Sustainable SRI and Rice Production

Learnings from an Irrigated Agriculture Management Project in Tamil Nadu

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In Tamil Nadu, the extreme variation in rainfall had reduced the availability of water to agriculture and caused the groundwater table to fall by 37%. The production of rice, an important crop, had became particularly precarious. A well-designed upscaling strategy boosted and sustained the production of rice; it also helped the build-up of organic matter and improved soil fertility. This experience shows that the System of Rice Intensification offers an attractive opportunity for increasing food production per unit of water and improving efficiency.

The views expressed in this article by the authors are purely personal.

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Over the past half century, technical advancements have significantly changed the ecosystem of rice production in India, but rice production has not increased apace with the increases in the population. The shrinking area, declining soil fertility, growing water scarcity, and climatic adversity affected production and food insecurity.

Paddy is believed to be an aquatic crop, and the cultivation field is kept flooded, but submergence suffocates and degrades the roots and drastically reduces production capacity. To achieve more food with less water, there is an urgent need for innovation in production.

Given the severe land and water constraints in Tamil Nadu, an appropriate strategy of increasing agricultural productivity (yields) is essential for food security. The strategy prior to 2013 needs to be understood in three broad phases. Phase 1, the period from 1971 to 1981 was the initial green revolution regime, when high yielding varieties (HYV) of rice were introduced in the state. The green revolution strategy continued in phase 2, 1982–90, when concerted efforts were made to expand canal irrigation in the state. Then during phase 3, 1990–2013, the increase in the area under borewell irrigation became prominent.

The temporal and spatial spread of irrigation availability from both surface and subsurface flows contributed to substantial increases in rice production from the 1990s, but the increase was mainly yield-led rather than due to an expansion in the area. The gain in yield could be attributed to a combination of improved varieties and intensive use of "modern" inputs, together with the increase in irrigated area.

However, the long-term trend in production did not sustain at the desired level, particularly in the past decade (Figure 1, p 47). The yield in 2017–18 was 11% higher than in 2000–01. From 2002 to 2006, successive monsoons failed, and the yield declined. From 2006 to 2013, however, the average productivity increased to 3,066 kilogram (kg) per hectare (ha); this increase is partly attributable to the adoption of System of Rice Intensification (SRI) methods throughout the state ever since 2006–07.

Genesis of SRI in Tamil Nadu

The agroecological innovations known as SRI were first tested in the Tamil Nadu Agricultural University (TNAU) in 2000, followed by large-scale adaptive research trials conducted in two major river basins (Tamiraparani and Cauvery) in 2003. In the

Figure 1: Rice Scenario in Tamil Nadu during 2000–18

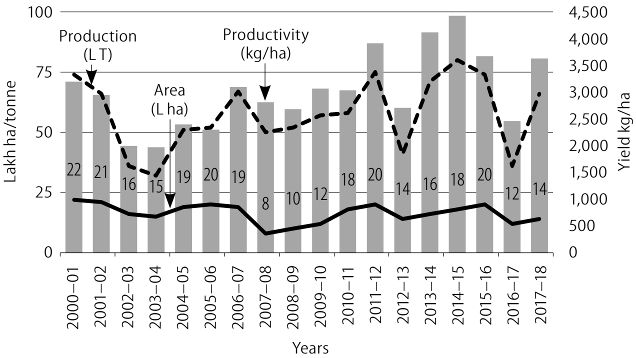
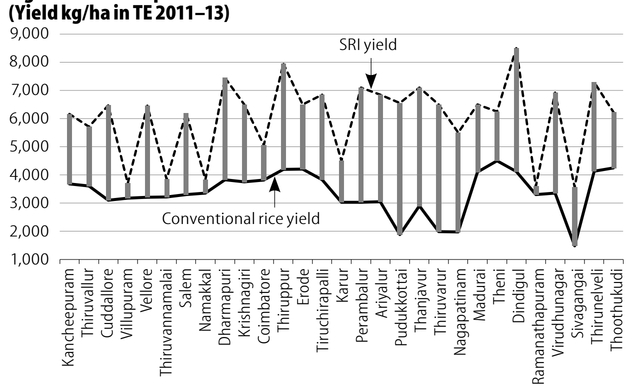


Figure 2: Yield Improvement Due to SRI across Districts under IAMWARM (Yield kg/ha in TE 2011–13)



on-farm trials, average rice yields were found to be 22% higher than under conventional methods of rice cultivation. Farmers' net income increased 15%–42% (Anjugam et al 2008; Barah 2009). However, the pace of adoption or spread of SRI in Tamil Nadu was slow until 2007 when, observing the slow pace and realising its immense potential, SRI was considered as one of the water-saving technologies in a large project planned by the project authorities in the World Bank-assisted Irrigated Agriculture Modernisation and Water-Bodies Restoration and Management (IAMWARM) project. The state government incentivised the promotion of SRI and provided funding to raise both crop and water productivity in rice cropping.

The fairly large-scale demonstration of SRI practices under the IAMWARM was undertaken for the first time during 2007–08. This demonstration served as a synergistic catalyst for the wider adoption of SRI, and the state's department of agriculture took a mission mode approach to promoting it. It was felt that long-term growth in agriculture in Tamil Nadu requires a strategy for increasing the efficiency and productivity of water use in a sustained manner.

The following analysis of the implementation of SRI under the IAMWARM project indicates that for maximising socio-economic impacts, there is an urgent need for understanding the concerns of land and water productivity. Table 1 shows the changes that have taken place in the rice sector after SRI was introduced in 2007–08 and compares the situation with the previous five-year period. The rainfall variability and vagaries of weather made the production relationships complex. After 2011–12, the area under SRI increased 18% over the preceding year, while total production jumped by 29%. The rice area was the same in 2010–11 and 2011–12; the increase in SRI area is responsible for improved production and productivity.

The disaggregated district-level analysis shows a clearer picture. Figure 2 shows difference in yields across the districts with SRI methods in 2011–13. In unfavourable weather, conventional practices are affected severely, but SRI practices perform well. In 2012–13, cyclonic weather conditions were adverse and affected the area, yield, and production of all crops in Tamil Nadu. In the case of rice, total production fell 46%, from a high of 7.46 million tonnes in 2011–12 to 4.05 million tonnes in 2012–13; the area under paddy declined by 22%; and the average yield declined by 31%. There was wide disparity within the state in the average yield of paddy—from only 588 kg per ha in Ramanathapuram district to 4,728 kg per ha in Kanyakumari district.

In the state, the area under SRI increased rapidly, almost doubling from 4,20,000 ha in 2007–08 to 8,00,000 ha in 2013–14 (Table 2). The share of SRI area in the total rice area increased

Table 1: Impact of SRI on Food Production in Tamil Nadu

Year	Rice Area (in million ha)	Area under SRI (in million ha)	SRI Area (%)	Productivity (kg per ha)	Total Production (in million metric tonne [MT])
Base years (2002–03 to 2006–07)	1.754	–	–	2,667	4.736
2007–08	1.789	0.420	23.5	2,817	5.040
2008–09	1.932	0.538	27.8	2,682	5.183
2009–10	1.846	0.649	35.2	3,070	5.665
2010–11	1.906	0.850	44.6	3,039	5.792
2011–12	1.904	1.001	52.6	3,918	7.459
2012–13 *	1.493	0.685	45.9	2,713	4.050
2013–14	1.726	0.799	46.3	4,122	7.115
2014–15	1.795	0.948	52.8	4,429	7.949
2015–16	2.000	0.987	49.4	3,676	7.375
2016–17 *	1.443	0.581	40.3	2,463	3.554
2017–18	1.828	0.722	39.5	3,630	6.638

*Drought year.
Source: Directorate of Economics and Statistics, Government of Tamil Nadu.

Table 2: Yield Improvement Category at the District Level

Yield Improvement Category (No of Districts)	Districts	Average Yield under Conventional Methods (kg per ha)**	SRI Yield (kg per ha)*	Improvement (%)
Up to 30% improvement (7)	Vellore, Namakkal, Salem, Karur, Theni, Tiruchirappalli, Coimbatore	4,124	4,664	13
30%–50% (4)	Sivagangai, Dharmapuri, Kancheepuram, Erode	3,896	5,602	44
50%–75% (5)	Thirunelveli, Madurai, Thoothukudi, Krishnagiri, Perambalur	4,236	6,937	64
75%–100% (6)	Thiruvallur, Dindigul, Villupuram, Ariyalur, Thiruvannamalai, Nagapatinam	3,192	6,192	94
More than 100% (6)	Cuddalore, Thiruppur, Pudukkottai, Thanjavur, Thiruvarur, Virudhunagar	2,898	6,955	140
State		3,223	6,229	93.2

*Field observations under TN-IAMWARM project (2007–14).
** Department of Economics and Statistics and various issues of Season and Crop Report (2007–14).

Figure 3: Adoption of SRI in Tamil Nadu (% Area)

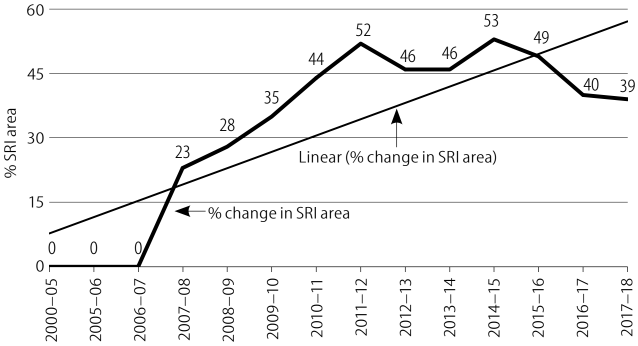


Figure 5: Yield Improvement (%) by Groups of Districts in Tamil Nadu

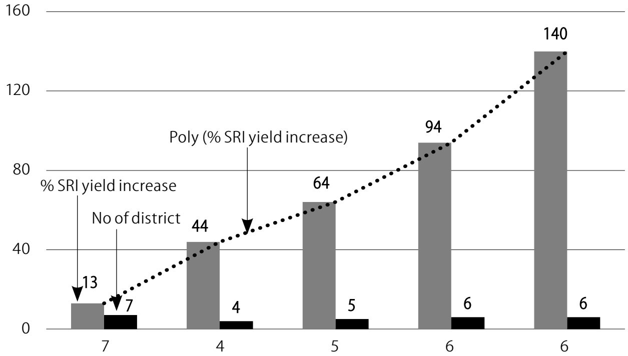
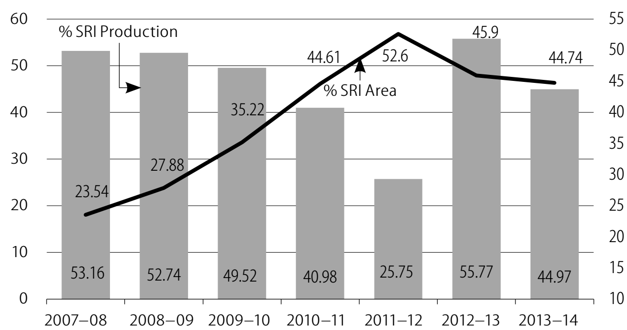


Figure 4: Performance of SRI in Tamil Nadu (2007–14)



from 23.5% in 2007–08 to a high of 52.8% in 2014–15. The prime reason for this increasing trend in SRI was probably the favourable policy environment of the promotion of SRI and in the rice sector. The innovation boosted rice production, and it was stabilised by the strategy of upscaling SRI in mission mode.

In the first two years since the introduction of SRI in 2007–08, the share of area over the base year average (2001–06) was slow, due to the occurrence of natural calamities of flood, unseasonal rainfall, and cyclones (Figure 3). After 2010–11, rice production witnessed a conspicuous increase over the base period as the area under SRI grew over 40%.

The yield also shows a positive upward trend, except in 2008–09 when the Nisha cyclone devastated 4,70,000 ha of rice crop and severely reduced output and yield (Table 2). It may be noted that the rice productivity level was higher than the base year during 2007–08, which indicates that SRI was capable of withstanding the stress of cyclones, droughts, and heavy rains. The unusual rains in March 2008 also directly affected nearly 1,68,000 ha under rice. It may be inferred that when the monsoon was favourable, SRI acreage as well as rice productivity show very good performance as in 2011–12 and 2014–15 (Figure 4).

On 30 December 2011, the cyclone Thane hit Tamil Nadu and caused extensive damage to the paddy crop in nine districts: Cuddalore, Villupuram, Thanjavur, Nagapattinam, Thiruvarur, Kancheepuram, Thiruvallur, Dharmapuri, and Thiruvannamalai. The crop damage was over 50% on 1,85,000 ha, and it affected the livelihood of 2,50,000 small and marginal farmers. Moreover, the areas under irrigation were severely affected by the prolonged dry spell, the deficit rainfall during the south-west monsoon, and the uneven temporal spread during the north-east monsoon. As a result, the availability of surface and subsurface sources of irrigation water declined, and resulted in an increase in the fallow land, while the productivity of SRI was sustained (Table 2).

Under the circumstances, the scope for the expansion of the area under cultivation and irrigation is limited; the only way to meet the growing food requirement is to narrow down the yield differentials among the districts amidst the temporal climate exigencies. SRI provides the opportunity for sustaining productivity in such situations, and it may be generalised that SRI performs well and sustains production in heterogeneous climate conditions too. The analysis of temporal data on production and productivity shows that from 2007–08 to 2012–13, rice productivity levels were higher than in the base year 2005–06; the productivity was attributable mostly to SRI. Therefore, it is reasonable to term SRI a "climate-smart" strategy. Incidentally, the paddy yields in Tamil Nadu are found to be consistently higher than the national average, a good part of which is attributed to the advantages rendered by the promotion and adoption of SRI.

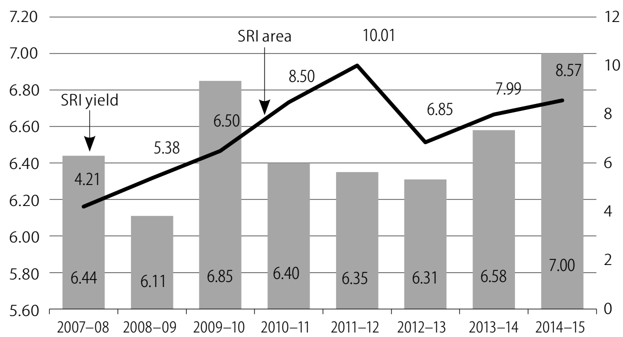
IAMWARM Project and SRI Promotion in Tamil Nadu

Tamil Nadu's geographic area is classified into 17 river basins (127 sub-basins), most of which are water-stressed. The World Bank project IAMWARM was implemented from 2007 in four phases in 61 sub-basins. The implementation of SRI was the main focus of rice production technology under the IAMWARM project from its beginning in 2007–08, and a substantial area under rice cultivation has been brought under SRI across the districts.

Depending on the intensity of adoption, the yield has increased up to 170%, except in a few districts. About 50% of the total area under rice in the state has been brought under SRI; in the districts, the percentage varies from 20% to 69%. This is a remarkable achievement, and it has contributed immensely to the total rice production at the state level. The adoption of SRI practices has led to a steady improvement in the rice yield compared to conventional methods of cultivation (Figure 5). In 67% of the districts, rice productivity increased more than 64%.

In the IAMWARM project area, there is a relative increase in rice productivity in SRI over the state average productivity

Figure 6: Performance of SRI in Tamil Nadu under IAMWARM



(Figure 6). Irrespective of annual variation, the yield-contributing parameters—number of tillers per hill, number of productive tillers per hill, and grains per panicle—are observed to be higher in SRI demonstration plots than under conventional practices. That results in raising the productivity of rice under SRI over that of rice under conventional methods in the state (Table 3).

Table 3: Comparison of Performance of Yield Attributes in SRI as Compared to Conventional Methods

Year	No of Tillers per Hill		No of Productive Tillers		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

Effect of SRI on Input Use Efficiency at the Farm Level

An attractive and motivating proposition of SRI is the substantial reduction in seed rate to 7.5 kg per ha from the 60 kg per ha under conventional methods. Assuming that the price of seeds is ₹35 per kg, SRI saves ₹1,837 per ha on seed (Table 4). At the same time, the total labour requirement under SRI was less (880 hours per ha) than the conventional method (1,000 hours per ha), amounting to a considerable saving of ₹2,359 per ha on labour cost (at the wage rate of ₹150 per day).

Table 4: Changes in Disaggregated Cost of Production (₹ per ha)

Input	Conventional Rice	SRI (₹ per ha)	Difference in SRI Over Conventional	
			Amount	%
Land preparation	2,005	1,955	50	2.49
Seed	2,100	263	-1,837	- 87.47
Fertiliser	7,254	6,996	-258	-3.68
Pesticides	680	660	-20	-2.94
Labour	13,505	11,146	-2,359	-17.46
Total expenditure	25,286	21,278	-4,008	-15.85

Table 5: Differences in Gross Return and Economic Returns for SRI and Conventional Methods

Parameter	Conventional (Mean, ₹ per ha)	SRI (Mean, ₹ per ha)	Difference of SRI Over Conventional
Total expenditure	25,286	21,278	4,008 (-18.8%)
Grain value	58,795	70,554	11,759 (20.0%)
Straw value	1,427	1,208	-219 (-18.1%)
Gross return	60,222	71,762	7,264 (19.2%)
Net return	34,936	50,484	15,548 (44.5%)

Figures in brackets are the percentage differences of SRI over conventional practices.

The decrease in the cost of labour under SRI is mainly because transplanting and weeding takes less labour and time. Transplanting takes about 378 hours per ha under SRI, but 435 hours under conventional practices. Weeding in an SRI field takes 100 hours per ha, but takes 122 hours under conventional practices. This cuts overall labour costs by 17.46%, and therefore, the total cost (Table 5), and hence the net return per ha of SRI is a significantly higher ₹15,548 (paddy grain valued at ₹11 per kg), which is 44.5% higher than that from the conventional methods.

Model of Upscaling SRI Practices

A distinctive feature of the SRI method is that it is knowledge-intensive rather than input-intensive as in green revolution technology; therefore, capacity-building of the stakeholders is a high priority in its promotion. An in-depth analysis of performance at the farmers' fields shows that SRI has a yield advantage of 20% over the conventional method, which catapults farmers' acceptance of SRI.

Adopter farmers were given intensive training under the direct supervision of scientists and researchers of the IAMWARM project, and demonstrations were conducted in selected basins in Tamil Nadu. The efficient use of external nutrients—with more foraging area of root volume, along with intermittent alternate wetting and drying (AWD) irrigation in SRI plots—enhanced the growth of tillers, root development, number of productive tillers, and the percentage of grain filling, which synergistically enhance the grain yield of paddy (Pandian et al 2011; Zhao et al 2009). The field observations show that the invigorated younger seedlings provide better crop establishment (Table 3). The efficient utilisation of resources and minimal inter- and intra-space competition create favourable conditions of SRI management (Dass and Chandra 2013). These tangible benefits attracted farmers' attention and enhanced the acceptance of SRI.

SRI allows each plant to be better exposed to sunlight; it enables the circulation of atmospheric air, and the penetration of light uniformly causes the "edge effect." The reduced canopy humidity along with the change in microclimate reduce the incidence of pest and diseases (Uphoff 2005; Mishra and Salokhe 2010). The field survey also revealed that the cost of pests and disease, including rodent control, is lower.

The adoption of SRI substantially enhances labour productivity and the net income of farmers compared to that under the traditional cultivation of rice (Bruno 2002). The study estimates that SRI yields a host of direct economic benefits over the conventional method; among these are a 17.46% reduction in labour cost, substantial saving in seed rates, and saving in nursery area. The saving in seed cost (87.47%) is a crucial tangible economic incentive to farmers for adopting this method. The significant water saving in the practice of AWD is the most critical consideration for the promotion of SRI in Tamil Nadu.

Conjunctive use and the water economy constitute the major concern in water-stressed agriculture like in Tamil Nadu. To understand irrigation use better and investigate it in depth at the micro level, a special study was conducted from 2007 to 2013

Figure 7: Saving in Energy Use (Hours of Pumping)

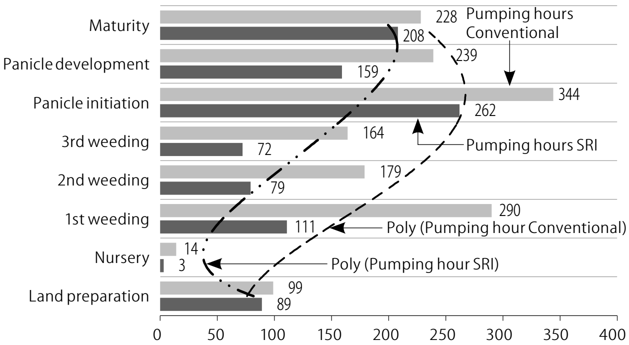
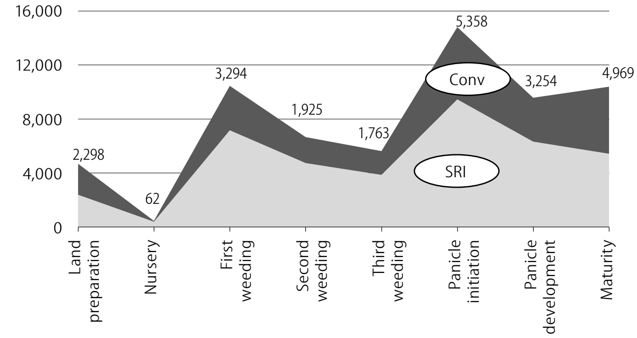


Figure 8: Difference in Water Use between SRI and Conventional Method (m^3/ha)



at Varaganadhi sub-basin (Villupuram district, Tamil Nadu), where the rainfall was relatively good and the groundwater recharge substantial. The experiment shows that the number of pumping hours fell, indicating substantial energy saving under SRI.

In general, the study of water use at the field level revealed variable differences in SRI and conventional practices. The difference is marginal at the land-preparation stage, even though no special water-saving tillage methods were employed in SRI. On account of the decrease in pumping hours under SRI, there was 36.72% energy saving as compared to that in conventional paddy, and 42% less water was consumed (Ravindra and Bhagya Laxmi 2010; Uphoff 2007; Kumar et al 2010). The water saving was highest at the nursery stage, followed by weeding and panicle initiation (Table 6). This has pinpointed the scope for saving critical inputs in various operations. Table 7 presents the number of irrigation and pumping hours for water lifting in both situations. An analysis of energy use for irrigation in various operations clearly shows water saving across the operations in the entire crop cycle (Figure 7).

Conventional paddy fields are kept continuously flooded in more than 10 centimetre of standing water, but SRI farmers followed intermittent irrigation with AWD cycle in the study area. The SRI method is thus credited for substantial reduction of irrigation numbers, pumping hours, and overall water usage in paddy (Table 7). The water consumption in conventional paddy fields was nearly two times that of SRI. Zhao et al (2009) report that SRI led to 40%–47% reduction in water use, 68%–94% increase in water use efficiency (WUE), and 100%–130% increase in irrigation WUE compared to traditional flooding. Other studies also report that AWD saves 42% of water, and there is no yield penalty (Uphoff et al 2013: Ravindra and Bhagya Laxmi 2010).

Table 6: Energy and Water Saving Due to SRI (%)

Crop Stages	Energy Saving (% Pumping Hours)	% Water Saving Due to SRI
Land preparation	10	4
Nursery	76	84
First weeding	62	54
Second weeding	56	59
Third weeding	56	54
Panicle initiation	24	43
Panicle development	34	49
Maturity	9	8
Total of all operations	37	42

Table 7: Difference in Wate r Use and Energy in SRI and Conventional Paddy Cultivation

Crop stage	Use of Water Pump (Hours)		Water Use (m^3 per ha)	
	Conventional	SRI	Conventional	SRI
Land preparation	98.7	89.3	2,388	2,298
Nursery	14.1	3.4	390	62
First weeding	289.7	111.3	7,166	3,294
Second weeding	178.7	78.9	4,738	1,925
Third weeding	163.8	72.4	3,862	1,763
Panicle initiation	343.7	262.3	9,458	5,358
Panicle development	239.4	158.6	6,325	3,254
Maturity	227.8	208.3	5,428	4,969
Total	1,555.9	984.5	39,755	22,923
Difference between SRI and conventional practice	571.4 (36.72%)		16,832 (42.33%)	
Water productivity			0.13	0.27

Savings in Power

The cumulative irrigation water use shows that SRI has a huge potential for reducing the quantum of water use and bringing in purposeful management in irrigation water usage (Figure 8). It depicts that under SRI management, crop operations uniformly use less water. The analysis notes that SRI saved about 571.4 pumping hours per ha in a season as compared to the conventional method. This amounted to 3,028 kilowatt-hour (kWh) of savings in electricity consumption, which is currently fully subsidised by the state. At the state aggregate level, SRI management saves about ₹12,112 per ha of paddy (cost of power is ₹4 per unit kWh).

Conclusions

In Tamil Nadu, water conflicts coexist with the dominant rice cultivation practice; therefore, identifying alternative methods of growing rice is of critical importance. It used to be believed that rice is an aquatic crop, but it does not require flooded or standing water; it is enough to keep the soil moist. This has been demonstrated in field experimentation and confirmed by a large body of empirical evidence. Observing the usefulness of SRI and encouraged by empirical demonstration, farmers were motivated and encouraged to adopt the practice in a manner that substantially reduces water use and increases the productivity of rice.

The evaluation of the impact of SRI on the production of rice in Tamil Nadu suggests that SRI methods can be used to produce significantly greater quantities of paddy. Under SRI, paddy yield is higher because of the synergistic effect of young seedlings, innovative transplanting methods, mechanical weeding operations, and intermittent irrigation, which together save considerable water and electric energy at the field level. Using these methods reduces the consumption of seeds and pesticides and the usage of labour, and therefore lowers the production costs on these accounts and raises farmers' profits. Using SRI methods also reduces the consumption of water (which is not priced currently).

The application of the principles of SRI empirically proved that rice can be grown with less water and other inputs than the traditional practice, and that yields can still be higher. The evidence derived from the analysis shows that there is an emerging opportunity for savings in electricity, conjunctive use of groundwater, and production costs (seeds, pesticides, labour). Robust planning efforts are needed to promote and upscale SRI for sustainable improvements in paddy production and efficient water resource management at the macro level.

Continuous adaptation at farmers' fields to suit their local conditions lies at the core of SRI practices. The perception analysis suggests that farmers are willing to continue the SRI method, which is an important condition for sustainability. To derive policy clarity for wider dissemination of various steps and phases, there is the need to validate not only the principles and practices of the technology, but also its scientific basis. Since SRI is a knowledge-intensive innovation, more emphasis is needed on capacity strengthening, motivation, and stakeholder participation, particularly on continuous crop care. Hence, it may be concluded that SRI combines both scientific rigour and socio-economic policy.

The academic acceptance of SRI is growing due to the evidence generated by the stakeholders as reflected in scientific papers and other documentation. The principles of SRI have already been validated both on-station and on-farm, and its socio-economic and ecological impact assessed. The method is now adopted by nearly 20 million farmers in 61 countries. The best part is that farmers in general and small and marginal farmers remained particularly insulated from the arguments and counter-arguments among the stakeholders, and they routinely adopt SRI. Farmers using groundwater will certainly appreciate and realise a quantum of saving of water, time, and electricity under SRI irrigation. If SRI is adopted in the entire command area, the water so saved can be utilised to cultivate a larger area and achieve crop diversification.

Unfortunately, SRI has not yet become a major method of cultivation, owing to prevailing institutional barriers, behavioural factors, and the political economy dimension of vested interests. Some of the principal challenges to overcome include the resistance to accept SRI, resistance of transplanting labourers, training and extension facilities that lack innovation, imprecise water management, and unavailability of essential tools. If these issues are addressed on priority, SRI will boost rice yields and farmer income not only in Tamil Nadu, but also in other states.

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