultivation, highly dependent on availability of large quantities of surface and ground water. It is estimated that under modern methods of rice cultivation, the typical water requirement to produce one kilogram of rice is 3000-5000 liters (WWF/ICRISAT 2007).

Climate change is expected to aggravate stresses on natural systems, including hydrological systems and groundwater resources. In semi-arid areas in India, rainfall is projected to be more erratic, with heavier precipitation events after longer periods of dry spells, resulting in reduced groundwater recharge and higher surface run-off.

Hence, climate variability and change are likely to pose new pressures on water resources, notably on already scarce groundwater resources, which are being exploited for agricultural use at unsustainable levels in many parts of India. The adverse climatic factors may also force the extension of cultivation to less resource endowed lands in the light of food security concerns. These challenges call for new technologies which help to increase water use efficiency in rice cultivation. The System of Rice Intensification (SRI) offers a valuable option in this context: It is a package of practices which reduce water requirements in rice cultivation while at the same time increasing yields and reducing the need for input of seeds, chemical fertilizers and pesticides. The secret behind the gains obtained through SRI practices is that they stimulate biological processes that are beneficial for the development of plants and the production of grains. Thus, SRI brings not only considerable ecological co-benefits, but also offers a pro-poor technological innovation in rice cultivation as it does not build on large investments and can be implemented on small and marginal land holdings.

It was therefore decided to promote the adoption of SRI practices among farmers in 2 villages (Kothur and Srirangapur) in Mahabubnagar district of Andhra Pradesh under the Vulnerability Assessment and Enhancing Adaptive Capacity to Climate Change in Semi-Arid India (V&A) pilot programme. Rice is one of the main crops grown in the area (besides maize, cotton, jowar, castor, redgram and groundnut). It is cultivated mainly under borewell irrigation. An analysis of the water requirements for irrigation in both villages revealed that paddy cultivation accounted for the largest share of total irrigation water requirement, with an average of one million m^3 per kharif season[1] in the years 2005 to 2008 in Kothur, and

[1] The cropping season in the monsoon period from June to October is called *kharif* season.

380,000 m^3 in Srirangapur, respectively. Groundwater resources are rapidly declining due to high irrigation needs in both villages, and have reached a status of over-exploitation in Midjil Mandal (where Kothur is located). The majority of farmers in the programme villages are marginal and small land holders. A high potential was therefore seen in SRI to help secure the livelihoods of the communities, and to enhance their resilience to the adverse impacts of climate change expected for the region.

This case study will first lay out the set of practices that together form SRI and explain how these practices enhance plant growth and lead to higher yields with lower inputs. It will then provide a detailed illustration of the SRI experience in Mahabubnagar district, Andhra Pradesh, under the V&A pilot programme, including yield increases and profitability gains that have materialized for the farmers. The V&A experience will be collated with a review of studies of SRI results under other programmes and in other areas of India. Based on these observations, the benefits of SRI in the context of climate change will be analyzed. Subsequently, strategies for upscaling of SRI will be discussed, based on past experience with promotion and adoption of SRI in India. The final chapter will summarize the key conclusions point out some emerging policy recommendations pointed out.

2. Definition of SRI

System of Rice Intensification (SRI) is a methodology for increasing the productivity of irrigated rice cultivation while at the same time reducing inputs, including seeds and fertilizers, and water requirements. This counter-intuitive effect is achieved by improved management of plants, soil, water and nutrients, which stimulates biological processes that have a positive effect on plant growth and tiller production. In contrast to the Green Revolution methods of stretching yields through improved genotypes, i.e., new high-yielding varieties of paddy seeds, or through augmenting external inputs, SRI does not require that a different seed is used, but basically capitalizes on potentials for optimized symbiotic processes in plant roots and leaves. In other words, it helps to produce more healthy and productive plant phenotypes (physical characteristics) from any genotype (initial genetic potential).

It is a combination of several practices that are applied to achieve these results, including changes in nursery management, time of transplanting, change in planting, water and soil fertility management as well as weed control. SRI should not be understood as a fixed package of technical specifications, but as a system of production that is still evolving. Moreover, it is not possible to give uniform recommendations for several parameters in SRI practices such as timing and spacing, soil disturbance and water management; rather, the practices need to be customized to local conditions.

The following list entails the key cultural practices, which in combination can help to achieve optimum results, as per recommendations by a SRI project implemented jointly by the World Wildlife Fund (WWF) and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT)[2]:

- **Land preparation:** In order to maintain the required moisture level uniformly, SRI requires careful leveling and raking of the land. Drainage is facilitated by 30 cm wide channels at two-meter intervals across the field.
- **Nurseries:** Like in conventional rice cultivation, seeds are sown into nursery beds for later transplantation. For SRI, it is vital that these seedbeds are nutrient-rich. Application of chemicals to the nurseries is not required. Nurseries should also be established as close as possible to the main field, so that once seedlings are ready for transplantation, both time and costs for transporting

[2] WWF-ICRISAT partnership programme "Producing more food grain with less water- Promoting farm based methods to improve the water productivity". More details under URL http://sri-india.110mb.com/html/wwf_project.html.

seedlings to the field are minimized.

- **Timing of transplantation:** Transplanting should take place when the seedlings are just 8 to 12 days old, soon after they have two leaves, and at least before the 15th day after sowing. This is at a notably earlier stage than in the conventional method, where seedlings are usually kept in the nurseries for 25-35 days.
- **Technique of transplantation:** The seedlings must be transplanted singly with their roots intact, while the seed sac is still attached. They must not be plunged too deep into the soil, but placed at a depth of 1-2 cm from the surface. This constitutes another important difference to the conventional method, where usually three or more seedlings are planted per hill.
- **Spacing between seedlings:** The seedlings should be planted at precise spacing, usually 25 x 25 cm (however, it must be noted that optimum spacing is a function of soil fertility, and for very fertile soils it can be up to 50 x 50 cm). Rice plant roots and canopies grow better if spaced widely, as each plant is exposed to more sunlight, air and soil nutrients. Another reason why accurate spacing is important is that it enables the application of the mechanical weeder.
- **Soil nutrients:** It is recommended to apply compost or farmyard manure instead of synthetic fertilizers, as organic manure enhances the abundance and diversity of microorganisms, beneficial bacteria and fungi in the soil. It promotes plant soil life interaction through mobilizing nutrients and mirco-nutrients. Yields will be improved by better microbial activity.
- **Watering:** SRI requires the root zone to be kept moist, not submerged. Water applications can be intermittent, leaving plant roots with sufficiency, rather than surfeit of water. Such management encourages more extensive, healthy root systems, which support water and nutrient uptake, and avoids root degeneration.
- **Weed management:** In the conventional rice cultivation method, continuous submergence of rice plants will prevent the emergence of weeds. Under SRI, since water is not standing in the fields, weeds tend to proliferate, and careful and frequent weeding is required. A manual weeder is to be operated perpendicularly in both directions in between the hills within 10 to 12 days of transplantation, and at intervals of 10-12 days afterwards. This operation not only controls the weeds but churns the soil for better growth of the crop.

Table 1 below provides an overview of the key differences between SRI practices and the conventional method of rice cultivation.

Table 1 : Comparison of SRI against conventional method practices

	Conventional method	SRI method
Seeds input	50-60 kg / ha	5 kg / ha
Transplanting of seedlings	after 25-35 days	after 8-12 days
Number of hills / m^2	about 30-40 hills	about 16 hills (with a spacing of 25 cm between the hills)
Number of seedlings / hill	3 or more	one
Fertilization	application of chemical fertilizers, pesticides, herbicides and insecticides	preferred application of organic fertilization, non-chemical weed management; pesticides & insecticides usually not required
Water management	continuous flooding	moist conditions, no submergence

Source: WWF/ICRISAT (2007).

3. Why rice plants perform better under SRI

SRI can help increase yields in rice cultivation while input of water, seeds, chemical nutrients and fertilizers is reduced. This superior performance, as it was also experienced by farmers adopting SRI in the villages selected for implementation of the V&A programme in Mahabubnagar district in Andhra Pradesh, results from biological processes stimulated by SRI practices that are beneficial for the development of plants and the production of grains.

Rice plants grown in mostly aerated soil develop larger root systems than rice grown under flooded conditions, where roots die back due to lack of oxygen. Further, soil microorganisms beneficial for plant development will be more abundant and diverse when soil is kept aerated. The transplantation of very young seedlings also contributes to an improved development of root systems, which ultimately leads to a better nutrient supply to the plant.

The wider spacing allows for sunlight to get through to the plant's lower leaves and results in a higher level of photosynthetic activity. This, in turn, enhances growth and physiological activity of the root system, since they get most of their energy from plants' lower leaves.

In addition, more balanced and more complete nutrition of soil and plants is achieved in SRI through the reliance mostly on organic materials like compost and mulch. This also renders plants more resistant to pests and diseases.

The stronger root systems and better nutrient supply allow for the development of more profuse and strong tillers with big panicles and well-filled spikelets with higher grain weight.


Figure 1: SRI rice fields in Kothur, Mahabubnagar district, Andhra Pradesh.


Figure 2: Conventional rice fields in Kothur, Mahabubnagar district, Andhra Pradesh.

4. SRI experience under the V&A pilot programme in Andhra Pradesh

The following section presents the experiences of farmers who have adopted SRI under the V&A programme in Mahabubnagar district in Andhra Pradesh. A detailed description is provided of the practices they have employed, including the use of fertilizer and pesticide inputs and labour input. The results that were achieved through SRI in terms of yield increase, water savings and increased profitability were monitored and a comparative analysis was made with the respective parameters under conventional paddy cultivation.

The section concludes with a review of experiences documented under other SRI study projects in India to validate the V&A results.

4.1 Methodology of study on SRI results under the V&A pilot programme

In the rabi season[3] of 2007/08, a detailed study was undertaken on the experiences and results of a total of 18 farmers who had adopted SRI practice in the two programme villages. Data on inputs and agronomic practices applied, irrigation requirements, cultivation costs, yields, and profits under SRI were compared to the respective inputs and results of 18 farmers who continued with conventional paddy cultivation.

[3] The cropping season in the dry period from November to March is called rabi season.

The data were collected at the end of the Rabi season in the first quarter of 2008 by NGO field staff. The format for data recording was developed jointly by NGO staff and AFPRO Hyderabad.

Table 2 provides an overview of the main crops cultivated in both villages in the year 2007/08. It indicates the important role of rice cultivation in relation to other crops for farmers in the area.

Table 2: Area under different crops in Kothur and Srirangapur in 2007/08(in m²)

	Kothur		Srirangapur	
	Kharif 2007	Rabi 2007-08	Kharif 2007	Rabi 2007-08
Paddy	712,000	560,000	244,000	220,000
Castor	148,000		0	
Cotton	1,276,000		816,800	
Maize	408,800		232,800	
Jowar	9,200		152,800	
Redgram	392,000		0	
Ground Nut	12,000		0	
Total	**2,958,000**		**1,446,400**	

Source: Primary data from Kothur and Sriranagapur, Mahabubnagar district, AP, collected by AFPRO Hyderabad.

4.2 SRI promotion strategy under the V&A pilot programme

The promotion of SRI under the V&A pilot programme in two villages in Mahabubnagar district, Andhra Pradesh, was initiated in 2005. V&A programme field staff introduced the SRI innovation to farmers in village meetings. They informed the farmers about the main features of SRI practices and the basic biological processes that underlie the superior performance of SRI paddy. A two day exposure visit was also organized to Krishi Vignan Kendra in Gaddipalli, Nalgonda district, Andhra Pradesh, to demonstrate to the farmers results achieved through adoption of SRI practices. About 20 farmers from the two villages participated in this exposure visit. However, only one farmer gained enough confidence from the exposure to try the innovative practice for the first time in Kharif season of 2005 on one acre of his land. It was only after witnessing the positive results on this pioneer farmers' field in their own village - a 25 per cent increase in yields and distinctly healthier plants - that other farmers took an interest and started adopting SRI in the following seasons. Field staff of the V&A partner NGOs - Eco - Club and AFPRO visited the villages regularly throughout the growing season to advice farmers on the spot on key steps in the cultivation cycle and how they should be done differently under SRI.

The number of SRI farmers in both villages progressively increased between 2005 and 2008 (Table 3).

One element of the V&A pilot programme activities was the concept of formation of Smart Farmers Clubs (SFCs). The SFCs were set up as community organizations to take an active role in the implementation of V&A pilot programme interventions and to function as a platform for exchange of knowledge around climate concerns for farming activities. In both Kothur and Srirangapur, experiences with SRI methods, including the choice of seeds and the use of weeders and markers, were regularly discussed among the SFC members at their meetings.

In 2007, the Government of Andhra Pradesh took up an aggressive promotion strategy for SRI adoption to help the spread of the innovation across the state: All farmers who adopted SRI on at least one acre of land were paid a one-time direct subsidy of Rs 1000. Table 3 indicates that this subsidy had a remarkable short-term effect in the villages selected for implementation of the V&A pilot programme, as the number of SRI farmers doubled in both Kharif and Rabi[4] seasons of 2007 as compared to the previous year, but again declined in the following year when the subsidy was no longer available.

Table 3: Progressive adoption of SRI between 2006 and 2008 by farmers under the V&A pilot programme in two villages in Andhra Pradesh

Year	Kharif (No. of farmers)		Rabi (No. of farmers)	
	Kothur	Srirangapur	Kothur	Srirangapuar
2005-06	1	0	01	01
2006-07	08	07	18	15
2007-08	21	14	42	18
2008-09	24	12	18	08

Source: Primary data from Kothur and Sriranagapur, Mahabubnagar district, AP, collected by AFPRO Hyderabad.

4.3 SRI practices adopted by V&A farmers

4.3.1 Seed treatment

Several traditional organic farming practices were promoted under the V&A pilot programme and taken up by farmers. For seed treatment, farmers applied Trichoderma, which is a bio-control agent against fungal diseases of plants, at the time of sowing in the nursery. In addition, farmers treated seeds with Azospirrillum or Azatobacter, both of which are nitrogen-fixing bacteria in the soil, which help reduce the need for the application of chemical fertilizers.

4.3.2 Raising of seedlings

One of the practices recommended to farmers in the SRI training under V&A was the raising of seedlings in elevated unflooded seedbeds of a size of 4 square feet, located close to the fields, to facilitate transplantation of very young seedlings with a minimum of root damage. Seven of the SRI farmers in Srirangapur (i.e. 38% of all SRI farmers in this season) adopted this particular practice. The rest of the farmers raised their seedlings in conventional nurseries.

4.3.3 Transplantation of seedlings: Timing and spacing

Almost all of the SRI farmers transplanted seedlings to the fields after 13 to 15 days, whereas under the conventional practice transplantation is done after 30 days. Farmers expressed that it was not feasible to schedule the transplantation at exactly 8 to 10 days after sowing as recommended for SRI. This was because labour was scarce when all farmers do the transplanting, which is highly labour-intensive, at the same time, and because power supply (required for the first irrigation of the newly transplanted

[4] The cropping season over the winter months from November to March is called rabi season.

seedlings) was highly irregular and erratic.

The majority of SRI farmers followed the recommendation regarding spacing between the seedlings and adopted square planting of seedlings with 25 cm space on either side. Most of the farmers used mechanical markers, developed by Acharya N.G. Ranga Agricultural University Hyderabad (ANGRAU), to draw squares patterns on the field.

However, as regards the number of seedlings planted per hill, the SRI farmers did not strictly follow the advice to plant only one seedling per hill for optimal growth conditions. Many preferred to plant up to 3 seedlings per hill in order to avoid the risk of "fallow" hills in case the single seedling might die. Farmers also stated that the labourers they employed lacked the skills for single seedling transplantation.

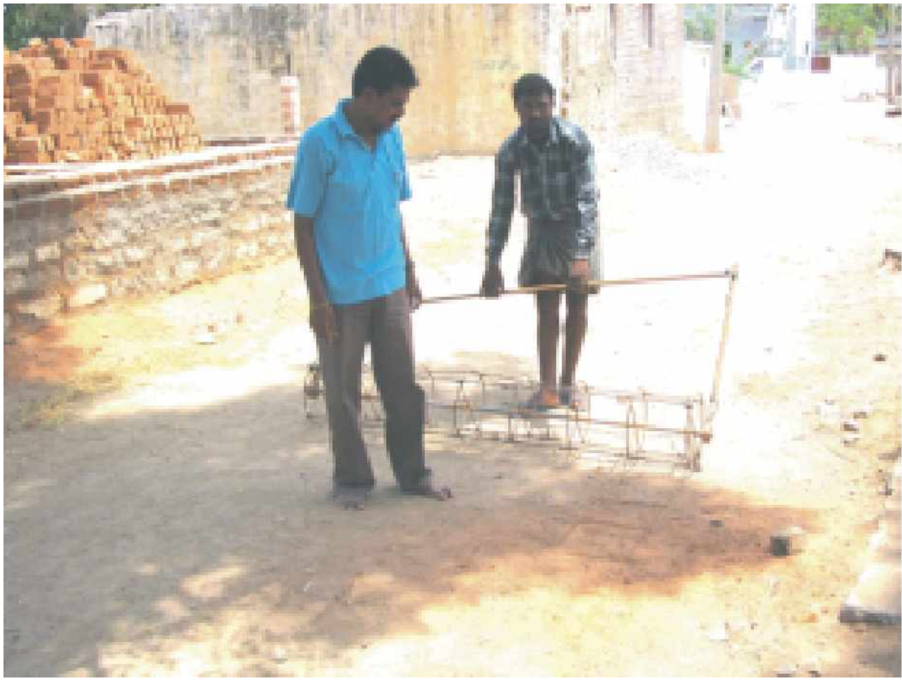


Figure 3: SRI Marker

4.3.4 Nutrient management

Both conventional and SRI farmers applied different non-organic and organic fertilizers to their fields, yet in different quantities. SRI farmers applied about 65 per cent less urea than under conventional practice. However, they applied more DAP (Diammonium Phosphate)[5] and potash. Table 4 shows a comparison of fertilizer inputs under conventional and SRI practice.

Table 4: Fertilizer inputs under conventional and SRI practice

Type of fertilizer	Conventional practice	SRI
Urea	360-480 kg/ha	240-300 kg/ha
DAP	180-240 kg/ha	240-360 kg/ha
Potash	120-180 kg/ha	240 kg/ha
FYM	4.8 tons /ha	24 tons / ha
Vermicomost	Not used	2.4 tons /ha

Source: Primary data from Kothur and Sriranagapur, Mahabubnagar district, AP, collected by AFPRO Hyderabad.

Under SRI, the use of chemical fertilizers was partly substituted and complemented by the application of organic manures. The input of farm yard manure (FYM) under SRI practice was 5 times higher than under the conventional practice. Vermicompost was only adopted by SRI farmers. The production of vermicompost had been promoted by the Andhra Pradesh Department of Agriculture as an organic nutrient supply source with sustainable benefits for soil quality. Farmers also adopted in-situ application of green manure in the fields to build soil fertility. They sowed sunhemp on the paddy fields

[5] DAP is a chemical fertilizer, which delivers nitrogen and phosphorus to the plants. 100 kg of DAP contain 18 kg of nitrogen and 46 kg of phosphorus.

Figure 4: Field under SRI cultivation in Srirangapur, Mahabubnagar district, Andhra Pradesh.

2 months before the transplantation of rice seedlings and ploughed the sunhemp plants into the soil as green manure once it had reached flowering stage.

4.3.5 Pest and disease management

The most important pests reported to occur on SRI paddy fields are brown plant hoppers *(doha)*, leaf folders *(akumudatha)*, yellow stem borer and case worms. Blast and bacterial blight are also commonly reported diseases in SRI field trials.

SRI farmers in the villages selected for implementation of the V&A pilot programme reported that some of the above mentioned pests could be controlled through judicious water management. Draining the fields for at least 3 days killed most of the larvae of case worm and brown plant hoppers. All SRI farmers used a bio-pesticide, namely 5 per cent solution of neem seed kernel extract (NSKE), instead of spraying chemical pesticides. This was one of the practices promoted through a training workshop on non-chemical pest and disease management practices to be adopted by communities under the V&A pilot programme.

Pheromone traps helped farmers control the Stem Borer. In addition, farmers recognized the value of indigenous predators like spiders, long horned grasshoppers, ladybird beetle, ground beetles, dragonflies and predatory birds. They realized that through minimizing the use of chemical pesticides they could also conserve these predators and take advantage of them as natural enemies of pests.

The incidence of blast and bacterial leaf blight was found to be lower on the SRI fields than on fields under conventional rice cultivation. The application of "Panchagavya" (a mixture of cattle dung, cattle urine, cow milk, curd or butter milk, mashed banana and ghee, allowed to ferment for a few weeks) brought good results for controlling these diseases on SRI fields. There is no standardized composition of "Panchagavya", but farmers who are using it as an organic fertilizer cum disease control measure have been reporting good results.

4.3.6 Weed management

Weed management emerges as an issue of particular concern in SRI practice. In conventional practice, submergence of rice plants reduces the growing of weeds (as a matter of fact, it is only for the purpose of weed control that paddy fields are kept under flooded conditions), so that weeding can be done manually by family members, usually by women. In the case of SRI practice, more intensive weed management is required, and weeding has to be done with mechanical weeders, mostly cono weeders, 3 to 4 times during the growing period, operating it in both directions in between the hills. A co-benefit of this practice is that incorporating the weeds into the soil improves the soil quality by increasing the content of organic matter. Farmers found it particularly difficult to apply mechanical weeders on black soil. They tended to engage male labourers to operate the cono-weeder on fields with black soil. On light soils most of the farmers operated the weeder themselves.

In Andhra Pradesh cono-weeders are manufactured centrally by ANGRAU and supplied to all districts across the state through the Department of Agriculture. Initially, they were distributed free of cost and later supplied with a 50 per cent subsidy through the Andhra Pradesh Agro Industries Corporation. Farmers purchase them at a price of Rs. 150. The Department of Agriculture has also supplied automatic weeders to farmers; however, these models did not meet farmers' needs as they were found to be too expensive and not functioning smoothly in heavy soils.

Figure 5: Operation of a cono weeder in Kothur, Mahabubnagar district, Andhra Pradesh.

4.4. Production increase

SRI can generate significant productivity gains with lower inputs as compared to conventional rice cultivation. In other words, it can improve the productivity of land, water and capital. However, yield increases depend on various factors, including the abundance and diversity of soil biota, which is partly determined by the management of inputs and the degree to which farmers adopt the SRI practices explained above. Consequently, yield advantages reported to be achieved through SRI adoption differ substantially from country to country, from region to region, and even from field to field depending on soil conditions and practices applied.

In the villages selected for implementation of the V&A pilot programme, farmers found that through adopting SRI they were able to grow rice plants with higher numbers of tillers per plant and with a bigger grain size as compared to conventionally grown rice plants. The yield increases through SRI depended on the variety of seeds applied, as indicated in table 5. The gain through adoption of SRI practices was highest for BPT 5204 seeds. While BPT 5204 seeds are only available on the private market, farmers purchased IR64 seeds from the ANGRAU at a price of Rs. 650 per bag of 30 kg. For the IR64 seed variety, grain yields under SRI were 23 per cent higher per unit of land than under conventional rice cultivation practice.

Table 5: Grain yields under SRI for different seed varieties

Seed variety	Grain yield under SRI (tons per ha)	Grain yield under conventional practice (tons per ha)	Yield increase through SRI
BPT 5204	5.651	4.5	25.6%
IR64	5.241	4.25	23.3%
JK104	5.065	4.2	20.6%
MTU1010	4.942	4.2	17.7%

Source: Primary data from Kothur and Sriranagapur, Mahabubnagar district, AP, collected by AFPRO Hyderabad.

It was also found that the maturing time was notably shorter for SRI paddy than for paddy cultivated under the conventional method. As per Andhra Pradesh State Seed Development Corporation and ANGRAU, the maturing time under conventional practice for IR64 seeds is 120 -125 days and for BPT5204 seeds it is 140-150 days. Under SRI, IR64 was found to mature in 98-119 days and BPT5204 in 99-100 days (excluding the maturing time of seedlings before transplantation).

4.5 Changes in input requirements

The most meaningful way to express increase in yields is per unit of land, as of all the production factors, land size is the one that farmers take as constant and thus the limiting factor for production. However, at the same time, inputs differed significantly between SRI and conventional practice. Hence, if expressed in terms of aggregated productivity increase of inputs, SRI results exceeded results of the conventional practice many times over.

4.5.1 Water

The amount of water required for irrigation was significantly lower under SRI than under the conventional method. Under SRI, approximately 40 irrigations of 2 pumping hours per acre were sufficient over the entire Rabi growing season, whereas under the conventional method approximately 60 irrigations of 2.7 pumping hours were needed. Taking into account different discharge rates of farmers' pumping systems, it was calculated that on average, 1608 m^3 of water were required for irrigation of one acre of land under SRI, compared to 2500 m^3 under the conventional method of rice cultivation. Hence, 35 per cent of irrigation water could be saved through SRI adoption.

Table 6: Water requirements per acre of land under SRI and conventional practice

	Conventional	SRI
Duration of irrigation	2.7 h	**2 h**
Water used/acre	2500 m^3	1608 m^3
Net output per m^3 of irrigation water input	0.68 kg	1.3 kg

Source: Primary data from Kothur and Sriranagapur, Mahabubnagar district, AP, collected by AFPRO Hyderabad.

This reduction in irrigation water requirements in combination with the yield increase through SRI adoption constitutes a remarkable increase in water use efficiency. It was calculated that the net output of one cubic meter of irrigation water was doubled through SRI (Table 6). Hence, SRI offers a valuable solution to attain "more crop per drop" of water, which is now a widely established objective of innovations in agricultural practices and technologies in light of growing pressures on water resources, mounting food needs of a growing world population and the large share of agriculture in total water consumption.

Another important aspect of the reduced need for irrigation requirement is the associated energy saving effect for operation of groundwater pumps. In Andhra Pradesh, power supply for irrigation is fully subsidized by the state government, which constitutes a radical undermining of incentives for farmers to use groundwater and electricity judiciously. As electricity is also provided at irregular timings, farmers have developed a habit of switching on pumps over night in order not to miss out on the limited hours of power supply, so that their pumps are operated without surveillance once electricity is on. This leads to overuse of water and electricity. The need for precise dosage of irrigation water in SRI therefore also helps to counteract wasteful use of energy, which is highly relevant from a climate change perspective as it contributes to mitigating carbon emissions for power generation through burning of fossil fuels.

4.5.2 Seeds

Farmers used between 7.5 and 12.5 kg of seeds per ha of land under SRI cultivation, whereas the input of seeds for conventional practice is about 75 kg per ha. Thus, the saving in seed input through SRI as compared to conventional method ranges between 83 and 90 percent.

4.5.3 Fertilizers

As mentioned above, the composition of fertilizers applied under SRI differed from that applied under the conventional method. Under SRI, farmers used more organic fertilizers like FYM and vermicompost. When analyzing the input cost for fertilizers, it is important to differentiate between farmers who had in-situ production of vermicompost and FYM from their own livestock, and farmers who had to purchase the organic fertilizer material from outside sources. Vermicompost was purchased at a price of Rs 3000-3200 per ton, and FYM at a price of Rs 1600-1800 per ton. The overall expenses for fertilizers were higher under SRI adoption than under conventional practice when farmers had to purchase the material (Table 7). However, farmers who could cover their FYM needs from their own livestock and who practiced vermicompost production could save on fertilizer expenses when adopting SRI.

Partly substituting chemical fertilizers in rice cultivation is particularly desirable in light of the rapidly dwindling global phosphate resources, which will most likely result in drastic increases of phosphate prices, and hence the cost of phosphorous-based fertilizers (see e.g. Dery and Anderson, 2007).

4.5.4 Labour

Farmers found that SRI was more labour-intensive than the conventional practice. They reported that various steps in the cultivation cycle had to be done with more care and required particular skills that could only be built through practice. Land-levelling had to be done with more care in order to enable even distribution of water over the field, which is vital as SRI requires alternate wetting and drying of soil. Transplanting of seedlings was also found to be more time-consuming if SRI recommendations were followed. The most substantial difference in labour requirement between SRI and conventional practice was for weeding, as noted above. Under SRI, weeding is required a minimum of 3-4 times over the growing period, with an involvement of at least 3 persons per acre to do the hard work.

4.6 Profitability

A comprehensive analysis of the data on yields and inputs indicates that SRI adoption raised profitability and income from rice production. Profitability is a key parameter as it is the primary motivation for farmers to adopt SRI. Table 7 provides an overview of all elements of input costs for rice production per ha of land under SRI and conventional practice. With a market value of Rs 5,850 per ton, farmers' sale proceeds per ha of land under SRI practice were on average Rs 30,660 and Rs 24,863 under conventional practice. As a result, profit gained from rice cultivation on one ha of land was Rs 8,023 under SRI and Rs 3,325 under conventional practice, which is a gain of 240 per cent.

4.7 Soil quality

Table 7: Input costs, proceeds and profits from SRI and conventional rice cultivation (per ha)			
		SRI practice	**Conventional practice**
Input costs	Land preparation	Rs. 5,113	Rs. 5,153
	Seeds	Rs. 126	Rs. 1,291
	Organic fertilizers	Rs. 6,000	Rs. 3,863
	Chemical fertilser	Rs. 3,764	Rs. 4,117
	Pest and disease management	Rs. 671	Rs. 914
	Weed management (incl. hired labour)	Rs. 2,582	Rs. 2,418
	Harvesting	Rs. 4,382	Rs. 3,826
	Total cost	**Rs. 22,637**	**Rs. 21,538**
Yield		5.241 tons	4.25 tons
Sale proceeds (Rs. 5850 per ton of rice)		**Rs. 30,660**	**Rs. 24,863**
Profit		**Rs. 8,023**	**Rs. 3,325**

Source: Primary data from Kothur and Sriranagapur, Mahabubnagar district, AP, collected by AFPRO Hyderabad.

Apart from these gains that could be directly measured in monetary terms, farmers reported about other benefits of SRI that will only pay off in economic terms in the long run. For example, SRI has notably improved soil quality and rendered even alkaline soils productive. This was a result of several practices: First, the content of organic matter in the soil was increased through the incorporation of weeds by use of the mechanic weeder, as well as by the practice of green manure adopted by some farmers. In addition, the application of FYM or compost led to a regeneration of soil ecosystems that are often highly degraded through prolonged exposure to chemicals fertilizers as prevalent in conventional rice cultivation systems.

5. Review of results reported in other studies on SRI in India

There is a history of over 10 years of systematic documentation of SRI practices and results by various actors and under a wide range of programmes and projects in India. Table 8 provides an overview of results measured under various pilot projects and field trials at different study sites all across the country. Even though there are gaps in this compilation as the recording and reporting of results has not been uniform across the different studies, it indicates an overall significant yield advantage of SRI as compared to conventional rice cultivation methods, as well as reduced water requirements and seed inputs. It thereby validates the results obtained under the V&A pilot programme in villages in Mahabubnagar district in Andhra Pradesh.

Cases of 'super-yields' through SRI have been reported for example in the Godavari delta of Andhra

Table 8: Results of SRI compared to conventional method, experience from different states in India				
Study area	**Seed input**	**Water requirement**	**Yield increase**	**Source**
Andhra Pradesh, study by WWF with support from ICRISAT and Acharya N.G. Ranga University, Hyderabad, covering 250 farmers in 11 districts	90%reduction in seed input as compared to conventional method	50% reduction in water requirement compared to conventional method	2 t/ha, i.e. 20% yield increase as compared to conventional method	WWF-Dialogue Bulletin, Issue No. 15, and June 2005
Tamil Nadu, experiments in 2003-2004 at Agricultural College and Research Institute (TNAU), Killkulam		53% reduction in water requirement	3.9 t/ha, i.e. 28% yield increase as compared to conventional method	India Development Gateway (INDG), http://www.indg.in /agriculture/agricul tural-best-practices /sri/agri-best-sri-state
West Bengal, study on the experiences of 59 farmers in Balrampur, Purulia district, Kharif 2004	90%reduction in seed input as compared to conventional method		6,282. kg/ha, i.e. 50% yield increase as compared to conventional method	S. Kumar Sinha and J. Talati, 2007
Experiments at Gujarat, Agricultural University, Anand		46% reduction in water requirement	no yield increase as compared to conventional method	Presentation at the 4th IWMI-Tata Annual Partners Meet held in February 2005 in Anand
Tripura, study under WWF-ICRISAT project	90% reduction in seed input as compared to conventional method		for high-yielding varieties: SRI yields ranging from 4.6-8.5 t/ha, as opposed to 2.5-5.2 t/ha under conventional method	WWF-ICRISAT project, SRI Fact Sheet Tripura
Punjab, study under WWF-ICRISAT project, kharif 2007	60% reduction in seed and seed treatment expenditure as compared to conventional method	14 times irrigation under SRI compared to 26 times under conventional method	2.1 t/ha, i.e. 27% yield increase as compared to conventional method	WWF-ICRISAT project, SRI Fact Sheet Punjab
Himachal Pradesh, study under WWF-ICRISAT project, 2007 data			2,4 t/ha, i.e. 82% yield increase as compared to conventional method	WWF-ICRISAT project, SRI Fact Sheet Uttarakhand & Himachal Pradesh
Uttaranchal, study under WWF-ICRISAT project, 2007 data			2.7 t/ha, i.e. 96% yield increase as compared to conventional method	WWF-ICRISAT project, SRI Fact Sheet Uttarakhand & Himachal Pradesh

Pradesh, obtained by middle and large-scale farmers, measured by the staff of the AP Department of Extension: A farmer, S. Lakshmana Reddy Ramavaram, harvested 7.25 t/ha on his land in rabi 2003-2004[6]. Even though such yields may be exceptional to date, they indicate the enormous potential for higher rice production, to be attained through optimized plant, soil, water and nutrient practices.

Profitability proved to be even higher than yield increases in many studies on SRI results due to reduction of input costs. For example, in an evaluation of the SRI experience of 110 farmers in Purulia district, West Bengal, a 17 per cent reduction in costs of production of SRI against standard upland rice production was recorded. This resulted in a 67 per cent increase in farmers' net returns per ha with SRI, where yield increase was around 50 per cent (Kumar Sinha and Talati, 2005). In Tamil Nadu, an 11 per cent average reduction in costs of production was recorded for 100 farmers doing on-farm comparison trials using SRI vs. standard methods. With higher SRI yields, farmers' net returns per ha went up by 114 per cent with SRI, from $242/ha to $519/ha (Thiyagarajan, 2004). Reductions in cost of production through SRI, like yield increase, varies largely across regions and conditions. Under certain conditions, costs have even been found to increase.

In general, experience has shown that when farmers adopted SRI, they usually had to put in significantly more labour in the initial stages while the methods were being learned. This was because land preparation had to be done with more precision than for the conventional method to enable good irrigation and drainage. Also, seedlings had to be transplanted individually and with due care as they were still young and delicate, which made transplanting more time consuming. In addition, a large number of farmers throughout the country shared the experience of farmers in the villages in Andhra Pradesh under the V&A pilot programme that weeding was a time consuming and difficult activity.

However, farmers in various SRI projects reported that once they had developed some routine and mastered the new techniques, their pace of work speeded up. Eventually labour requirements were found to decrease in comparison to conventional method in some cases. For example, farmers surveyed in the IWMI evaluation of SRI impact in Purulia district, West Bengal, were found to be able to reduce their labor input/ha by 8.7 per cent with SRI, while farmers' labor productivity (kg of rice produced per day of labor) went up by 43.5 per cent (Kumar Sinha and Talati 2005).

Similar to the experience under the V&A programme, SRI fields in other areas have been found to be more resistant to pests and diseases than rice fields under conventional cultivation practice, without using different varieties. Researchers at Tamil Nadu Agricultural University have documented significant decreases in rice pests both in nurseries and in the field: cutworm, thrips, green leaf hopper, brown plant hopper, whorl maggot, and gall midge, although more stem borers and leaf folders were observed in the field (Thiyagarajan 2004).

Another observation that was highlighted by various reports on SRI projects was that SRI rice is less vulnerable to severe weather events like heavy rainfall and strong wind. This can be attributed to the more vigorous rice plants and stronger root systems generated by SRI. For example, when a typhoon hit the rice crop in Andhra Pradesh in December 2003, it was reported that conventional rice crops were badly affected, whereas SRI rice was hardly affected. Likewise, SRI has proved to be resistant to extreme temperatures: a cold spell in Andhra Pradesh in February 2004 hardly affected SRI plots, but had an adverse impact on conventionally-grown rice (Uphoff 2005).

Reports also validate that under SRI practice the maturation period for various varieties of rice is shorter

[6]Data provided by Dr. Alapati Satyanarayana, Director of Extension, Acharya N. G. Ranga Agricultural University, Hyderabad, India, February, 2005 **(alipatisatyam@yahoo.com).**

than when grown with conventional practices, as observed under the V&A pilot programme. In Andhra Pradesh, data collected by ANGRAU in rabi season 2003-2004 showed that SRI rice matured 7-10 days sooner as a result of the more favorable growing conditions. Harvesting earlier can reduce the risk of loss due to bad weather, pests or disease, which often come at the end of the normal growing season (Uphoff 2005).

6 Conclusions on SRI benefits in the context of climate change

6.1 Climate change implications for rice cultivation

The inter-linkages between climate change and agriculture are multi-dimensional and complex. It is beyond the scope of this study to take into account all potential factors that determine how rice production is affected by climate change impacts, or how it contributes to the global phenomenon. An elementary observation is that crop yields are influenced by three parameters that are expected to alter with climate change:

(a) the level of carbon dioxide in the atmosphere (termed carbon fertilization);
(b) temperature rise; and
(c) the level and distribution of precipitation.

For most crops, including rice, elevated levels of carbon dioxide and higher precipitation rates (except where rainfall is excessive) promote crop growth. The effect of carbon fertilization differs considerably between different plant species and local physiological conditions. The impact is generally lower where water availability or temperature is limiting plant growth.

However, crop responses to climate change depend on the location-specific baseline climate and soil conditions, which is why estimations of climate change impacts on agriculture production vary tremendously. In fact, no consensus has emerged so far on how rice production will be affected by climate change impacts in India. A study by Aggarwal and Mall (2002) estimated that the direct effect of climate change on rice crops in different agroclimatic regions in India would always be positive irrespective of various uncertainties, with increases of up to 33 per cent under an optimistic scenario. Similarly, an assessment of climate change impacts on rice production in China by the UK-based Institute of Physics (Huang et al., 2009) concludes that rice production in China is likely to benefit from global warming. Other estimates, including those that Prof. M.S. Swaminathan has presented at various occasions, project a decline of Asian rice production due to climate change based on the present systems. Experiments by the International Rice Research Institute (IRRI) indicated that a one-degree increase in temperatures could cause rice yields to drop by 10 per cent (Bennett, 2004).

These contradictory projections call for a closer look at the climate-related factors that determine rice production. The following climatic conditions and their biophysical impacts on agricultural environments have been identified as key factors that can reduce rice crop yields (Mitin, 2009):

a. erratic rainfall conditions;
b. temperature rise leading to increased soil evaporation and evapotranspiration from plants;
c. soil moisture stress resulting from (a) and (b) above;
d. extreme weather events like cyclones and typhoons;
e. heat waves;

[7]The irrigation demand for agriculture in arid and semi-arid areas in India is expected to increase by 10 per cent for a temperature increase of 1°C (FAO, 2008).

f. increased weed, pest and disease challenges through temperature and humidity rise;
g. soil erosion and loss of soil organic matter, and hence loss of soil fertility, due to extended dry spells and increased frequency of heavy rainfall events.

In the context of irrigated rice cultivation in semi-arid areas in India, aspects a. and b. above deserve particular consideration. First, as future precipitation in most of these areas is projected to be more erratic and the risk of droughts is expected to increase, this will reduce soil moisture and limit groundwater recharge capacities. Second, as soil evaporation and evapotranspiration will increase with rising temperatures, irrigation requirements for rice cultivation will also grow, adding to stresses on groundwater levels.

In order to ensure food security in the face of climate change while maintaining balanced ecosystems that underpin agricultural production in the long run, it will be vital to find ways to adapt farming systems to the changing climatic conditions. There is a wide range of options for strategies to reduce the vulnerability of agricultural systems, including rice cultivation, to climate risks. Some examples are:

- investments in water storage;
- development of drought-tolerant crops;
- crop diversification to reduce risks at the level of individual farmers;
- water-saving technologies such as alternate wetting and drying irrigation; and
- site-specific adjustments in crop management (e.g. shifting planting dates, adapted water management).

The choice of effective options will depend on the specific features of the agricultural and natural systems that are at risk, and on exact ways in which climate change impacts are expected to occur.

For rice cultivation systems, adaptation to climate change means not only reducing the vulnerability of the rice production per se, but also taking into account the increased pressures on natural resources that are associated with modern rice cultivation. The need for high levels of input of water, chemical fertilizers and pesticides of high-yielding varieties can have considerable negative external effects as they may exacerbate vulnerabilities of natural and human systems at a broader scale. For example, as water scarcity becomes a more pervasive agricultural constraint, finding ways to limit the irrigation water requirements in rice cultivation will enhance the overall sustainability of agriculture and food security in the face of climate change.

6.2 SRI potential for reducing vulnerability to climate change impacts

The System of Rice Intensification offers multiple benefits against the background of the various climate change implications for agriculture. The following two elements of SRI results, experienced under the V&A programme and in many other study areas, are of particular relevance for reducing externalities of modern rice cultivation:

i. By cutting the demands that rice farmers make on surface irrigation and groundwater supplies, SRI can take pressures off scarce freshwater and aquifer supplies. This is of particular relevance in those areas where groundwater levels are being exploited at unsustainable levels, as is the case for the area selected for implementation of the V&A pilot programme in Andhra Pradesh.

ii. Reduced use of chemical fertilizers and pesticides coupled with higher inputs of organic manures are key elements of improved environmental management. These practices reduce the risk of groundwater contamination and enhance soil quality, including water retention capacity of the soil. The result is enhanced resilience of the natural resource base to multiple stresses, including those related to climate.

In addition, SRI helps to increase the resilience of rice cultivation systems per se to various climate related risks. This is mainly a result of the more robust and healthy plants and the larger and deeper root systems that evolve under SRI methods.

iii. Through the deeper root systems, SRI plants are better prepared to survive short periods of water stress associated with drought conditions, dry spells and irrigation water shortages. Drought tolerance of rice cultivation is of special relevance to poor farmers who tend to have less access to irrigation water in many areas.

iv. SRI plants are more resistant against various pests and diseases. For example, under the V&A programme the incidence of blast and bacterial leaf blight was found to be lower under SRI than under conventional cultivation practice. Given the increase in pest and disease challenges through temperature rise, this benefit will be particularly relevant in the face of climate change.

v. SRI rice is less vulnerable to severe weather events like heavy rainfall and strong wind, which are expected to occur more often in large parts of India, owing to the more vigorous rice plants and stronger root systems.

vi. Under SRI practice the maturation period for various varieties of rice is shorter than when grown under conventional practices. Harvesting earlier can reduce the frequency of losses due to bad weather, pests or disease which often come at the end of the normal growing season and are expected to occur more often with climate change.

Apart from these characteristics of SRI that pertain to bio-physical features of rice cultivation and outcomes, there is another dimension in SRI that deserves attention with regard to enhancing adaptive capacity: Adopting SRI encourages, or rather requires farmers to take an active role in experimenting with the package of SRI practices and adapting them to suit the local environment, including climatic conditions. The optimal spacing between plants, for example, needs to be determined in relation to particular soil features and hydrological conditions. When and how to best apply water will depend on rainfall patterns, soil characteristics and field position. Recommendations for spacing, water management, age of seedling, etc. are not offered as universal recipes; rather, principles are presented to be understood, tested and adapted by users.

This dimension of research, practice and the spirit of open learning that are inherent in SRI adoption will build farmers' capacities for experimenting, evaluating and innovating. Ultimately, a more flexible approach to cultivation practices taken by farmers has a potential to enhance adaptive capacity to climate change. This capacity may emerge at the individual as well as at the community level, when farmers develop a culture of sharing their experiences and exchanging which practices have proved successful and which have failed. In the case of the villages selected for implementation of the V&A programme, the 'Smart Farmers Clubs' that were set up under the programme have provided a platform for exchange of SRI experiences among the members.

Last but not least, the yield increase and productivity gains offered by SRI, as well as the reduced dependency on external inputs if farmers replace chemical fertilizers and pesticides with in-situ produced organic inputs, will improve farmers' overall livelihood situation. This, in turn, will enhance their resilience against risks and enhance their adaptive capacity.

All in all, SRI combines a number of features that make it highly valuable with regard to reducing vulnerability of agricultural systems to climate change. The benefits are in terms of

- reducing pressures on vulnerable ecological systems;
- enhancing resilience of the rice cultivation system per se;
- improving farmers' overall livelihood situation; and
- building adaptive capacity of farmers as the key human resource in agricultural systems.

6.3 SRI potential for contributing to climate change mitigation

Agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases (GHG) such as carbon dioxide, methane, and nitrous oxide. Of the total global anthropogenic emissions of GHGs, agriculture accounts for 10-12 per cent. As per estimates by the Intergovernmental Panel on Climate Change (IPCC), agriculture is the major contributor to total anthropogenic methane (47%) and nitrous oxide emissions (58%). Rice production is considered to be a main cause of rising methane emissions from the agriculture sector during the past century (Smith et al., 2007). A study of GHG emissions from irrigated rice in India revealed that total methane emission over kharif season (105 days) ranged from 24.5 to 37.2 kg ha^{-1} (Gosh et al., 2002).

SRI has therefore often been subject to discussions on how changes in agricultural practices can contribute to climate change mitigation. Under the conventional method of rice cultivation, methane is emitted by bacteria that thrive in flooded rice paddies by decomposing manure used as fertilizer and other organic matter in the oxygen-free environment. The gas is emitted through the plants or directly into the atmosphere. Thus, by avoiding the flooded conditions on rice fields, SRI can help bring down methane emissions from rice cultivation.

On the other hand, it has been pointed out that unflooded paddy under SRI methods may produce more nitrous oxide. However, when less or no nitrogen fertilizer is used, this effect is likely to be small. However, a recent evaluation of the mitigation potential in rice cultivation has revealed that the gains in methane reduction (almost 30%) through draining of flooded rice fields at least once during the growing season are considerably greater than any offset from generation of more nitrous oxide (Yan et al., 2009). The evaluation was done according to guidelines of the IPCC. From this result it can be assumed that there is a considerable potential for emissions reduction in avoided flooding of rice fields all throughout the growing period, as recommended for SRI.

More systematic research will be needed to validate these findings and quantify the contribution that SRI adoption can make to reduction of GHG emissions.

SRI contributes to mitigation of climate change through another lever. Through requiring precise dosage of irrigation water, it helps reduce energy consumption for operation of water pumps, and therefore has a potential to mitigate carbon emissions from burning of fossil fuels for power generation. Notably, SRI helps prevent overconsumption of energy in a situation where power supply for irrigation is fully subsidized by the state government (see section 4.1.7).

Finally, another factor of mitigation of GHG emissions through SRI is the reduced need for application of chemical fertilizers. Production of chemical fertilizer is associated with significant energy and process related GHG emissions which outweigh the respective GHG footprint of organic fertilizers.

7 Successful approaches for promoting SRI

For all the reasons discussed above, scaling up the adoption of SRI constitutes a promising step towards a more climate resilient agriculture sector in India, to enhanced food security and improved agricultural livelihoods of rural communities. The following section analyses how SRI has emerged, how it has been promoted and what roles different actors have played in developing and promoting SRI. Some important conclusions will be drawn with regard to approaches that have been most effective in triggering the spread of SRI.

7.1 Evolution of SRI

SRI was developed in Madagascar by Fr. Henri De Laulanié, a French priest with a background in agriculture and passion for rural development, whose keen observations of deviant practices in rice cultivation and continued experimentation led to SRI. It has emerged over a decade as a package of principles that are different, often radically, from conventional rice cultivation techniques.

The spread of SRI from Madagascar to around the globe has been credited to Norman Uphoff, Director of the International Institute for Food, Agriculture and Development at Cornell University, Ithaca, New York from 1990 to 2005. Following a three-year study with Malagasy farmers, Uphoff carried the idea to Asia, which has the biggest share in the global rice production and consumption, and promoted SRI in different Asian countries from 1997. The beneficial effects of SRI methods have been documented in 46 countries all over the word, and validated in 35 countries. More than 1 million small farmers producing rice around the world on over 1 million hectares have adopted it by now and benefitted from the improved input efficiency.

7.2 Promotion and adoption of SRI under different programmes in India

Today SRI is being practiced in all the rice growing states and agro-climatic zones in India. There are several ways in which the spread of SRI has been promoted with different actors taking a lead role. They can be broadly classified under four categories:

1. Active support from research (agricultural universities) and extension (both through the government extension system and NGOs) with external support: The best example of this is Tamil Nadu, which has by far the largest acreage under SRI in India. A main factor that has boosted upscaling was a World Bank funded project on irrigation water management.
2. Active support from Government: This is best exemplified by Tripura where SRI has been integrated as part of the State Government's overall strategy for food security much before the National Food Security Mission was in place. Tripura has used local bodies such as the Gram Panchayats as extension agents.
3. Active support from CSOs: In many states such as Uttarakhand, West Bengal, Bihar, Jharkhand, Chattisgarh and others, SRI activities are largely led by civil society organizations, some of which have been supported by donor agencies such as the Sir Dorabji Tata Trust (SDTT).
4. Active support from research and extension initially, tapered down overtime: This has been

the case in Andhra Pradesh. Despite being a leader in SRI, Andhra Pradesh failed to take off because of a lack of sustained support from the Department of Agriculture since 2008.

7.3 The role of civil society and government actors in SRI development and promotion

At the national level, the National Food Security Mission (NFSM), launched in 2007, is the only policy document that contains a mention of SRI and recognizes it as a strategy for improving rice productivity. It seeks to spread SRI through field-level demonstrations, including Farmers' Field Schools. SRI promotion will be limited to areas where progressive farmers have assured irrigation facility and provision of drainage. In general, governments at national and state level have been relatively slow and hesitant about integrating SRI into policies, plans and programmes.

One reason why SRI has not fitted into the conventional way of government support for an innovation is that the Indian National Agricultural Research System, like in most other countries, has a division between research and extension. The extension system usually has to take on the results of the research done by scientists. The relation between these two arms (extension and research) does not anticipate the extension arm to provide any insights into the process of research except for providing 'user feedback'. SRI innovation has followed an alternate tradition of research where the relation between scientists, extension agents and farmers have not been hierarchical and knowledge flow unidirectional. Some scientists, who have been sensitive to the principles of SRI, have picked up insights on SRI directly from farmers fields and incorporated them in their research design. It has been through such non-linear innovation processes that the stock of knowledge on SRI and rice cultivation worldwide has grown.

Andhra Pradesh has been an interesting case where extension scientists have taken a lead in researching SRI. The extension department of ANGRAU has been at the forefront of providing insights into the early maturity of SRI crops, its pest resistance, milling outturn, etc. Extension officers in Andhra Pradesh have carried out detailed evaluations on spacing and transplanting options for farmers.

SRI, being a skill and not an input-intensive method of increasing rice yields, requires a different extension approach than the conventional one. The government extension system in India (like in most other countries) is not designed to support innovations that consist of a change in practices rather than a change in inputs. Government extension services are based on delivering improved inputs to farming communities; however, promoting the adoption of SRI requires intensive support to farmers throughout the agricultural production cycle, as farmers need to change long-standing routines in their practices. This time-consuming support is often beyond the scope of what extension agents can offer within the established extension structures.

For this reason, civil society actors have played a particularly important role in the promotion of SRI. They have been able to take up extension methods that meet the special requirements of promoting SRI. Farmer Field Schools (FFS), for example, which have emerged as an important element of civil society approaches to extension, have proved a highly effective way of promoting SRI. Other examples have been organizing exposure visits, farmer-to-farmer extension, and promotion of SRI through women Self Help Groups (SHGs).

Important contributions of civil society to SRI have been in the area of experimentation and innovation. NGOs have fostered innovation in many different ways; they have promoted farmer-led innovation around SRI, but also taken an active role in research and development of SRI practices and inputs. For example, a large number of weeder designs have been developed by WASSAN (Watershed Support

Services and Activities Network).

In addition, many CSOs have seen in SRI the possibility of pursuing broader social and ecological development objectives, like improvement of soil quality, reduction of groundwater contamination risks through reducing chemical inputs, the use of traditional and indigenous varieties of rice, and empowerment of farmers through their active involvement in innovation processes.

These observations make the case for a stronger collaboration between government research, extension systems and civil society. The role of governments should be focused on intensified research around SRI and development of inputs like weeders and markers. In addition, ways should be found to integrate SRI into the government extension systems more effectively. NGOs could complement the government extension services for SRI by providing intensive handholding and soft support throughout the cultivation period.

Table 9 in the Annex provides an overview of CSOs that have taken initiatives towards SRI development and promotion in different states in India.

8 Conclusions

The System of Rice Intensification offers multiple benefits for reducing vulnerability of agricultural systems and livelihoods to climate variability and change:

- It helps to reduce pressures on vulnerable ecological systems by reducing irrigation water requirements and need of pesticide inputs and chemical fertilizer. Reducing chemical fertilizer requirements is also relevant in light of the world's rapidly dwindling phosphate resources, which will eventually result in a surge of chemical fertilizer prices, urgently calling for alternative options especially for poor farmers.
- It enhances the resilience of rice cultivation systems against climate risks as it generates healthier and more robust rice plants with deeper and more vigorous root systems.
- It improves farmers' overall livelihood situation by increasing yields and profitability; the substantial savings in seeds are particularly relevant in the context of food security.
- It builds adaptive capacity in farmers and farmer communities as they are encouraged to experiment, evaluate, innovate and share experiences.

Upscaling of SRI adoption will therefore contribute to a more climate resilient agriculture sector in India, to enhanced food security and improved livelihoods of rural communities. The following conclusions can be drawn with regard to how SRI promotion may be most effective and which main hurdles remain to be overcome:

- When farmers adopt SRI for the first time, they need "hand-holding" support for all key steps throughout the cultivation cycle. Civil society actors have been particularly successful in adapting their extension services to the special requirements of SRI than government extension systems. Partnerships between government extension systems and civil society could therefore be the way forward in promoting SRI. NGOs could complement the government extension services by providing intensive handholding and soft support throughout the cultivation period.

- Witnessing positive results of SRI on neighbouring farmers' fields can encourage farmers to try SRI on their own fields. This has proved to be more effective than theoretical trainings and also more effective than exposure visits to other sites. Accordingly, a focus on a very small number of "pioneer" farmers in a village offers an option for efficient promotion efforts. Participatory technology development and Farmer Field Schools are thus important elements of a dissemination strategy.
- SRI promotion is most effective if it comes along with training on in-situ production of organic farming inputs, like vermicompost or organic pesticides. Opportunities should be sought to align SRI promotion with other ongoing extension programmes that provide a favourable basis for SRI adoption. This was the case in the villages selected for implementation of the V&A programme in Mahabubnagar district, where the promotion of vermicompost production under a state government programme was conducive for SRI activities.
- A key constraint to SRI adoption is the high labour intensity of various steps in the cultivation cycle. Weeding is a particular concern, especially for farmers whose fields have heavy black soils. Further improvements of mechanical weeders should therefore be a priority for research and development around SRI. Civil Society Organizations have made notable contributions to the development of appropriate weeders, as they work closely with farmers and directly incorporate user feedback. Governments can support farmers' access to good weeders by subsidizing successful models.
- Payments of one-time direct subsidies to motivate farmers to adopt SRI have not proved to show sustainable effects beyond the season in which the subsidy was paid. Governments should therefore consider alternative strategies for SRI promotion.
- One important benefit from SRI is the reduction of irrigation water requirements. However, farmers in areas where irrigation (or power supply for irrigation) is heavily subsidized do not take this benefit into account. Efforts are needed in such situations to make the status of groundwater resources more transparent to farmers and raise awareness around groundwater over-exploitation. A participatory Crop Water Budgeting (CWB) exercise provides a useful tool in this context.
- Experience sharing amongst all the stakeholders such as state governments, researchers, civil society groups and farmer organizations should be promoted at national, state and district levels.
- Rashtriya Krishi Vikas Yojana (RKVY) is one of the important schemes of the Government of India to support upgrading and growth in the agriculture sector. It takes a holistic and a bottom-up approach involving district level planning. Integrating support for SRI under RKVY would therefore be a viable option.
- SRI has been already included as a component under the National Food Security Mission (NFSM), which was launched in 2007. In the context of the mid-term evaluation, to be undertaken in 2010, the performance of the SRI component may be critically reviewed and appropriate corrective measures and modifications may be brought about to realize the expected goals.

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Annex

Table 9: Civil Society Organisations active in SRI development and promotion in different states in India	
State	**CSOs active in SRI development and promotion**
Andhra Pradesh	WASSAN, CROPS, Nava Jyothi, CWS, AME partners, Jalaspandana
Arunachal	WWF India
Assam	Rashtriya Gramin Vikas Nidhi, Nest, Gramin Sahara, Gram Vikas Mancho
Bihar	PRADAN, IGS (Basix)
Chattisgarh	Riccharia Campaign, Choupal, PRADAN
Gujarat	FES, Sadguru Foundation, BAIF
Himachal	PSI through its partners
Jharkhand	PRADAN, NEEDS, Jan Seva Parishad, SPWD
Karnataka	AME, Green Foundation, Srijan
Kerala	RAASTA
Madhya Pradesh	ASA, Bypass, SPS, PRADAN
Maharashtra	BAIF, Bosco Grammin Vikas Kendra
Orissa	Centre for World Solidarity (CWS) and its partners, Sahabhagi Vikas Abhiyan, PRADAN, Sambhav, Rishikulya Raitha Sabha, Karrtabya,
Tamil Nadu	Vaanghai, Ekoventure, Kudumbam, CCD, Sri Sadada Ashram, CIKS, farmers' network of Murugamangalam, Tamilaga Velaan Neervala Niruvanam, Erode
Uttarakhand and HP	PSI and its partners, GVK India
West Bengal	PRADAN, Ambuja Cement Foundation, PRASARI, Baradrone Social Welfare Institution