System of Rice Intensification (SRI) versus farmer practice — A comparative evaluation in the Timbuktu region of Mali

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Abstract

Cereal production is chronically deficient in the Timbuktu region, sufficient for only 4.5 months of yearly consumption. Small-scale, village-based irrigation schemes, usually 30–35 ha, run off one diesel motor pump, have become important to improve food security. Given high production costs and average cultivated area of only 0.3 ha per household, farmers seek to increase productivity in these irrigated systems. The NGO Africare has worked since 1997 with farmers in Goundam and Dire circles to establish irrigation schemes and provide technical assistance. In 2007, Africare undertook the first test of the System of Rice Intensification (SRI) in Goundam circle. After witnessing a yield of 9 t/ha of paddy compared with 6.7 t/ha in the control plot, farmers expressed great interest in larger-scale testing of the SRI system.

In 2008, Africare, in collaboration with the local Government Agriculture Service, implemented a community-based evaluation of SRI with 60 farmers in 12 villages. Each village selected five volunteer farmers. Each farmer installed both SRI and control plots, side by side, starting the nurseries on the same day and using the same seed. For SRI, seedlings were transplanted at one plant/hill at the two-leaf stage, on average 11.6 days old, with spacing of 25 cm × 25 cm between hills and aligned in both directions. This alignment allowed farmers to cross-weed with a cono-weeder, used on average 2.4 times during the season. In the control, farmers planted three plants/hill at average of 29.4 days old, with spacing of 23.7 cm × 23.7 cm, not planted in lines. Weeding was done by hand. In the SRI plots, 13 t of organic matter were applied per hectare, and 3 t/ha in the control plots. Fertilizer use was reduced by 30% under SRI. Although alternate wetting and drying irrigation is recommended for SRI, this was not optimally implemented due to constraints on irrigation organization within the scheme, thus water savings were only 10% compared to the control.

Average SRI yield for all farmers reached 9.1 t/ha (range 5.4–12.4 t/ha). SRI yields were on average 66% higher than the control plots (5.5 t/ha), and 87% higher than the surrounding rice fields (4.9 t/ha). Number of tillers and panicles per hill, number of tillers and panicles per square meter, panicle length and number of grains per panicle were superior under SRI than in the control. Farmers tested five varieties, all of which produced better under SRI. The SRI system allowed for a seed reduction of 85–90%, from 40–60 kg/ha for the control to 6.1 kg/ha under SRI. Although production costs per hectare were 15% higher for SRI, revenue was 108% higher than the control.

Farmers were very satisfied with these results. In 2009/2010, Africare and the local government agriculture service worked with over 300 farmers in 27 villages to scale up SRI practices and to test innovations, including composting techniques, optimization of irrigation, and techniques to reduce labor requirements and production costs. The good crop performance and advantages were confirmed in this third year with, among others, SRI yields of 7.7 t/ha (n = 130 farmers) compared to 4.5 t/ha in farmers' fields.

Introduction

The Goundam and Dire circles in the Timbuktu region are among the most food-insecure areas in Mali (CSA, 2005). Due to the very low annual rainfall (150–200 mm), recessional agriculture is practised along river branches, ponds, and lakes seasonally flooded by the Niger River. The intensity of the flooding determines the amount of land under agriculture, which is highly variable from year to year. Yield levels in this cultivation system are low, with deep-water rice producing, on average, 750 kg/ha, and sorghum 600–900 kg/ha (DRA Tombouctou, 2007).

The NGO Africare has worked with local farmers to build village-based small-scale irrigation schemes of 30–35 ha each that can be irrigated by one diesel motor pump. With these irrigation systems, farmers can have full water control and can achieve higher and more reliable yields compared to the traditional recessional agriculture. As 80–100 farmers share the land under irrigation in such schemes, the average irrigated crop area available per household is only about one-third of a hectare (0.83 acre). Getting maximum yield from these small landholdings is essential for reducing poverty in the area. These irrigation schemes have become an important support for improving the food-security situation of the region. With high land and water availability in this region, there is much potential and scope for improving production and extending the surface areas.

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In 2007, Africare undertook the first test of the System of Rice Intensification (SRI) in Goundam circle. After witnessing a yield of 9 t/ha of paddy compared with 6.7 t/ha in the control plot, farmers expressed great interest in larger-scale testing of SRI (Africare, 2008). SRI is a methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients, while reducing external inputs. It was developed in the 1980s in Madagascar by Father Laulanié, and is practised in over 36 countries worldwide (Ravichandran and Xie, 2010). SRI is based on six principles: (i) transplanting young seedlings; (ii) transplanting single seedlings; while (iii) allowing wider spacing between the plants; (iv) applying organic matter for fertilization (in preference to chemical fertilizer); (v) frequent weeding with a simple mechanical weeder; and (vi) reduced irrigation-water application, keeping soils moist but not flooded (Uphoff, 2007).

On the basis of the first results and farmers' interest, the Better U Foundation of Los Angeles, California made a grant to Africare for a larger project: to assess the performance of SRI in 12 villages during the 2008 growing season in the circles of Goundam and Dire.

The two main objectives of this work were to (i) adapt SRI principles to the local rice cropping system, and (ii) compare SRI practices with farmer practices in 12 sites in two administrative circles of the Timbuktu region.

Methodology

The Goundam and Dire circles are characterized by a Sahelo-Saharan and Saharan climate with annual rainfall of 150–200 mm, a rainy season extending over 3 months, and a mean annual temperature of 29.1°C. Twelve villages participated in this SRI evaluation. They are located on the seasonally flooded tributaries of the Niger River. The distance from the Niger River determines when the water arrives at the village irrigation perimeter; only then can the rice season begin. The SRI plots were planted over a 2-month period between 26 June and 2 September 2008. Harvest extended from 31 October to 23 December 2008.

Village communities selected five farmers, who collaborated entirely on a voluntary basis. Farmers did not receive any inputs (seed, fertilizer), with the exception of two cono-weeders (a tool previously unknown in the area) per village. Africare and the Goundam Government Agriculture Service provided ongoing technical support. Each farmer was entirely responsible for managing his or her plot. Each farmer installed both SRI and control plots, side by side, starting the nursery for both plots on the same day and using the same seed. Farmers supplied their own seed. They were free to choose the variety, as well as the plot size. Average plot size was 400 m^2 (range 81–828 m^2).

Technical SRI guidelines to be implemented by the 60 farmers were developed by the technical team using the six SRI principles, which were adapted to local rice-cropping and agro-ecological conditions (see Table 1) (Styger *et al.*, 2009). Technical and economic data were collected on a weekly basis from all 60 farmers for the SRI and control plots, including data on field establishment and management, crop performance, labor requirements, cost of inputs, harvest and yield.

In each SRI and control plot, three squares of 4 m^2 (2 × 2 m) were harvested. The grain was threshed immediately on location and weighed using a precision PESOLA™ scale. At the same time, the moisture content of the grain was measured using a FARMEX MT-PRO™ moisture meter. The grain yield results were later adjusted to 14% grain moisture content. Additionally, six panicles per plot were randomly selected to measure panicle length and to count the number of grains per panicle. A 1 m^2 frame was placed within the 4 m^2 square, within which plants were cut at the base, and number of hills/m^2, number of tillers and number of panicles per hill were counted. From the total of 60 plots, seven SRI and seven control plots were disqualified. Three SRI plots were not irrigated for 1 week after planting, resulting in a high plant mortality, one farmer harvested the plots in the absence of the technicians, and migrating birds destroyed three plots before they could be harvested.

During the field evaluation, we noticed that some of the control plots were better weeded and more heavily fertilized than the surrounding fields in the village irrigation scheme (or PIV, Périmètre Irrigué Villageois). Based on these observations and intending to compare the SRI field performance with the average rice fields within each PIV plot, five randomly selected fields surrounding the SRI and control fields were harvested according to the same procedure as for SRI and control plots. Additionally, soil preparation methods, variety, and amount and type of fertilization were noted. These plots are referred to as 'farmer practice' or PIV plots in this paper.

Results

Cropping system practices

Crop establishment and crop management practices for the SRI and control plots are summarized in Table 1.

Traditionally, farmers do not till their land, but irrigate a plot and transplant the rice seedlings directly the following day. Since 2006, some farmers in some villages have had their plots plowed by tractor. In our experiments, 48% of control plots were tilled by tractor or by hand, while the figure for the entire PIV was 20%. All SRI plots were tilled, incorporating 13 t manure and 8 kg diammonium phosphate (DAP) per hectare at the same time. In the control plots, farmers applied 3 t manure and 34 kg DAP per hectare, whereas in the PIV plots it was 20 kg DAP/ha only. Puddling and field leveling were new concepts to the farmers. For SRI plots, limited puddling was done, followed by field leveling with a hoe or wooden board, which was manually pushed or pulled across the soil surface.

Table 1. Cropping practices in SRI and control plots (average for 60 farmers) in Goundam and Dire, Timbuktu

Cropping practice	SRI (n = 60)	Control (n = 60)
Soil preparation		
Base fertilization	Organic matter 13 t/ha + 8 kg DAP/ha	Organic matter 8 t/ha + 34 kg DAP/ha
Tilling	100% of farmers	48% of farmers
Puddling	Limited	No
Plot leveling	Yes	No
Nursery and transplanting		
SRI nursery	Tilling; mix of clay, sand, manure; use of watering-can 1–2 times/day	Tilling; organic matter surface application, surface irrigation every 3–4 days
Seed preparation	Seed soaked in water for 24 h	No seed soaking
Seedling emergence	2 days	5 days
Transplanting (age of seedlings)	11.6 days (8–12 days)	29.4 days (22–45 days)
Number of leaves/plant	2	5
Number of plants/hill	1	3 (2–5)
Spacing between plants	25 × 25 cm or 30 × 30 cm	23.7 cm × 23.7 cm
Planting pattern	Planted in lines, aligned in both directions	Not planted in lines
Number of hills/ha	160 000 or 111 111	177 833
Number of plants/ha	160 000 or 111 111	533 499
Seeds used/ha	6.1 kg	40–60 kg
Seed saving under SRI	85–90%	
Crop management		
Weeding practice	Cono-weeding (first time 20 days after transplanting, repeated every 7–10 days, up to 4 times in total) and hand weeding	Hand weeding
Number of weedings	2.4 (1 to 4) times cono-weeding, and 1.2 times hand weeding	1.8 times hand weeding
Pests and diseases	None, except for some bird damage very late in the season	None, except for some bird damage very late in the season
Fertilization recommendations	Organic matter 10–15 t/ha, inorganic fertilizer to correct for deficiencies	100 kg DAP/ha, 200 kg urea/ha
Organic matter applied	13 t/ha	3 t/ha
DAP applied	8 kg/ha	34 kg/ha
Urea applied	120 kg/ha	145 kg/ha
Irrigation	Alternate wetting and drying	Flooded plots

DAP = diammonium phosphate.

For SRI, seedlings were transplanted at one plant/hill at the two-leaf stage, on average 11.6 days old, with spacing of 25 × 25 cm between hills and aligned in both directions. This allowed farmers to cross-weed with a cono-weeder, used on average 2.4 times during the season. In the control, farmers planted three plants/hill at 29.4 days old. Spacing between the plants was 23.7 × 23.7 cm, but not in lines. Hand weeding was done an average of 1.8 times per plot in the season.

In the SRI plots, additional inorganic or organic fertilization should complement initial organic matter application and only be used to correct for observed nutrient deficiencies. Decisions as to what type and how much fertilizer to be used remained with the farmers. SRI farmers used 8 kg DAP and 120 kg urea per hectare, whereas in the control plots it was 34 kg DAP and 145 kg urea. Thus, SRI farmers reduced inorganic fertilizer application by 28% compared with the control.

The change from constant flooding to alternate wetting and drying during the vegetative period would have required adjustments of irrigation scheduling and amounts of water applied per irrigation event. Alternate wetting and drying is done by applying a thin layer of water (2.5 cm) to the plot. The soils are left to dry until cracks become visible, when another thin layer of water is applied. Farmers were at first reluctant to reduce irrigation-water application for fear of crop desiccation, but became more confident over time. Also, it was not possible to change the irrigation-water distribution within the PIV for only a few test plots. Thus, reduction in irrigation water per plot was estimated to be only 10%.

Yields and yield parameters

Grain yield for 53 SRI plots averaged 9.1 t/ha, which is 66% higher than the control (5.49 t/ha), and 87% higher than yields from the farmer practice plots (4.86 t/ha; Table 2). All reported yield data were adjusted to 14% grain moisture. Lowest yield attained with SRI methods was 5.4 t/ha. More than 50% and 60% of the control and farmer practice plots, respectively, gave less than this yield. A third of all SRI farmers achieved yields of more than 10 t/ha. The highest yield was 12.4 t/ha (Fig. 1).

Table 2. Grain yield (t/ha) and yield parameters for SRI, control and farmer practice plots

Plot type	Yield (t/ha)†	SE	No. tillers/ hill	SE	No. panicles/ hill	SE	Fertile tillers (%)	
SRI (n = 53)	9.10	0.24	24.1	0.73	23.5	0.69	98	
Control (n = 53)	5.49	0.27	16.2	0.5	15.9	0.49	98	
Farmer practice (n = 60)	4.86	0.18	14.7	0.56	14.2	0.52	97	
Plot type	**No. tillers/m^2**	**SE**	**No. panicles/ m^2**	**SE**	**Panicle length (cm)**	**SE**	**No. grains/ panicle**	**SE**
SRI (n = 53)	371	9.88	361	9.08	24.0	0.73	133	4.86
Control (n = 53)	283	9.23	276	9.17	21.3	0.30	97	3.31
Farmer practice (n = 60)	266	12.18	257	11.77	19.8	0.30	86	2.38

n = sample size; SE = standard error.
† Yield is reported at 14% grain moisture content.

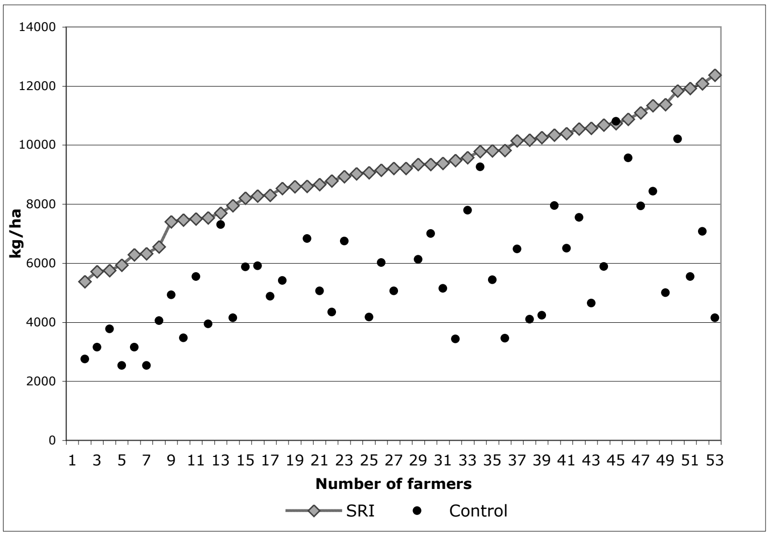

Figure 1. SRI and associated control plot rice grain yields (kg/ha) for 53 farmers in Goundam and Dire circles of Timbuktu, 2008 (SRI yield plotted out from lowest to highest yield with associated control plot yields)

All measured yield parameters were superior for SRI, followed by the control, and were lowest in the farmer practice plots (Table 2). Although SRI plots required only 21–30% of the plants used in the control plots at the time of transplanting (see Table 1), at harvest the number of panicles per square meter was 31% higher than in the control plots. Also, the one-plant SRI hills produced almost 50% more tillers than the three-plant hills in the control plots. The percentage of fertile tillers (tillers with a panicle as a percentage of the total number of tillers) reached almost 100% in the three treatments. Panicles of SRI plants were on average 13% and 20% longer, and the average number of grains was 37% and 55% higher than in the control and farmer practice plots, respectively.

Yield performance of five varieties

Farmers used five varieties in this evaluation. Best performing varieties under SRI were BG90-2 and Wassa, followed by Adny-11, D52 and RPKN2 (Table 3). Compared with the control and farmer practice yields, SRI yields were between 44% and 99% higher, showing that high yield increases could be obtained with all varieties used.

Table 3. Rice grain yield of the five varieties in SRI, control and farmer practice plots

Variety	SRI		Control		Farmer practice		SRI increase over control (%)	SRI increase over farmer practice (%)	Crop cycle (days)
	Yield (t/ha)	SE (n)	Yield (t/ha)	SE (n)	Yield (t/ha)	SE (n)			
BG90-2	10.01	0.26 (20)	6.94	0.46 (20)	5.29	0.31 (24)	44	89	141
Wassa	9.59	0.53 (6)	6.10	0.77 (6)	5.34	0.36 (5)	57	80	133
Adny 11	8.75	0.53 (14)	4.44	0.37 (14)	4.39	0.42 (12)	97	99	133
D52	7.73	0.24 (6)	4.56	0.67 (6)	4.58	0.36 (9)	69	69	118
RPKN2	6.95	0.57 (8)	3.94	0.34 (8)	4.78	0.56 (5)	76	45	109

Labor requirements

Data on labor and costs were collected during the cropping season by monitoring the time required to carry out the various tasks, and via a survey in each of the 12 villages. It can be expected that SRI labor requirements will change in the future as farmers become accustomed to SRI practices. The data from this first season remain therefore preliminary. Labor data for SRI and for farmer practice cultivation are reported in Table 4. Changes in labor allocations were observed for most of the field and crop management tasks under SRI compared to farmer practice.

Table 4. Labor needed for cropping activities (work-days/ha)† for SRI and farmer practice systems, taking into account different soil preparation options

Crop management	SRI		Farmer practice	
	Tractor	Manual tillage	Tractor	Manual tillage
Plot boundary	5	5	5	5
Tillage	30	34	30	0
Breaking up chunks	30	7	8	0
Leveling	14	14	0	0
Total soil preparation	***79***	***60***	***43***	***5***
Nursery	8	8	23	23
Transplanting	77	77	24	35
Hand weeding	6.5	6.5	28	28
Cono weeding	7	7	0	0
Harvest	31	31	31	31
Threshing	56	56	34	34
Total	***265***	***246***	***183***	***156***

† One work-day = 8 h work, is paid 1000 FCFA.

Soil preparation, transplanting and threshing took more time using SRI techniques than under farmer practice. On the other hand, nursery management, seedling removal, and transportation and weeding times were more labor intense under farmer practice. Farmers have only since 2006 begun to till their soils by tractor. Breaking up soil chunks, puddling and field leveling were all done without machinery, which required a large amount of labor. SRI nurseries required less work because (i) they are much smaller; (ii) they required only 11 days of attention instead of the 29 days for farmer practice; (iii) SRI seedlings were quickly removed from the nursery bed with a hoe, whereas under farmer practice women sit for hours in flooded plots and pull the plants out of the ground one by one; (iv) it is easier to transport small seedlings than older heavier seedlings; and (v) fewer seedlings are needed per planted surface area using SRI techniques than under farmer practice. Transplanting SRI plots took two to three times as long as it did for the control plot. This number is not unexpectedly high, given that SRI requires new planting techniques — handling small seedlings and planting with precise spacing in straight lines — and that farmers had never done it before. In many instances, a large number of villagers would come to the PIV, wanting to take part in the planting. Often these first-experience events were difficult to keep well organized, and labor was not used very efficiently. It is expected that farmers will reduce planting time considerably once they are used to handling the small seedlings and gain expertise in in-line planting techniques. Weeding SRI plots took about half the time required for weeding plots under farmer practice. We assumed that time required for harvest would be the same under both SRI and farmer practice, and increased time required for threshing would be proportional to the increased yield under SRI.

Costs and benefits

Input costs, production value, and the net revenue for SRI, control and farmer practice plots are shown, based on the data presented in this article and on information from farmers in the 12 villages (Table 5). Net revenue for SRI farmers was more than 1 million FCFA/ha, compared to 490 000 FCFA/ha for the control plots and 426 000 FCFA/ha for the farmer practice plots. Although input costs for SRI were slightly higher — 15% and 25% compared to the control and farmer practice plots, respectively — SRI net revenues were 108% and 141% higher than the control and farmer practice plots, respectively, indicating a markedly higher profitability for SRI over the conventional system. Comparing the ratio of input costs to the value of the rice produced, under SRI input costs were only 32% of the total production value, whereas for control and farmer practice plots they were 46% and 47%, respectively. Measuring the cost to produce one kilogram of paddy rice, SRI production costs were reduced by one-third. The calculated costs of production were 76 CFA/kg in the control plots, 77 CFA/kg for the farmer practice plots, and 52 CFA/kg for the SRI plots.

Conclusions and further developments

SRI practices were successfully adapted to the local rice cropping system of the Timbuktu region in northern Mali, based on which technical guidelines were developed (Styger *et al.*, 2009). Yield increases with all tested varieties and income improvement were so marked with SRI that farmers expressed continued interest in working with and further adapting SRI practices. Main constraints identified during this season's evaluation related to the need for farmers to learn new technical skills and for increased labor for land preparation and transplanting. Also, if SRI becomes more popular, there will likely be a lack of sufficient animal manure for all the SRI fields in the area. Based on these findings, Africare and the Government Agriculture Service — with funding from USAID and Better U Foundation — continued to provide technical support to over 300 farmers in 27 villages in the 2009/10 season. Africare introduced and tested a hand tractor, manufactured and used in the Office du Niger rice-growing zone of Mali, that allows good-quality soil tilling, puddling and leveling, and reduces labor requirements and costs for soil preparation. Africare also began working with SRI farmers to produce *in-situ* compost based on rice straw and manure for the continued fertilization of the rice fields.

Farming communities have begun to develop a farmer-to-farmer extension approach to pass the SRI technical knowledge on to their fellow farmers. A number of villages regrouped their SRI plots within a single location of the PIV, in order to apply SRI irrigation principles correctly, and thus were able to use more than 30% less water than under the usual farmer practice. Farmers have also begun testing adapted SRI techniques to growing the off-season wheat crop. During the 2009/10 season, SRI practices were further introduced to the regions of Gao, Mopti, Segou, other circles of Timbuktu, and to the rainfed systems of the Sikasso region through the USAID-funded IICEM project (Initiatives Intégrées pour la Croissance Économique au Mali) and IER (Institut d'Economie Rural) SRI project funded by the Syngenta Foundation.

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Table 5. Rice production costs, production value and net revenue for SRI, control and farmer practice plots (FCFA/ha)

Input	Quantities			SRI		Control		Farmer practice	
	SRI	Control	Farmer practice	FCFA/ha	Percentage of total cost	FCFA/ha	Percentage of total cost	FCFA/ha	Percentage of total cost
Irrigation (200 L diesel × 550 CFA)	90%	100%	100%	99 000	21	110 000	27	110 000	29
Depreciation of motor pump (yearly)	90%	100%	100%	40 500	8	45 000	11	45 000	12
Seed (380 FCFA/kg)	6 kg	50 kg	50 kg	2 280	0.5	19 000	5	19 000	5
Urea (350 FCFA/ha)	120 kg	145 kg	97 kg	42 000	9	50 750	12	33 950	9
DAP (350 FCFA/kg)	8 kg	34 kg	20 kg	2 800	0.5	11 900	3	7 000	2
Manure (300 FCFA/100 kg)	13 t	3 t	0	39 000	8	9 000	2	0	0
Labor (person-day × 1000 FCFA)†	251	169	161	251 000	53	169 000	41	161 000	43
Total input costs				***476 580***		***414 650***		***375 950***	
Production (paddy) (165 FCFA/kg)	9.1 t	5.49 t	4.86 t	1 501 500		905 850		801 900	
Net revenue (FCFA/ha)				***1 024 920***		***491 200***		***425 950***	
Production cost for 1 kg paddy (FCFA)				52		76		77	
Input costs as percentage of total production value				32		76		77	
Labor costs as percentage of total production value				17		19		20	

† Labor was calculated from Table 4: for SRI: 40% tractor, 60% hand; Control: 33% tractor, 15% hand, 52% no till; Farmer practice: 20% tractor, 80% no till.
US$ 1 ≈ 450 FCFA.

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