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An Evaluation of the SRI on Increasing Yield, Water Productivity and Profitability; Experiences from TN-IAMWARM Project

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Abstract

The increasing dependence on groundwater for growing staple food crops like paddy causes lowering of water table and serious depletion of groundwater storage in many parts of India including Tamil Nadu, a southern Indian state. This study is based on field research conducted during the Kharif seasons in 2011-2013 in Villupuram district, Tamil Nadu, to evaluate the impact of TN-IAMWARM Project's adoption of SRI on agronomic productivity and irrigation water use efficiency. The adoption of SRI method in paddy cultivation has resulted in increased by 20% in paddy yield and net income 44.50% over the conventional cultivation. This has been achieved with substantial reduction in irrigation water application (42.33%), labor input (17.46%) and seed cost (87.47%). The economic attractiveness of SRI cultivation is very high, giving farmers a strong incentive to accept water-saving techniques as a new norm for irrigated paddy production. Hence, the cultivation of Kharif paddy (which is a high water consuming crop) through SRI practices promises to be a significant alternative for not only increasing paddy productivity, but also for savings on irrigation water and energy costs in the resource-starved regions of India.

Keywords: SRI; Kharif paddy; Water use efficiency; Ground water potential

Introduction

Tamil Nadu covers 4% of the geographical area (13.01 Million ha) and caters to 5.96% of the population of the country with 7.21 crore people living along the 17 river basins. More than 95% of the surface water potential and 80% of groundwater potential have been put into use. The total water potential of the State including ground water is 47,125 MCM (1664 TMC ft.). The total surface water potential of the State is 24,160 M cum (853 TMC ft) including the contribution (7391 MCM or 261 TMC ft.) from the neighboring States, viz., Kerala, Karnataka and Andhra Pradesh [1]. The annual per capita water availability in India is about 2200 M^3 whereas it is about 750 M^3 in Tamil Nadu. As per World standards (per capita availability - 1000 M^3), our State is under severe water scarcity. It has been assessed that the against the water potential of 47,125 MCM, the agriculture demand alone works out to 49,000 MCM indicating the overdrawal of the ground water resulting in the increase of overexploited blocks (Figure 1). This trend needs to be arrested which is possible only with adoption of new innovative technologies in agriculture practices and diversification of less water intensive crops.

Area irrigated and sources of irrigation

The State's irrigation potential in per capita terms is 0.08 ha when compared to the all-India average of 0.15 ha. The three main sources of irrigation in the State are rivers, tanks and wells [2]. There are about 41,127 tanks, 2239 Kms irrigation main canals and 18.26 lakh irrigation wells in the state. The area irrigated by various sources is furnished in the Figure 2. Among the production constraints, availability of irrigation water is a major one, with consumption of 70% of the water for paddy alone in agriculture. The gap between demand and supply for irrigated crops in Tamil Nadu is projected to reach 21,000 Mm^3 by 2025 [3]. Tamil Nadu State's policy of supplying free electricity to agriculture prompting farmers highly reluctant towards water conservation techniques for agriculture with consequent irrigation inefficiencies.

Under traditional methods of rice cultivation, 3000-5000 liters of water was used to produce one kilogram of rice [3]. A significant portion of the total water requirement for rice production is used for land preparation alone. Farmers have an urgent need for irrigated rice-based systems with technologies that save water by improving water productivity. The intensified efforts to improve both crop and water productivity and subsequently the farmers' income have resulted in many efficient water management practices in wetland rice [4]. The System of Rice Intensification (SRI) is a holistic agro-ecological crop management technique seeking alternatives to the high-input oriented agriculture and also a climatic resilient activity in the change in climate scenario.

Materials and Methods

Farm-level investigation was conducted by the researchers in Villupuram district located in the North Eastern part of Tamil Nadu during 2011-2013. From a list of farmers in this district, a random sample of 60 SRI (IAMWARM) farmers and also an equal number of farmers cultivating paddy through conventional method under tube-well irrigation system were drawn from the same blocks (Kandamangalam, Olakkur and Kanai) and interviewed in-depth and collected primary data. The selected farmers were cultivating paddy using both SRI method and conventional practices on fields' side-by-side on similar type of Clay Loam soil [5]. The sampling location was purposively selected due to prevalence of SRI adopters in this area and for ease of monitoring as in this block, SRI cultivation has been promoted for over 6 years by World Bank assisted Tamil Nadu-Irrigated Agriculture Modernization and Water Bodies Restoration and Management (TN-IAMWARM) project.

The mean area under paddy cultivation for the total sample was 0.72 ha. This indicated that most of the farmers in the sample belonged

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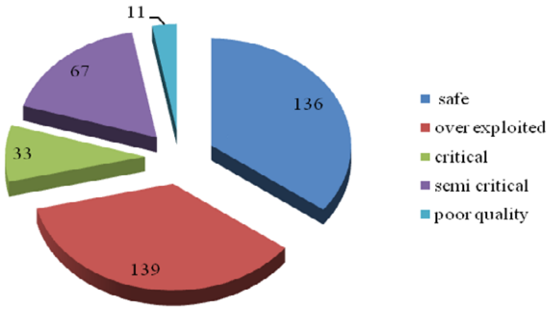

Figure 1: Block wise ground water status in Tamil Nadu.

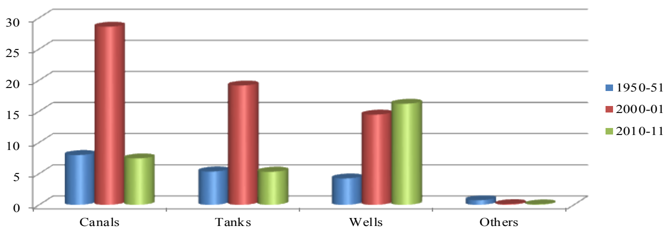

Figure 2: Source-wise/year-wise irrigated area in Tamil Nadu (L ha).

to small and marginal category and there was no significant difference seen in sampled land area between the two sets of farmers (Table 1). At the end of the season, four SRI farmers had to be dropped from the analysis because their data were incomplete. Thus, there were full sets of data for 56 SRI and 60 conventional farmers. The data was collected at an interval of 8-10 days, which coincided with the interval of activities performed by different farmers [6]. The data for labor and other inputs were collected throughout the crop period, starting from seed treatment to measuring the final yield. However, it was difficult to measure irrigation water volumetrically in the field situations. So, to derive a first approximation of the impact of SRI methods on irrigation water use, the number of pumping hours used for growing paddy was selected as a proxy variable to understand the differences in water consumption between SRI and conventional paddy cultivation. Thirty farmers under tube-well irrigation were selected for in-depth study and data generation [7-11]. Of these, 17 were practicing SRI and 13 were conventional paddy farmers. These sample farmers were selected in such a way that their tube-wells represented similar conditions in terms of water pump discharge and power rating. The data was collected from individual farmers on their method of watering, number of irrigations and the pumping hours for each irrigation required in different crop growth stages. Initially the water discharge from each tube well was calculated for a minute using physical measurement [3]. Observations were also recorded for various agronomic practices under the two methods as difference in agronomic practices is hypothesized to generate difference in output [12-16].

Observations on plant growth attributes, yield components and yield were recorded over the study period at regular intervals for both SRI and conventional methods. Field level activities and data measurement were supervised and monitored by the qualified technical staff and researchers of TN-IAMWARM. For comparing various observations taken on water parameters as well as yield under both SRI and conventional methods, mean values of the last three year demonstrations were taken into consideration and standard statistical tools were used to analyze the data for interpretation between two methods of paddy cultivation.

Results

Comparisons of Productivity and Profitability

The overall performance of SRI introduced at the project area of IAMWARM indicated an increase in rice productivity in SRI over the conventional cultivation in all the year. It could be observed from the Table 2. SRI methods significantly showed higher grain yield of 1069 kg/ha than conventional method. The reduction in straw yield was noticed in SRI method.

Irrespective of years, the yield contributing parameters viz., number of tillers per hill, number of productive tillers per hill and number grains per panicle were also higher in SRI than conventional method (Table 3).

It could be observed from the Table 4, that the seed rate was much lower (7.5 kg/ha) in SRI compared to conventional methods (60 kg/ha), which enabled savings of Rs. 1837/-per hectare on seed input, assuming that farmers purchased seed at Rs. 35/kg. The total labor requirement of SRI was less (880 hour/ha) than the conventional method (1000 hour/ha), enabling a considerable saving of Rs. 2359/ha on labor cost (considering the existing daily wage of Rs. 150 /labor in Villupuram district). The major contributor to labor cost in paddy cultivation is transplanting and weeding operations [17,18]. The estimated time for transplanting per hectare in SRI against conventional practices was 378 versus 435 hour/ha. Similarly, SRI also took 100 hour/ha for weeding compared to 122 hour/ha for conventional. Farmers using SRI practices had a 17.46% reduction in their overall labor costs, with disaggregated cost reductions shown in Figure 3. A comparison of net return per hectare, as shown Table 5, indicated that the increase in grain yield had a marked impact on farmers' net return from SRI cultivation. The net return per ha with SRI was significantly higher by Rs. 15548 (paddy grain valued at a constant price of Rs.11/kg), which was 44.5% higher than the conventional method of paddy cultivation.

However, the relative results are consistent with farmers' observations during the study period. Figure 4 summarizes in graphic form of the relative differences between expenditure, yield and economic returns for SRI and conventional.

Water use in SRI and conventional paddy cultivation

An attempt was made to evaluate the differences in water use between SRI and conventional paddy production. The data pertaining to 2011-2013, the years with relatively good rainfall and substantial groundwater recharge. The number of pumping hours was treated as a proxy for actual water use. The selected tube-wells with an electric submersible motor of 10 HP power rating were similar in average discharge of 78,000 litre/hour based on the physical tube-well discharge measurements done by our researchers [14,19,20]. This was an approximate estimation of water use at field level, but even reveled it reasonable relative differences between SRI and conventional practices. Figure 5 presents comparisons of the number of irrigations and the number of pumping hours at each stage of the crop growth, under conventional and SRI management [5,21].

There was not much difference during the land preparation stage, as no special water-saving tillage methods were employed in SRI for the season. Table 6 presents the number of irrigations and number of pumping hours per ha in SRI fields, which were 36.72% less than the conventional paddy. Ravindra et al. [22] and Mahendra Kumar et al. [23] have reported an observed reduction in water use on SRI over conventional paddy by observing through this method. The major irrigation savings with SRI irrigation management was during the

Particulars	Conventional		SRI		Total		Comparison of means F statistic (5%)
	Mean	SD	Mean	SD	Mean	SD	
Total land area	1.83	0.65	1.69	1.11	1.76	0.89	2.65
Total area under Paddy	0.62	0.31	0.78	0.46	0.72	0.41	2.17
Sampled area	0.63	0.32	0.59	0.30	0.60	0.31	*N.S*

N.S: Not Significant

Table 1: Landholding pattern of the sampled farmers (ha).

Cropping year	Grain yield (kg/ha)		Straw yield (kg./ha)	
	Conventional	SRI	Conventional	SRI
2011	5238	6285	2749	2347
2012	5415	6437	2823	2410
2013	5381	6519	2989	2491
Mean	5345	6414	2853	2416
SRI over conventional	1069 (20%)		-437 (-18%)	
SD	0.93	1.18	1.22	0.97
F statistic (5%)	2.30		*N.S*	

Notes: Figures in brackets are the differences in per cent between SRI and conventional results.

Table 2: Average productivity of paddy under conventional and SRI methods.

Year	No. of tillers per hill		No. of productive tillers per hill		No. of grains per panicle	
	SRI	Conventional	SRI	Conventional	SRI	Conventional
2011	23.5	11.2	19.3	8.4	138	127
2012	25.8	12.5	21.2	9.4	152	134
2013	24.6	11.8	20.2	8.9	145	128
Average	24.6	11.8	20.2	8.9	145	129

Table 3: Performance of yield components in SRI.

Input	Conventional (Mean)	SRI (Mean)	SRI over conventional	
			Amount	%
Land preparation	2005	1955	50	2.49
Seed	2100	263	-1837	- 87.47
Fertilizer	6996	7254	258	3.68
Pesticides	680	660	-20	-2.94
Labour	13,505	11,146	-2359	-17.46
Total expenditure	25,286	21,278	-4008	-15.85

Table 4: Input expenditures (Rs./ha).

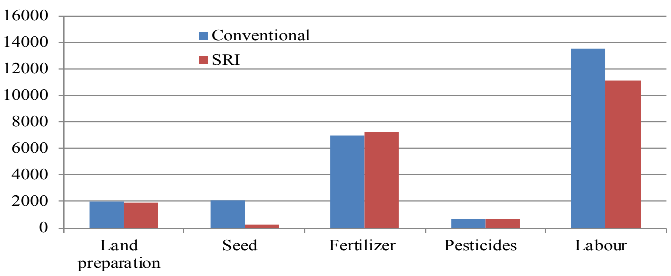

Figure 3: Comparison of input expenditure in SRI and conventional (Rs./ha).

nursery, weeding and upto panicle initiation stages. Adherence to all of the principles of SRI, with only slight variations, by giving higher yields and better returns would reinforce motivation for controlling irrigation and making savings in irrigation water. The cumulative irrigation water application (Figure 6) showed a large potential with SRI for reducing the quantum of water use and also to bring in purposeful management in irrigation water usage. Our study was also noted that each ha of SRI saved about 571.4 pumping hours in one season compared to the conventional method. This amounted to 3028 kWh of savings in electricity consumption, which was currently fully subsidized by the state. The state will be able to save about Rs. 12,112 on every ha of paddy (cost of power- Rs. 4 per unit kWh) converting to SRI management. The preliminary results of the study were very promising, but irrigation management with SRI needed more detailed systematic study to determine how to make use of SRI as a lever for introducing management reforms in groundwater irrigation system.

Discussion

SRI versus conventional

Evidence from the sample of farmers showed 20% yield advantage in SRI over conventional method, indicating better adoption of standard practices by SRI among farmers. In selected blocks of Villupuram district, prospective farmers were initially trained and demonstrations were conducted for adoption SRI under direct supervision of the scientists and researchers of IAMWARM project. Efficient utilization of externally applied nutrients with more foraging area of root volume along with intermittent irrigation in SRI plots enhanced the growth of tillers, root development, number of productive tillers and % of grain filling over conventional practices, which ultimately reflected on the grain yield of paddy [11,21]. Similarly from the field observations,

Parameter	Conventional (Mean)	SRI (Mean)	SRI over Conventional Difference	Comparison of means:Conventional and SRI F statistic (5%)
Total expenditure (Rs./ha)	25,286	21,278	-4008 (-18.83)	*N.S*
Grain value (Rs/ha)	58, 795	70,554	11,759 (20.00)	3.13
Straw value (Rs./ha)	1427	1208	-219 (-18.13)	*N.S*
Gross return (Rs./ha)	60,222	71,762	7264 (19.16)	2.43
Net return (Rs./ha)	34,936	50,484	15,548 (44.50)	2.75

Notes: Figures in brackets are the differences in per cent SRI over conventional difference.

Table 5: Differences in expenditure, yield and economic returns for SRI and conventional methods.

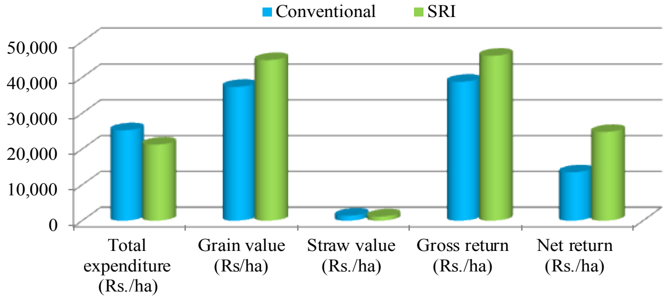

Figure 4: Comparison of expenditure and returns in SRI and conventional method.

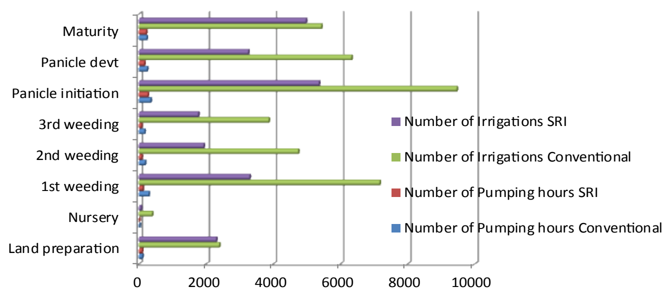

Figure 5: Comparisons of Tubewell irrigation between SRI and conventional method, according to different crop growth stage.

the innovations in the method of using invigorated younger seedling have better crop establishment and positive yield components over conventional practices (Table 3). This favorable influence might be due to efficient utilization of resources and less inter-and-intra space competition under SRI management, which may be responsible for yield attributes of rice and consequently increased yield [4].

SRI system of rice cultivation enhanced the labor productivity substantially with far higher net income than traditional cultivation of rice [6]. Present study suggested 17.46% reduction in labor cost than conventional method (Table 4). The direct economic benefits of SRI included lower seed rates, lesser nursery area lower expenses on labor and higher output of paddy grain. High reduction of seed cost (87.47%) in SRI gave farmers enough economic incentive to adopt this method. SRI allows each plant to be better exposed to sunlight and circulating air and this promotes the 'edge effect' besides dropping canopy humidity with change in micro climate an added advantage for disease reduction. It also includes the mutual/synergistic effects of all the components of SRI such as younger seedling age, wider spacing, better soil aeration through the use of weeder etc. [10,17]. Field study also evaluated that, lowering cost of pesticides due to less incidence of disease in SRI practices might be attributed to wider plant spacing, less stagnation of water in fields and better aeration and light penetration. Besides the rodent nuisance is also reduced due to more land areas exposed to sun because of line planting.

Water saving effects of SRI

In the study area, the SRI farmers followed intermittent irrigation with Alternate wetting and drying cycle compared to continuous flooding of fields (>10 cm standing water) by conventional paddy farmers. This practice has led to a substantial reduction of irrigation numbers, pumping hours and overall water usage in paddy under SRI management (Table 5). The water consumption in conventional paddy fields was nearly two times greater than the normally suggested crop-water requirement of 12,500 m^3/ha in paddy. Zhao et al. [21] found 40- 47% reduction in water-use with SRI, 68-94% increase in water use efficiency (WUE) and 100-130% increase in irrigation WUE compared to traditional flooding.

Water saving during nursery preparation

The size of nursery bed and duration of seedling in nursery were relatively more in conventional than SRI. For conventional, it was necessary to supply more irrigation water continuously to large size nursery beds (0.032 ha nursery required for transplanting 1ha land) for a period of one month (as seedlings transplanted at 25-30 days age). The total amount of irrigation water supplied during nursery operation was estimated to about 390 m^3/ha. However, only 16% of this amount of water was required for SRI nursery management.

Water saving during weeding

In conventional paddy cultivation, the flooding is being practiced to suppress the weed growth up to 45–50 DAP. However, with SRI cultivation, weeds are incorporated into the soil by way of mechanical weeder which helps to build the organic matter in the soil and subsequently the large and diverse microbial population in the soil. Thus mechanical weeding operation facilitates the process of aeration in the soil and provides soil churning effect and pruning the older roots facilitating plants to produce new roots which help in the uptake of enhanced nutrients. This in turn mobilizes the micro nutrients required for the healthy growth of the rice plant. Under intermittent irrigation more availability of soil Phosphorus [15] favors root growth. Hence, SRI cultivation saved water by lowering 42% water consumption requirements and applying AWD without affecting the crop yield. This was supported by previous studies of Uphoff et al. [19] Ravindra et al. [22]. It had a great significance particularly in paddy cultivation which caused high absorption of groundwater and a serious depletion of groundwater storage in many locations of the state. This has helped

Crop stage	Number of pumping hours		Water application (m³/ha)		Cumulative water application(m³/ha	
	Conventional	SRI	Conventional	SRI	Conventional	SRI
Land preparation	98.7	89.3	2388	2298	2388	2298
Nursery	14.1	3.4	390	62	2778	2360
1st weeding	289.7	111.3	7166	3294	9944	5654
2nd weeding	178.7	78.9	4738	1925	14682	7579
3rd weeding	163.8	72.4	3862	1763	18544	9342
Panicle initiation	343.7	262.3	9458	5358	28002	14700
Panicle development	239.4	158.6	6325	3254	34327	17954
Maturity	227.8	208.3	5428	4969	39755	22923
Total	1555.9	984.5	39755	22923		
Reduction between SRI and conventional	571.4 (36.72%)		16832 (42.33%)			
Water productivity					0.13	0.27

Table 6: Estimated water applications in SRI and conventional paddy cultivation.

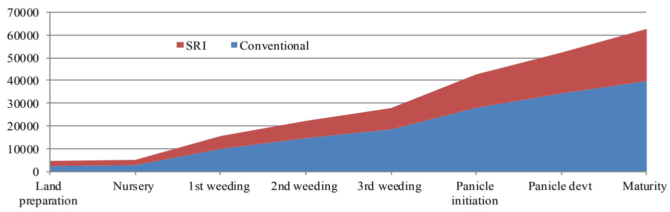

Figure 6: Cumulative water application in SRI and conventional rice cultivation.

farmers to reduce 42% of their irrigation during the crop season and still get higher yield and economic return. Moreover, the burden of power subsidy of the state would be reduced by saving pumping hours with SRI.

Adherence to all of the principles of SRI, with only slight variations guarantees higher yield with better returns reinforcing motivation for controlling irrigation and saving irrigation water. This further encourages farmers to extend their area under paddy with the savings made in water with SRI. Therefore there is more scope for expansion of SRI method, as it addresses the issues of excessive groundwater exploitation which resulted in lowering the water table and polluting water with salinity and arsenic [10]. But a majority of farmers in the tube-well commands are still wasting water by practicing continuous flooding. In this context, there is an urgent need for local institutions to take charge and initiate attitudinal and informational changes among the farmers at the village level for effective water management and more efficient use of valuable water resources.

Formation of effective more functional root system with abundant foraging area resulted in efficient absorption of externally applied nutrients and through positive physiological factors favoring yield components and yield in SRI paddy compared to conventional practice. The reduced straw yield (Table 2) under SRI reflects that efficient translocation of photosynthates to economic produce i.e grain from the vegetative portion.

Conclusion and Policy Implication

It is widely believed that one of the world's major staple foods, rice, is also one of the larger contributors to water scarcity. The search for alternative ways of growing rice, in a manner that substantially reduces water use resulted in the identification of SRI as one of the important alternative.

Firstly, SRI methods can produce significantly higher paddy yield with lower production costs (seeds, pesticides, labors) than conventional practices, therefore, generating higher profits to farmers. Higher paddy yield obtained with SRI cultivation is the result of the combined effects of

(a) SRI transplanting methods,

(b) Mechanical weeding operation and

(c) Intermittent irrigation.

Secondly, the considerable savings of water with SRI at field level results in substantial savings of electric energy. The reduced extraction of groundwater and increased water productivity in SRI would be an additional benefit, having long-term implications for maintaining groundwater reserves which are declining faster due to over use, especially for the cultivation of paddy. The opportunity for making savings in electricity, groundwater and lower production costs (seeds, pesticides, labors) can justify more robust planning efforts for the promotion of SRI to engender systemic improvements in paddy production and efficient water resource management at the macro level. Such a policy measure is also necessary for improving the food security situation of India as a combination of irrigation and paddy production systems improvement. By reviewing the results of some of the studies across the globe and the experience in Villupuram district of Tamil Nadu, India, we find that SRI uses less water and fewer inputs including energy; reduces costs substantially and results in higher yields compared with conventional cultivation practices [11-16]. There is substantial net reduction in water use in SRI rice cultivation under a controlled water regime as compared to conventional practice [18].

In spite of these outstanding positive findings, not only validated at the field level in our own research which corroborates that of other scientists, but also widely recognized by national, state and local governments, civil society organizations and small-marginal farmers, the spread of SRI to newer rice growing areas is extremely slow. It has failed to make any significant effect on conventional practices and technologies.

Obstacles like the need to follow rigid, time-bound practices, the shift to relatively monotonous isolated work like mechanical weeding, are shown to be not insurmountable. Ingenious modifications to tools and practices have to be invented. But a further array of factors such as:

- The lack of resources for research and development in breeding appropriate varieties to overcome the rigid short-duration transplanting schedule,
- Facilitating the availability of Laser leveling machines at nominal cost to maintain uniform thin film of water,

- The lack of the appropriate type of weeder including simple mechanized ones that would remove the psychological strain from using the current designs of weeders,
- Proper IEC (Information, Education and Communication) measures for farmer to farmer exchange through FFS, exposure visits and using media as a tool for propagating success stories to local communities
- Reduced subsidies on irrigation water will be important cost savings for government and provides a real incentive for farmers to use SRI principles. Investments in training and extension for SRI could be covered in part by reducing present subsidies on water, fertilizer, and electricity for pumping water and
- Political resistance to adopt a framework to integrate training in SRI practices with TN-IAMWARM scientists so as to overcome certain perceived skill deficiencies
- Initially practicing of SRI should not be forced on farmers by the way of target to Agricultural ministry officials.
- SRI should not be advocated to all paddy growing areas. The extensions personnels should identify the right area highly suited for SRI
- The water resources department engineers and the Agriculture Officers shall mutually discuss and adopt water saving technique by way of effecting turn system of water delivery, in the canal commend area.
- During initial days of introduction of SRI critical inputs were given at free of cost to enable the farmer to apply necessary inputs in time to reap more benefit and to reduce the risk factor or fear of adoption. Now it is the right time to withdraw in phases the subsidy for SRI.

It is evident now that only 20% of adopters of SRI take to all core practices of SRI and the balance 80% are either partial or low adopters [14]. So, a commitment to adopt SRI on a large scale, if done, can save money for governments by reducing budget allocations needed for food imports and agricultural subsidies. For governments to maximize cost savings and efficiencies in national water use and energy, they will need to invest in better control over the delivery of irrigation water. This includes the design and management of water resources. It may also require institutional reforms and capacity building for water users to readjust water delivery mechanisms and schedules for more precise water allocation within irrigation schemes.

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