System of Rice Intensification (SRI) - Community-based evaluation in Goundam and Dire Circles, Timbuktu, Mali, 2008/2009

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Abbreviations

AMSS	*Association Malienne pour la Survie au Sahel*, or Malian Association for the Survival of the Sahel
CNRA	*Comité National de la Recherche Agricole*; National Committee for Agricultural Research
IICEM	*Initiatives Intégrées pour la Croissance Économique au Mali*
IER	*Institut d'Economie Rurale du Mali*
PACR	*Projet d'Appui aux Communautés Rurales*
PIV	Village Irrigated Perimeters (*Périmètres Irriguées Villageoises*)

Glossary

Tiller	Shoot of a rice plant
Panicle	Or inflorescence, is the terminal component of the rice plant. It bears rice spikelets, which develop into grains
DAP	Di-Ammonium Phophate: chemical fertilizer that contains 18 kg of Nitrogen and 46 of Phosphorus in 100 kg of fertilizer (or according to standard formula: 18-46-0, or 18 kg N, 46 kg P, 0 kg K in 100 kg fertilizer)
Urea	Nitrogen fertilizer (46 kg N in 100 kg fertilizer)

Currency

1 USD = 450 CFA

Photo Credit

Photos in this report were taken by Erika Styger, Hamidou Guindo and Oumar Aboubacrine

Acknowledgments

The work presented in this report is a result of exceptionally strong teamwork among farmers, Africare field and office staff and the Mali Government agriculture service office of Goundam. It has been an extremely rewarding experience to work with so many dedicated people who were ready to take on this very demanding fieldwork in spite of the many logistical constraints, and to sacrifice many of their weekends in order to make this work a success. The belief in this important innovation made all participants exceed their day-to-day duties, creating a high-spirited team, and I am tremendously grateful to have been part of it.

In particular I would like to thank the staff of Africare Bamako and Goundam offices, who provided steadfast administrative, logistic and technical support, allowing me to focus on my technical work.

My sincere gratitude goes to the team of SRI field agents, for each member I carry deep respect for their professional qualities and personal dedication, and who have today become the leading experts on SRI techniques in Mali! (see picture and names below)

The farmers of Goundam and Dire were ready to test this innovation, always open to our suggestions, and provided the utmost care to their evaluation plots. I would like to thank the leaders and communities of the 12 villages and the 60 SRI farmers who trusted us to embark on this evaluation and committed their resources out of a genuine curiosity and willingness to improve and advance in their farming practices. (The pictures and names of the 60 SRI farmers can be found at the end of this report).

My acknowledgment extends to the Goundam office of the Mali Agriculture Service and the Regional Agriculture Service office in Timbuktu for supporting and participating in the SRI evaluation from the very beginning.

I am thankful to the Better U Foundation for their financial support. The quick responses, timely transfers, and minimal administrative burden allowed us to concentrate fully on our fieldwork.

The findings presented in this report have widely surpassed my expectations, and I hope that with the recognition of these achieved results, SRI practices will continue to spread across the Timbuktu region, and across Mali.

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The team that carried out the SRI field tests in Timbuktu, Mali 2008/2009

From left to right: Minkaila Sidi Mahamar (Agriculture Supervisor, Africare), Hamidou Guindo (Field Supervisor SRI), Erika Styger (Technical Coordinator, Consultant with Africare), Harouna Ibrahim (Africare Field Agent for the villages of Horogoungou, Douegoussou, and Hara Hara), Ibrahima Abba (Africare Field Agent for the villages of Donghoi, Niambourgou, and Bagadadji), Mohamed Traore (Africare Field Agent for the villages of Kessou-Koreye, Adina, and Katoua), Mahamane Diaty (Africare Field Agent for the villages of Findoukaina, Morikoira, and Bourem), and Malik Ag Attaher (Agriculture Service Extension Agent, Circle of Goundam)

Executive Summary

The Goundam and Dire circles in the Timbuktu region are among the most food-insecure areas in Mali. Due to very low annual rainfall of 150-200 mm, farmers practice either recession agriculture or deepwater rice cultivation along the many seasonally flooded river branches, ponds and lakes. Yields are usually very low, below 1 ton per hectare for rice and sorghum. In recent years, farmers begun to exploit small-scale, village-based irrigation schemes, most often at a size of 30-35 hectares. These schemes have become important for improving the food security of the region. Africare has worked for the past ten years with farmers in this area to establish irrigation schemes and provide technical advice. During the 2007/2008 cropping season, Africare undertook a first demonstration of the System of Rice Intensification (SRI) in two villages. The yield increase using SRI was remarkable: 8.98 tons/hectare (t/ha), 34% more than the best use of farmers' rice planting methods. Based on this success, the Better U Foundation gave a grant to Africare for a much larger project: to assess the performance of SRI with 60 farmers in 12 villages during the 2008-2009 growing season in the circles of Goundam and Dire.

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 is based on six principles: i) transplanting single seedlings, ii) transplanting at the 2–leaf stage (8-12 days old), iii) wide plant spacing of 25cm x 25cm or wider, planted in lines, iv) minimum water applications during vegetative growth period, keeping soils moist but well-drained and aerated, v) frequent weeding with a simple mechanical hand weeder, and vi) application of organic matter, in preference to chemical fertilizer.

Sixty farmers worked with Africare entirely on a volunteer basis, and received on-going technical support, no other material support, except two simple mechanical weeders for each village. Farmers were free to choose plot size, rice variety and fertilization strategies. Rice nurseries were installed for the SRI and control plots (managed according to local practice) with the same seed the same day. Africare staff collected detailed data regarding land preparation, nursery, rice varieties used, planting parameters, fertilization, irrigation, and weeding. At harvest, staff measured yields from SRI, control, and as an additional measure, other plots taken at random (called "farmer practice" plots) in each village using a predetermined protocol to assure consistent measurement. The SRI plots were planted over a two-month period from June 26th to September 2nd, and were harvested from October 21st to December 23rd, 2008. Seven of the 60 SRI and control plots had to be disqualified due to crop damage or plot abandonment.

Average SRI yield of 53 farmers reached 9.1t/ha, with lowest yield being 5.4 t/ha and highest being 12.4t/ha. On average SRI yields were 66% higher compared to the control plots with 5.49t/ha and 87% higher compared to the surrounding rice fields with 4.86t/ha. All yield parameters were superior in SRI compared to the control plots. Although SRI plots contained from 3.5 to 5 times fewer plants per square meter at the time of transplanting, at harvest the number of panicles/m^2 was 31 % higher than in the control plots. Also, the one-plant SRI pockets produced an average of 50% more tillers than the three plants per pocket in the control plots.

Although production costs per hectare were slightly higher for SRI -- 15% and 25% compared to the control and farmer practice plots, respectively-- SRI revenues were 2.1 and 2.4 times higher. Net revenue for SRI farmers this season would equal more than 1 million CFA/ha, compared to 490,000 CFA/ha for the control plots and 426,000 CFA/ha for the farmer practice plots. The calculated costs to produce one kilo of paddy were 76 CFA and 77 CFA for the control and farmer practice plots respectively, in contrast to 52 CFA for SRI. Under SRI, only 6 kg of seeds were used per hectare compared to 40-60 kg under farmers' practice, a reduction of 85-90%. With the application of organic matter, chemical fertilizer inputs were reduced by 30%. Irrigation was reduced by 10%, which is not yet an optimal result, as reductions of 25-50% were achieved elsewhere in the world.

Experiences across the 12 villages were quite varied, as SRI plots were established on a number of different soil types, different rice varieties were used, different fertilization strategies applied, and farmers practiced different weeding intervals. Many lessons have been learned from this evaluation, but most importantly that the yield and economic improvement of SRI compared to the control plots were significant across all locations.

At the end of the season, farmers were excited and enthusiastic about SRI, stating they are ready to adopt SRI practices at an increased scale next year. Farmers listed many advantages, from reduced seed use, reduced water use, less weeding time, better and faster plant development, and most important, increased yields. Overall, farmers did not find any real disadvantages with SRI, although they mentioned constraints, mostly to do with increased labor for land preparation and for transplanting, and as SRI becomes more popular, the likely lack of sufficient animal manure for all the fields. Responding to these constraints, it is essential to further adapt SRI practices to local conditions, and improve technical feasibility for farmers to expand the area under SRI. Among the most important topics are i) the in-situ production of compost to generate quality organic matter for fertilization, ii) to improve soil preparation techniques by testing and introducing small machinery for tilling and leveling, iii) to improve transplanting techniques, iv) to evaluate locally available *Oryza glaberrima* varieties and NERICA varieties under SRI, and iv) to rigorously examine the reduction potential for irrigation, in order to generate solid technical recommendations for the Timbuktu region.

The challenge remains to introduce SRI across the region where farmers who have not yet seen rice perform under SRI, and to assist all interested male and female farmers to carefully apply the SRI techniques, in order to take full advantage of the synergies and the production potential of SRI.

1. Introduction

The Goundam and Dire circles in the Timbuktu region are among the most food-insecure areas in Mali. Due to the very low annual rainfall of 150-200 millimeters (mm), recessional agriculture is practiced 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 kilograms per hectare (kg/ha), and sorghum between 600 and 900 kg/ha. In recent years, Africare has worked with local farmers to build village-based small-scale irrigation schemes of 30-35 hectares each that can be irrigated by one diesel motor pump. With these irrigation systems, farmers can have full water control and can develop irrigated cropping systems with the potential for much 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 an improved food security situation of the region, and there is much potential and scope for extending the surface areas and improving production.

During the 2007/2008 cropping season, Africare undertook a first round of System of Rice Intensification (SRI) demonstrations in farmers' fields in the villages of Douegoussou and Bagadadji in the Goundam and Dire circles of the Timbuktu region.

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 has been raising yields by 50% to 100%, and sometimes more, with reduced requirements for water, seed, fertilizer, and crop protection. To date, the effects of the SRI methodology have been empirically demonstrated in over 30 countries, including most of the rice-producing countries of Asia and many others in Africa and Latin America (Uphoff, 2007).

SRI is based on six principles: i) single seedlings are transplanted, ii) seedlings transplanted at 2–leaf stage, or about 8-12 days after germination, iii) wide spacing between plants: 25cm x 25cm or wider, planted in lines, iv) minimum water applications during vegetative growth period, keeping soils moist but well-drained and aerated, v) frequent weeding with a simple mechanical hand weeder, ideally every 7 to 10 days or four times during the cropping season, and vi) application of organic matter (manure, compost, or mulch), in preference to chemical fertilizer.

During this first field test, farmers installed and managed the fields with technical advice from Africare's consultant agronomist and field agents. Africare organized three field visits during the growing season for farmers from surrounding villages and for agents of the Government of Mali agricultural service. The yield increase using SRI was remarkable: 8.98 tons/hectare (t/ha), 34% more than farmer's practice (6.7 t/ha in the associated control plot next to the SRI plot), and more than double the regional average of irrigated rice yields for that year (4.03 t/ha; Source: Agriculture Service of Timbuktu).

Based on this remarkable yield increase and the ensuing interest in SRI in the region, 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 2008-2009 growing season in the circles of Goundam and Dire. The selection of the 12 villages was based on the following criteria:

i. A history of strong and efficient collaboration with Africare over the previous 5 to 10 years,
ii. Farmers' interest in SRI,
iii. Potential for improving rice production, and
iv. High potential to disseminate SRI to neighboring villages.

The objectives of this assessment were to:

i. Obtain solid information on the performance of SRI in various field settings of the region,
ii. Get farmers acquainted with the technical requirements of SRI,
iii. Create a general awareness in the rice-growing areas of Timbuktu about the potential of SRI, and
iv. Draw major lessons from the current season's experience to further promote SRI in the upcoming years in the Timbuktu region, and also for Mali.

2. Methodology

2.1. Site description

Five SRI villages are located in the Dire Circle and seven villages in the Goundam Circle. The total population of the 12 villages amounts to more than 14,000 people. In addition, 875 households from 39 surrounding hamlets and villages farm within the Village Irrigated Perimeters (*Périmètres Irriguées Villageoises*, or PIVs) of the 12 villages. These neighboring villages often do not have their own PIVs and farm on land belonging to other villages. In total, we estimate that about 2,600 households were able to witness the SRI evaluation first-hand. Locals inform us that nearly all farmers living in the larger SRI evaluation zone had heard about SRI by the end of the season. The total area of rice under cultivation in the 12 villages is more than 1,900 ha, roughly more than10% of the entire area of irrigated rice in the Timbuktu region. Details for each village are provided in Table 1 below.

Table 1: SRI villages, population, households producing rice, and total area of irrigated rice (ha), (according to information provided by villages in January 2009)

Circle	Commune	Village	Population	Households (HH)	Rice producing HH %	Number of PIVs	Rice surface ha	HH from other villages on PIVs	Number other villages on PIVs (not exclusive)
Dire									
	Arham	Morikoira	1365	136	100	3	88	50	9
	Bourem	Bourem Sidi Amar	2865	413	100	13	413	70	8
	Bourem	Hara Hara	900	149	100	4	230	60	5
	Bourem	Horogoungou	1321	160	100	6	424	400	6
	Kondi	Fendoukaina	830	75	100	9	176	15	2
Goundam									
	Douekire	Adina Koira	727	63	100	1	25	12	3
	Douekire	Bagadadji	517	66	100	1	30	0	0
	Douekire	Donghoi	850	115	87	1	10	3	2
	Douekire	Douegoussou	637	76	100	4	222	80	8
	Douekire	Katoua	1130	150	100	5	117	95	3
	Douekire	Kessou-Koreye	1050	86	100	6	156	60	3
	Douekire	Niambourgou	1888	220	100	3	51	30	3
Sum			**14080**	**1709**		**56**	**1942**	**875**	

The SRI villages are not located next to the Niger River itself, but on its seasonally flooded arms, and lie at some distance from the main river. The distance to the Niger River determines when the water arrives at the village; only then can the rice season begin. The SRI plots were planted over a two-month period, beginning in the village of Hara Hara on June 26th, 2008, and ending on September 2nd in the village of Donghoi. To better understand the location of the villages in respect to the water sources, see Satellite Map (Figure 1) below. On the map, also note the location of Dire (located on the Niger river) and Goundam, located next to seasonally-flooded Lake Tele. The Niger River runs from southwest to northeast.

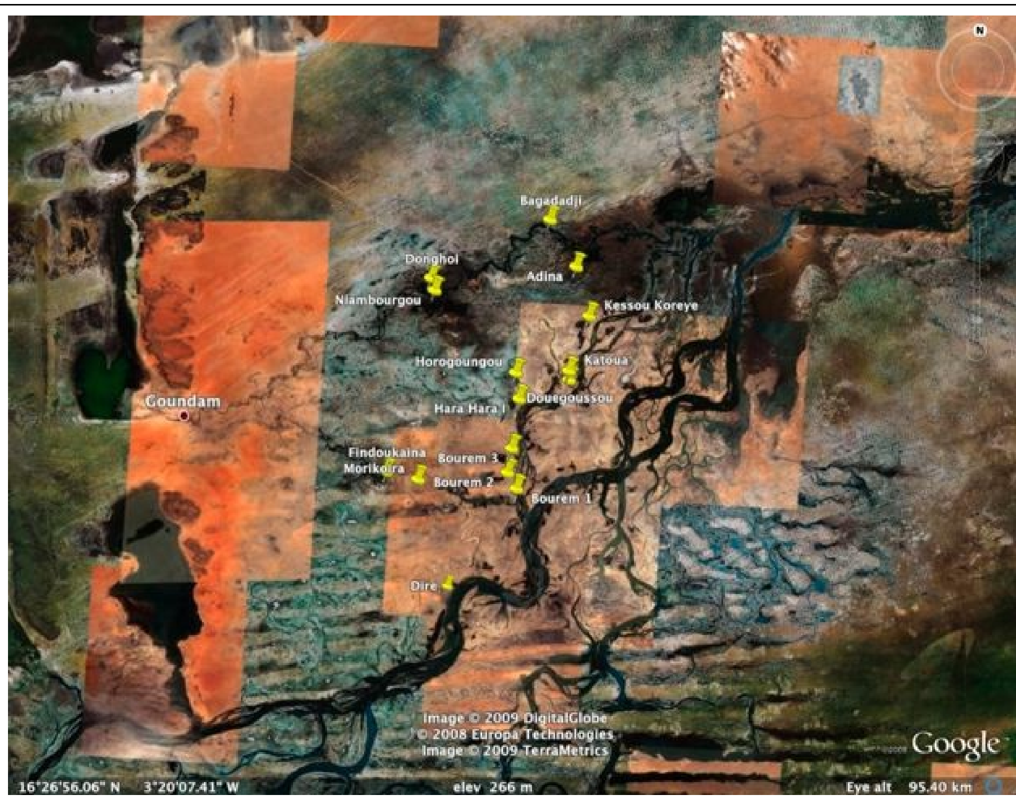


Figure 1: Location of 12 SRI villages along the seasonally flooded Niger River arms.

2.2. Farmer selection and Africare support

Africare staff introduced the idea of an SRI evaluation to the village assembly in each of the 12 pre-selected villages two months prior to the beginning of the cropping season. The villages were given some time to discuss and select five volunteer farmers to participate in the evaluation.

There are three reasons why we chose to work with five farmers in each of 12 villages, for a total of 60 farmers:

i. This reaches a relatively large number of villages, giving many farmers the opportunity to follow the evaluation, as compared to concentrating the test in fewer locations.
ii. With five farmers participating per village, we get a good sample size for each location, and any differences in performance among the five farmers' fields, located at the same site, will be due to differences in crop management as the environmental conditions (soil, rainfall) and field planting dates remain largely the same.
iii. To better a maintain quality oversight, the limit of five farmers per village allows the Africare field agents to assure a thorough technical follow-up.

Farmers undertook the field evaluation and worked with Africare entirely on a volunteer basis. The farmers did not receive any inputs — seed or fertilizer — from Africare, nor were they paid or otherwise compensated. Africare did provide on-going technical support, and supplied two cono-weeders, a simple tool previously unknown in the region, for each village. Each farmer was entirely responsible for managing his or her own field.

The project employed four field agents, each of whom was responsible for three villages, thus each field agent worked with 15 farmers, five in each village. Each of the field agents lived in one of the villages where he worked. An agricultural supervisor, based in Goundam, covered the whole project area and made sure that all the fieldwork went smoothly and that data were properly collected. The overall technical supervisor, based in Bamako with frequent visits to the project sites during the cropping season, provided technical guidance, oversaw the first field plantings and harvests to train the field agents in the proper methodology. She assured that the SRI techniques were well understood and adhered to by the field staff.

Africare established a close working relationship with the Mali Government agricultural service office in Goundam, which allowed one of its staff - the agent in charge of agricultural production - to work with the project nearly full-time. He actively participated in the project throughout the entire season and made significant contributions to adapting SRI to local conditions.

2.3. Field implementation and data collection

Plot selection and plot size: Once the farmers were identified, villagers and Africare field agents discussed plot selection. Proximity to the water source and accessibility were the main criteria. Farmers were left to decide how big the plot size should be. We recommended dividing a standard plot of 1250 m^2 (or 1/8 hectare) into two, and use half (or 625 m^2) for SRI and half for the control plot. At the end, average plot size was 400 m^2, ranging from 81 m^2 to 828 m^2 as presented in Figure 2.

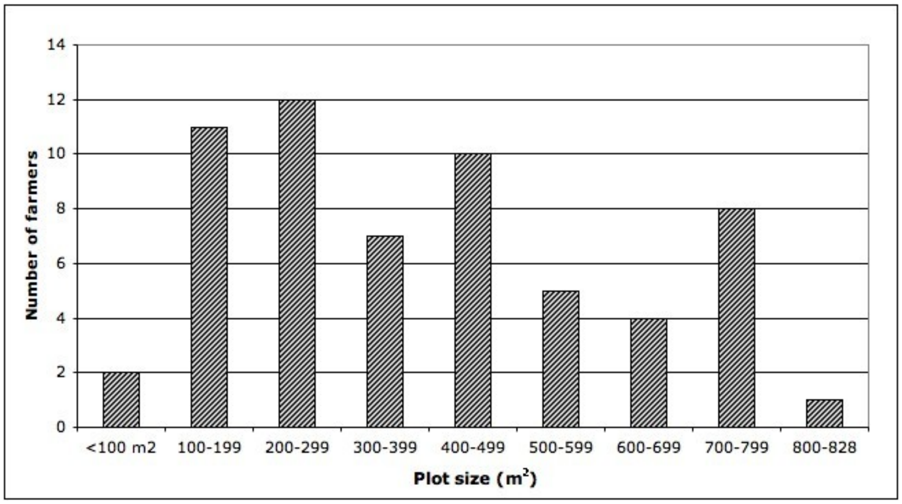


Figure 2: SRI and control plot sizes for 60 farmers

Rice variety: Farmers supplied their own seed, and were free to choose the variety. In all cases the same rice variety was used for each SRI plot and its corresponding control plot.

Germination of seeds (we also refer to it as nursery establishment) was done on the same day for the SRI plots and control plots. For the SRI plot, germination began when seeds were soaked in water 24 hours prior to seeding, as is recommended for SRI. For the control plot, germination began when the nursery was seeded and watered, which is the usual method.

Fertilization: We advised farmers to use the recommended amounts of manure in the SRI plots: 10-15 tons per hectare (t/ha). Decisions on control plot fertilization remained with the farmers. However, in order to control for effects of fertilization alone, we asked two of the five farmers in each village to use identical fertilization for the SRI and control plot, ideally one farmer testing manure fertilization only, the second farmer testing both manure and chemical fertilizer. This was done on a volunteer basis. In total, ten farmers tested equal fertilization with manure and chemical fertilizer, and three farmers applied manure only.

Data collection: Field agents collected data from each farmer's SRI plot and designated control plot, beginning from the time the field was established until the harvest. Data collected included detailed information on field establishment (land preparation, nursery, variety, planting), field performance during the season (counting tillers every ten days, qualitative observations), field management (weeding, irrigation), labor for each of the interventions (leveling, planting, weeding, etc.) performed on the SRI and control plots, costs of inputs, and finally, the harvest and yield data.

Harvest procedure: In order to obtain accurate measurements of the grain yield for each SRI and control plot, we harvested three 2m x 2m squares, for a total of 12 square meters for each plot (3 x 4 m^2 =12m^2). A 2m x 2m wooden frame was placed in the field at three different locations, each location representative of conditions in about one- third of the plot. Prior to harvest, field agents examined each plot, discussing the crop performance within the plot with the SRI farmer until they agreed on the three locations to be harvested. For the analysis of counting tillers and panicles a 1m x 1m frame was placed within each 2m x 2m frame. All plants within the 1m x 1m frame were cut at the base to count the number of tillers and the number of panicles of each plant. The three 4 m^2 squares of harvested grain were threshed immediately on location and weighed using a precision PESOLA™ scale. At the same time, the moisture content of grain was measured using a FARMEX MT-PRO™ moisture meter. The field yield results were then adjusted to the standard reported yield with a 14% grain moisture content to ensure consistent moisture content for all harvested rice. Additionally, we randomly selected six panicles per plot (two panicles per square), to measure panicle length and to count the number of grains per panicle.

Three 4-square-meter plots are harvested in each of the SRI and control plots for grain yield and yield parameters

16 harvested plants from 1-square-meter SRI plot; For each of the plants number of tillers and panicles are counted

Harvest from a 4-square-meter plot, threshed immediately after harvest. Grain weight and moisture content are determined

Harvesting of farmer practice plots: During the field evaluation, we noticed that some of the control plots were better cared for than the surrounding fields in the PIV. They were more fertilized and better weeded. Some SRI farmers apparently wanted to impress fellow farmers, not only with their SRI plots, but also with their control plots. A few farmers even tried to out-compete SRI.

Based on these observations and intending to compare the SRI field performance to the average rice fields within each PIV, we decided to harvest sample plots within five randomly selected fields surrounding the SRI and control fields, in addition to the SRI and control plots. We call these "farmer practice" plots. Farmers cultivating these plots were usually not the SRI farmers. For these plots, as for the SRI and control plots, we measured grain yield, counted tillers and panicles, panicle length, and number of grains, and noted soil preparation methods, rice variety, and the amount of fertilizer and/or manure used.

Timing: All 60 plots were planted between June 26 and September 2, 2008. Fields are planted only when there is sufficient water available for irrigation from the annual flooding of the arms of the Niger River; thus villages close to the river plant earlier, those farther away plant later when the water arrives. Harvesting extended from October 31 to December 23, 2008.

Disqualified plots: From the total of 60 plots, seven SRI and seven control plots were disqualified. Two SRI plots in the village of Niambourgou were disqualified from the beginning because they were not irrigated the day after planting, resulting in a very high mortality rate, and the two farmers abandoned these plots. One farmer in the village of Findoukaina also lost most of the SRI plants due to delay of the first irrigation. Unfortunately he replanted the field with a different variety, with seedlings much older than 10 days (in contradiction to SRI techniques). What remained of the 'original' SRI plot was too small to obtain representative data. One plot in the village of Bagadadji was disqualified because a farmer harvested without the presence of the Africare field agent, thus it was impossible to measure the yield consistently with the others. And finally, in the villages of Niambourgou and Donghoi, birds ate the rice in three SRI plots before the plots could be harvested. These were the last plots to be harvested in the season, when migrating birds had arrived from other regions into the Goundam - Dire area.

2.4. Information sharing and exchange

During the months of September, October and November, Africare organized different types of farmer visits; many other interested parties visited the SRI plots as well.

- Intra-village field visits: which allowed all interested farmers in each SRI village to visit the local SRI plots, ask questions to the five SRI farmers and the Africare field agent, learn from the SRI farmers' experiences, and discuss their observations. A total of 201 farmers participated in these visits.
- SRI farmer exchange visits: Africare organized three two-day events, each for 20 SRI farmers from four neighboring villages. During the first day, the 20 SRI farmers visited the SRI fields of three neighboring villages, and each farmer shared his or her experiences with the others. They all stayed overnight and continued discussions the following day. Farmers from each village shared their observations, identified advantages and disadvantages of SRI, any difficulties encountered, and made recommendations for the future.
- Farmer visits from other regions of Mali: The USAID-funded project IICEM (*Initiatives Intégrées pour la Croissance Economique au Mali*) sent farmer representatives with whom it is collaborating from the Mopti, Gao and Timbuktu regions. IICEM plans to introduce SRI with its farmers for the upcoming 2009/2010 cropping season.

- Mali Government Representatives: a number of representatives from different institutions from local to national level were able to visit the SRI fields: most importantly from the Ministry of Agriculture, the national research institutions IER (*Institut d'Economie Rurale du Mali*) and CNRA (*Comité National de la Recherche Agricole)*, and the Chamber of Agriculture.
- Donors, projects and NGOs: USAID Mali, World Bank Mali, PACR Project (*Projet d'Appui aux Communautés Rurales)*, Millennium Village Project, IICEM Project, and AMSS NGO (*Association Malienne pour la Survie au Sahel)*.
- Presentations: In January 2009, the author of this report gave two presentations about SRI and this project to i) US Peace Corps volunteers in training, and ii) the quarterly meeting of USAID and its partners (organizations receiving USAID funding in Mali). The presentations have stimulated much interest in SRI for Mali. We anticipate further presentations for different audiences once the season report is released.

Web site: Our SRI internet blog follows the development of this SRI season step by step, including soil preparation, fertilization, nursery establishment, transplanting, weeding, development of tillers, etc. The blog has proved to be very effective in communicating our work to a large audience in Mali, in the US, and around the world.
(http://www.erikastyger.com/SRI_Timbuktu_Blog/SRI_Timbuktu_Blog.html)

Farmers from Kessou-Koreye village visit the 5 SRI evaluation plots in their village

Maya Abdoulaye, one of two SRI female farmers explains how she is conducting her evaluation, while standing in her SRI plot

Inter-village exchanges created animated discussions among farmers and technicians

3. Results

3.1. Land preparation

Traditionally, farmers do not plow their land, but irrigate a plot and transplant the rice seedlings directly the following day. Where the soil is hard, farmers use a stick to make a planting hole. For the SRI plots, we recommended superficially tilling the plot in order to: i) incorporate the manure, which was spread over the entire surface of the plot immediately before tilling, and ii) create a friable soil surface layer, conducive to root development.

All SRI farmers followed the basic recommendations. Since 2006, some villages in the region have paid for a tractor to plow their land. 40% of the SRI farmers used tractor plowing, and 60% tilled their land by hand. In the control, 33% plots were tractor plowed, 15% tilled by hand, and 52% did not receive any preparation. In the farmer practice plots, land preparation was done on only 20% of the plots (Figure 3). Although, we would expect tilling to have a yield increasing effect, we did not find a clear relationship between tiling/not tilling and the grain yields in the three systems.

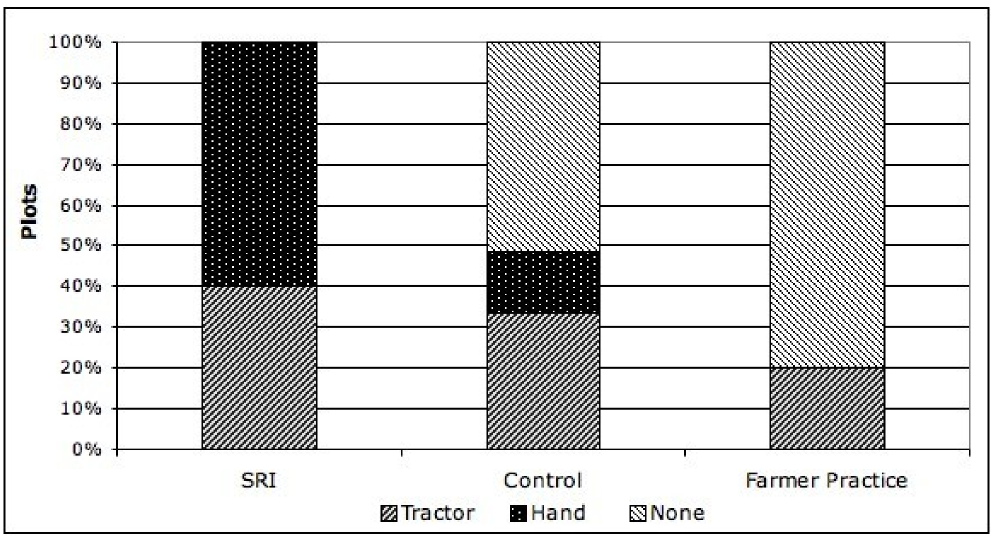


Figure 3: Land preparation methods in the SRI, control, and farmer practice plots (in % of all 60 plots)

3.2. SRI nursery and seed use

We established SRI nurseries on small rectangles one meter wide and a few meters long depending on SRI plot size, mixing clayey soils with sand and organic matter to create a permeable and friable seedbed. After soaking the seeds in water for 24 hours, they were broadcast onto the nursery bed and covered with some sand. For transplanting a 400 m^2 SRI plot, about 240 grams of seed were necessary, which represented a nursery bed surface of about 2.5 m^2.

- We used only 6.13 kg of seed per hectare for the SRI plots (average of 60 farmers). This stands in stark contrast to the 40-60 kg of seed per hectare used in conventional planting methods: a reduction of 85-90%.

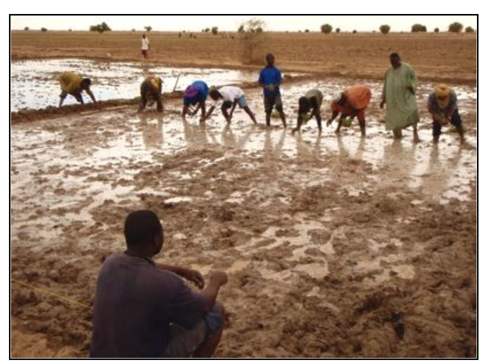
SRI nursery of Ibrahima Hamidou (left), in the middle of his traditional nursery. Rice seedlings are 8 days old, have two leaves, and are thus ready to be transplanted.

SRI nursery for Imam Mahamdou (left), SRI pioneer farmer from last year. His nursery is ready for transplanting.

3.3. Planting parameters

Planting parameters of SRI and control plots are presented in Table 2. Under SRI, seedlings were transplanted singly, one per planting pocket. Under the control, from two to five seedlings were put into one pocket, averaging three seedlings in each pocket. SRI seedlings were transplanted from 10 to 12 days after germination, whereas in the control plots, seedlings were transplanted from 22 to 45 days after germination, averaging 29 days. At the time of transplanting, SRI seedlings had on average 2.4 leaves and the control plot seedlings had 4.8 leaves.

54 SRI plots were planted in straight lines with a plant spacing of 25 cm x 25 cm. Six farmers tested a spacing of 30 cm x 30 cm. Spacing of control plot seedlings, not planted in straight lines, was on average 23.7 cm, which was not much inferior to the 25 cm SRI spacing.



SRI seedlings to be transplanted at 10 days of age in the village of Hara Hara: notice how roots remain protected and surrounded by soil. Thus the shock of transplanting is reduced.

Seedlings of between 30 and 45 days old under farmer practice. Seedlings are pulled up and roots are washed before transported to the fields for transplanting.

Total number of pockets planted per hectare was 177,883 for the control plots, 160,000 for the SRI plots with 25cm spacing, and 111,111 for the SRI plots with 30cm spacing. Five times more seedlings were used per hectare in the control plots than in the SRI plots with 30 cm spacing, and 3.5 times more than in the SRI plots with 25cm spacing.

Table 2: Planting parameters for the SRI and control plots (average 60 farmers)

Parameters	SRI (n=60)	CONTROL (n=60)
Number of plants/pocket (range)	1	2 to 5
Number of plants/pocket (average)	1	3.05
Number of leaves (range)	2 to 3	4 to 6
Number of leaves (average)	2.4	4.8
Age of transplanting, range (days)	10 to 12	22 to 45
Age of transplanting, average (days)	11.6	29.4
Plant spacing (cm)	25 x 25 (30x30)	23.7 x 23.7
Plant density (pockets/ha)	160,000 (11,111)	177,833
Plants used per ha	160,000 (11,111)	542,390

3.4. Fertilization

Following the SRI guidelines from Madagascar (Tefy Saina SRI Manual) we recommended farmers to use well-decomposed manure or compost, ideally 10-15 metric tons per hectare. We hoped this would allow farmers to forego the use of chemical fertilizer. In this area, manure is traditionally applied only to rice seedling nurseries, not to rice fields. Only in recent years have farmers begun to use manure in rice fields, following advice from Africare and the government agriculture extension service.

All SRI farmers applied organic manure on average at 13t/ha (n= 60 farmers). A third of the farmers also applied an average 8.7 t/ha of organic matter to their control plots. On the other hand, no manure was added to any of the 60 farmer practice plots that were sampled in addition to the SRI and control plots.

Despite the application of manure, rice plants in most SRI plots started to turn yellow six to eight weeks after planting, most likely indicating a nitrogen deficiency. This meant that the applied organic matter did not supply the nutrients needed at the time of tillering. The reasons for this could have been:

- Insufficient amount of organic manure was applied,
- Manure quality and time of nutrient release did not correspond to plant needs,
- Due to soil depletion and the lack of previous organic matter applications to the soils, a one-time application of organic manure may not be enough to establish a balanced nutrient supply to the crops. A soil build-up over several seasons may be necessary,
- Crop management practices are affecting availability of nutrients to the plants.

Normally farmers in the region apply urea to the fields, which will help the yellowed rice plants to regain their green color almost instantly and continue developing. According to farmers, omitting urea application when plants turn yellow will reduce the number of tillers produced per plant, thus reducing yields.

Because the SRI evaluation aimed to adapt SRI practices to local conditions, and responsibility for field management remained with the farmers, we did not interfere in farmers' decisions as how to fertilize their plots. Nevertheless, we recommended applying chemical fertilizer only if farmers judged it to be absolutely necessary, and if they did, to use the least amount possible. See Table 3 for a summary of fertilization used (the term 'fertilization' as used in this text can include both chemical fertilizer and manure)

The results were satisfying, as three farmers did omit urea application completely. When they observed the field greening effect after the use of the cono-weeder (see discussion in section 3.6), they held off applying urea, and eventually never felt the need to do so. It has to be noted that these farmers cultivated on fertile and non-depleted soils.

As we recommended, farmers reduced overall the amount of urea used in the SRI plots to an average 120 kg/ha, compared to 145 kg/ha in the control plots. In the farmer practice plots, 98% of farmers applied urea, on average at 97 kg/ha. This is remarkably less than for the control and SRI plots. Many of the SRI farmers, most of them innovators, tried to apply state-of-the-art practices to their control plots, thus created an 'improved' control over the farmer practice fields. Note that the government agriculture service recommends applying 200 kg/ha for urea and 100 kg/ha for DAP.

Some farmers also applied DAP (Di-Ammonium Phosphate) fertilizer, which provides 18 kg of nitrogen and 46 kg of phosphorus for each 100 kg of fertilizer. 40% of the farmers used DAP in the control plots, 24% in the farmer practice plots and only 8% in the SRI plots. In parallel, the amounts applied were highest in the control plots (34 kg/ha), followed by the farmer practice plots (20 kg/ha), and the SRI plots (8 kg/ha).

- ➢ This indicates that for the SRI farmers, applying manure substituted for the DAP they might normally use.

Table 3: Amount of manure and fertilizers used in SRI, control and farmer practice plots, with associated costs, and percentage of farmers using different types of fertilization

	Manure t/ha (% farmers)	**Urea kg/ha** (% farmers)	**DAP kg/ha** (% farmers)	**Sum (CFA)**
Quantities *				
SRI	**13** (100%)	**120** (93%)	**8** (8%)	
Control	**3** (33%)	**145** (95%)	**34** (40%)	
Farmer practice	-	**97** (98%)	**20** (24%)	
Costs (CFA)				
SRI	12,900 - 64,450	30,000 - 48,050	2,050 - 3,300	45,000 - 115,800
Control	3,050 - 13,200	36,350 - 58,200	8,600 -13,800	48,000 - 85,200
Farmer practice		24,250 - 38,800	5,000 - 8,000	29,250 - 46,800
Cost/unit	100-500 CFA/100kg	250-400 CFA/kg	250-400 CFA/kg	

* Quantities are reported as average of 60 farmers

When comparing fertilization input costs per hectare, the range for the SRI fields varies from 45,000 CFA to 115,800 CFA, for the control plots from 48,000 to 85,000 CFA and for the farmer practice plots from 29,000 to 47,000 CFA. Because of reduction in fertilizer use (urea and DAP) in the SRI plots, their cost was on average 30 % less than in the control plots. The widely differing input costs for the SRI fields are a result of the highly variable price of manure, ranging from 100 to 500 CFA for a 100 kg bag across the 12 villages. Although most SRI farmers did not pay for the manure, but collected and transported it to the fields themselves, we report this as an opportunity cost based on prices reported by the villagers.

It can be foreseen that the easy availability of manure will decrease as farmers adopt SRI and demand for organic matter increases. Thus, farmers will need to produce more compost in order to respond to the demand for it. Composting is ideally done on location, both to minimize or avoid transportation costs and to use rice stalks for composting after harvest. Africare is working with SRI farmers to develop a practical system to produce compost for SRI fields.

It is likely that the composition of input costs will vary considerably in the future until a SRI fertilization system based on the optimal use of organic matter has been developed, possibly to be complemented by judicious use of chemical fertilizers. Note also that because manure has residual beneficial effects for the soil, one can expect that its yield-increasing properties may become more apparent over several years. In time, it may become necessary to apply compost only every two to three years, further lowering the long-term costs.

3.5. Irrigation

Irrigation practices change with SRI. Rice fields are no longer flooded. Only a thin layer of water is applied during the vegetative growth of the rice plant, enough to keep soils moist but well-drained and aerated. This can be achieved either through small daily water applications, or through alternate wetting and drying.

Only a shallow layer of water is introduced into the rice plot

Soils are left to dry until cracks are visible

Another small water layer is added. Soils are kept moist, but are never flooded during the vegetative growth stage of rice.

This irrigation system is called 'alternate wetting and drying'

Farmers were not able to optimally practice alternate wetting and drying because of the way irrigation water distribution is organized within the PIV. During a given period (usually 8 to 10 days), water is pumped to a different section in the PIV each day, while other sections are left dry. This reduces pumping costs.

Depending on soil, climate and plot management, the optimal schedule to irrigate SRI plots varies from that for conventionally-grown rice. Given the predetermined irrigation schedules, SRI farmers were not able to follow the SRI-specific intervals for alternate wetting and drying, but had to irrigate SRI at the same time as the control plots. Although field agents strongly encouraged farmers to reduce the amount of water allowed into a plot, they were often reluctant, fearing that plants would dry out before it was time to water again.

Based on an estimate of the amount of time each SRI and control plot was irrigated, we found that the quantity of water used overall in the SRI plots was about 90% of the amount used in the control plots. We attribute this reduction to two factors: the more level SRI plots fill more quickly, and farmers were willing to accept a slight cutback of water despite their reluctance. This water reduction was observed, even though the SRI plots were irrigated two times more (an average of 11.7 times during the entire cropping season) than the control plots (9.7 times). Because under SRI the seedlings are transplanted at a much younger stage, SRI plots were transplanted about 20 days before the control plots, which translates into two additional irrigations. Once the control plots were transplanted, the irrigation schedules were the same.

Although farmers and field agents are confident of having observed a water reduction with SRI, the results are not yet satisfactory. According to Uphoff (2007), water reductions in other countries have reached 25-50%. In order to understand the potential for water reduction in the Timbuktu region, it is recommended to isolate SRI plots from the farmer practice plots and to measure irrigation water use for the two systems separately. Also, irrigation water should ideally be available when needed, and not depend on a predetermined irrigation schedule.

3.6. Weeding

SRI weeding practices include the use of a simple mechanical hand-weeder every seven to ten days, ideally four times during the first part of the cropping season. Weeders churn up weeds, incorporate them into soil, and aerate the soil. We were able to import a prototype of a Sri Lankan "Cono-Weeder" (or conical weeder) from Senegal (see photo), from which we had 24 copies made by local metal-working shops. Each village received two weeders. Weeding the SRI plots by this implement took half the time required to weed the control plots by hand (Table 4). Total cono-weeding time was 6.8 person days/ha. In addition, farmers worked 6.6 person days/ha to hand weed SRI plots in order to remove weeds growing next to the base of the plant. Control plot weeding, all by hand, totaled 28 person days/ha. The cono-weeder, practical only on SRI plots, was used on average 2.4 times during the season, although three to four times is recommended. 10% of farmers used the weeder four times, 30% three times, 50% twice, and 10% used it only once.

Table 4: Weeding time in SRI and control plots, and number of weedings during the cropping season (average for 58 SRI and 60 control plots)

Weeding parameters	SRI (n=58)	Control (n=60)
Cono weeding (number)	2.4	-
Hand weeding (number)	1.2	1.8
Cono weeding (person day/ha)*	6.75	-
Hand weeding (person day/ha)	6.6	28
Total time weeding (person day/ha)	**13.4**	**28**

* 1 person day = 8 hours work, paid at 1000 CFA

When using the cono-weeder four times, total time used for weeding SRI plots is still less than the control: 18 person-days compared to 28 person-days, respectively (Table 5). It is assumed that the amount of hand weeding required is about the same for all SRI plots, and is unrelated to the number of cono-weeding performed.

Table 5: Time required if cono-weeder is used from one to four times, compared to control

Cono-weeding Number	h/ha*	SRI Handweeding h/ha	Total Time SRI h/ha	SRI Person days/ha	Control Person days/ha
1	22.5	53	76	9	28
2	45	53	98	12	28
3	68	53	121	15	28
4	90	53	143	18	28

* hours per hectare

There are two possible reasons why many farmers did not use the weeders the recommended three to four times:

- For their first experience with SRI, farmers may not fully understand the importance of using the cono-weeder and its yield improving effects, especially if there are relatively few weeds in a given plot.
- Cono-weeding is best done when there is a thin layer of water on the soil surface. Thus it needs to be done shortly after irrigation, and farmers may not have been available for weeding at that time. Many farmers were busy planting and looking after other rice fields, sometimes located far away in other PIVs.

At the end of the season, farmers and field agents cited many advantages of using the cono-weeder:

- Pulls up weeds and buries them in the soil, which fertilizes the soil
- The superficial tillage allows for better soil aeration and improves water infiltration
- Stimulates root development
- Stimulates tiller development
- Water stagnated in puddles on the soil surface is redistributed across the plot, and further levels plot

- Cross-weeding (using the weeder in two directions, across both the length and width of the plot) creates an effect of mounding soil around the base of the rice plants, thus the roots are surrounded by a mixture of water, soil and organic matter, making nutrients better available to the plant roots.

SRI farmer Ibrahim Hamidou from the village of Hara Hara using the cono-weeder: water that stagnated in puddles is redistributed across the plot. The use of the cono-weeder contributes also to further leveling the plot.

Cross-weeded SRI plot, increasing the effects of irrigation, fertilization, and weed control, and slightly mounding the soil around the base of each plant.

Cono-weeding results in superficial tillage of the soil, which allows for better soil aeration and improves water infiltration, stimulating root growth and tiller development.

3.7. Rice grain yield

The 2008/2009 season was very favorable for rice growing. The yearly rains started early and were plentiful further south in Mali and at the source of the Niger River in Guinea, so the Niger River rose early and fast. Overall, rice production was very good this year.

Grain yield for 53 SRI plots averaged 9.1 t/ha, which is 66% higher compared to the control at 5.49 t/ha, and 87% higher than yields from the farmer practice plots at 4.86 t/ha (Table 6). All reported yield data are adjusted to 14% grain moisture.

Table 6: Rice grain yield for SRI, control and farmer practice plots (reported at 14% grain moisture content, average of 53 and 60 farmers)

	SRI	Control	Farmer practice
Yield t/ha*	**9.1**	**5.49**	**4.86**
Standard Error (SE)	0.24	0.27	0.18
% change compared to control	66	100	-11
% change compared to farmer practice	87	13	100
Number of farmers	53	53	60

* adjusted to 14% grain moisture content

Lowest yield attained with SRI methods was 5.4 t/ha. More than 50% and 60% of the control and farmer practice plots, respectively, were less than this yield. A third of all SRI farmers achieved yields of more than 10t/ha. The highest yield was 12.4 t/ha (Figure 4).

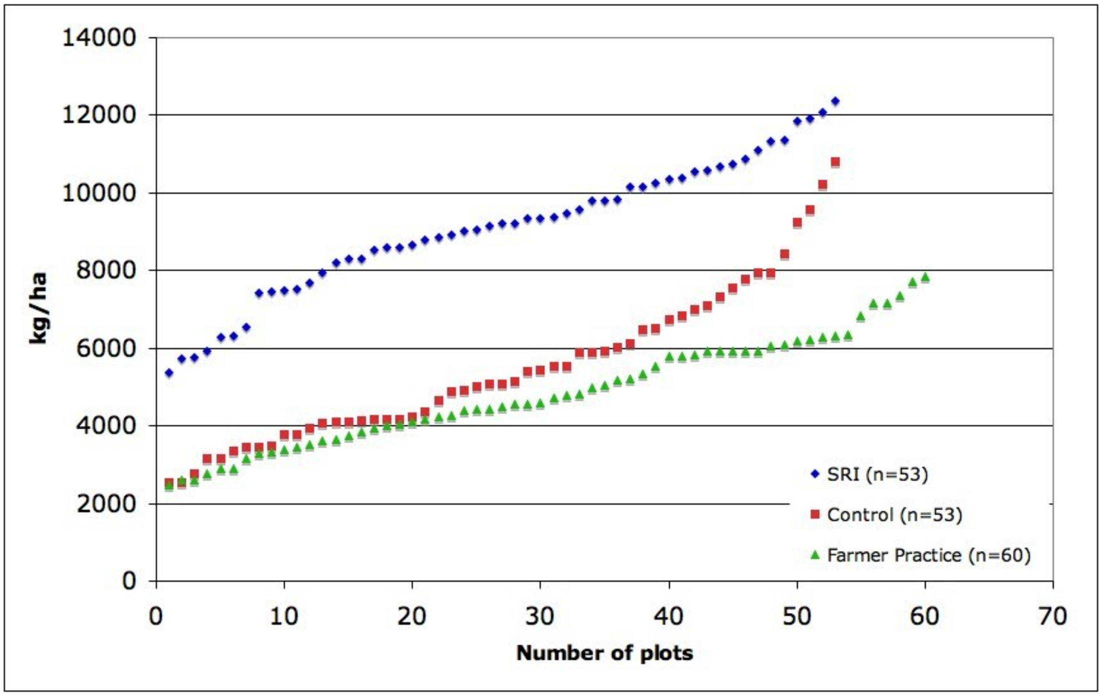


Figure 4: Rice grain yields for SRI, control, and farmer practice plots for 53 and 60 farmers

3.7.1. Distribution of yields

The number of farmers achieving a certain yield range is shown in Figure 5. Control and farmer practice plots have similar yield distribution curves except for the few outliers in the control, where five farmers produced more than 8t/ha. These yields were obtained with the medium-cycle varieties BG90-2 (4 farmers) and Wassa (1 farmer). These five farmers were able to plant early in the season, applied fertilizers at recommended levels and at the appropriate moment during the cropping season, and managed the weeds in time.

- This indicates that some of the rice varieties used in this evaluation do have the potential when using conventional methods, to reach higher yields compared to yields obtained by the majority of farmers, but that the conditions to reach these yields are only rarely obtained.

The SRI yield distribution curve stands in stark contrast to the control and farmer practice curves. 87% of the SRI plots produced more than 7t/ha, whereas 92 % of the farmer practice plots produced less than 7 t/ha. In short, at yield levels where farmer practice plots reached their upper limits, SRI plots just got started.

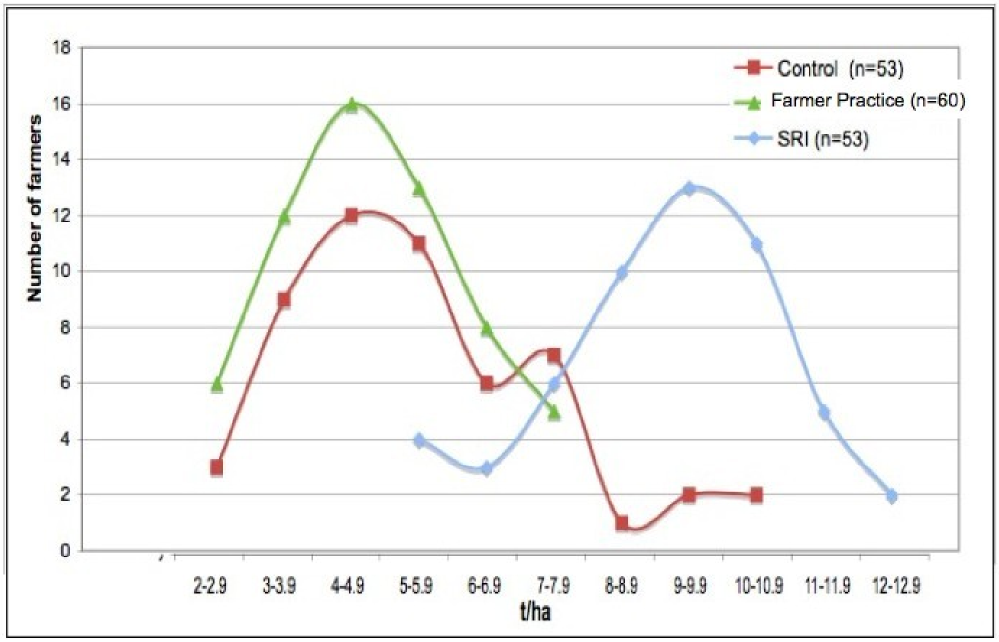


Figure 5: Yield distribution curves for SRI, control and farmer practice plots

- These curves indicate that SRI practices allow the rice crop to reach a distinctly higher yield level compared to conventional rice farming (control and farmer practice).

3.7.2. Yield performance with the advancing season

SRI and control plots were planted over a two-month period from the end of June until early September. As the cropping season advances, farmers must switch to less productive, shorter-cycle varieties. Comparing yields along the timeline of first to last plantings, a declining trend in yields can be observed for the three treatments (see trend lines in Figure 6).

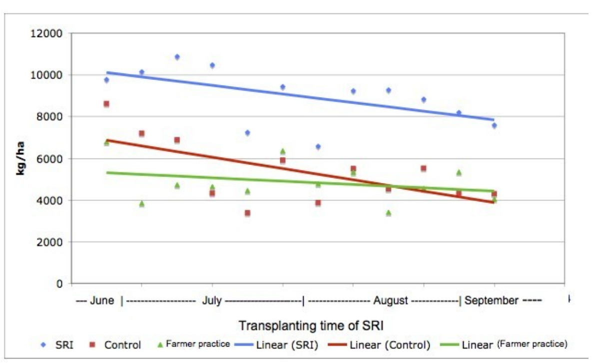


Figure 6: Rice grain yields for SRI, control, and farmer practice plots, according to time of planting (village averages for all 12 villages)

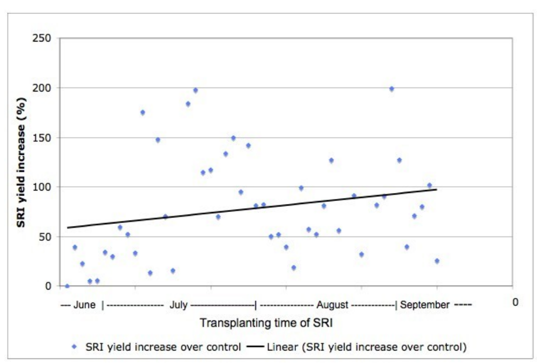


Figure 7: Yield increase (%) of SRI plots compared to control plots according to time of planting (for 53 farmers)

On the other hand, the yield increase trend line for SRI compared to the control increases as the season advances (Figure 7). This may indicate that for rice planted early in the season, high yields under conventional farming methods are more easily achieved than for rice planted later in the season.

- The advantage of using SRI practices increases for farmers as the season advances, or as rice-growing conditions become less optimal.

3.7.3. Yield parameters

All yield parameters were superior for SRI, followed by the control, and finally by the farmer practice plots (Table 7). Although SRI plots used from 3.5 to 5 times fewer plants at the time of transplanting (see Table 2), at harvest the number of panicles per square meter was 31 % higher than in the control plots. Also, the one-plant SRI pockets produced an average of 50% more tillers than the three plants per pocket in the control plots. The percentage of fertile tillers (tillers with a panicle as compared to the total number of tillers) was very high this season and reached almost 100% in all plots: SRI, control, and farmer practice. This stands in contrast to last year's results, when fertile tillers were only 77% of total tillers in control plot plants and 88% in SRI plot plants (see SRI season report 2007/2008). The very high fertile tiller number may be a result of this year's very good rice-growing conditions. Panicle length of SRI plot plants was on average 13% longer, and the average number of grains was 37% higher than in the control plot.

Table 7: Yield parameters for SRI, control and farmer practice plots

	Yield		Tillers/plant		Panicles/plant		Fertile tillers	
	t/ha	SE*	Number	SE	Number	SE	%	
SRI (n=53)	9.10	0.24	24.1	0.73	23.5	0.69	98	
Control (n=60)	5.49	0.27	16.2	0.50	15.9	0.49	98	
Farmer practice (n=55)	4.86	0.18	14.7	0.56	14.2	0.52	97	
	Tillers/m2		**Panicles/m2**		**Panicle length**		**Grains/panicle**	
	Number	SE	Number	SE	cm	SE	Number	SE
SRI (n=53)	371	9.88	361	9.08	24.0	0.73	133	4.86
Control (n=60)	283	9.23	276	9.17	21.3	0.30	97	3.31
Farmer practice (n=55)	266	12.18	257	11.77	19.8	0.30	86	2.38

* SE: Standard error

The evolution of tiller numbers per pocket for the entire season is shown in Figure 8 below. From the beginning, tiller development in the SRI plots was much superior compared to the control plots. Highest tiller numbers were reached at about 90 days after nursery establishment with 40 tillers/pocket for SRI and 25 tillers/pocket for the control. After flowering, which occurs at about 90 days, all the rice plant's energy goes into filling the rice grains. Small tillers that are not able to produce any panicles are often aborted and their nutrients translocated to fertile tillers (Figure 9 for illustration). This explains the decline in tiller numbers during the second half of plant development.

SRI farmers Bouba Boureima from Morikoira village (left picture) and Sidi Mido of Bourem village (right picture) are holding up plants from one control plot pocket of 3-4 plants (left) and one SRI plant (right).

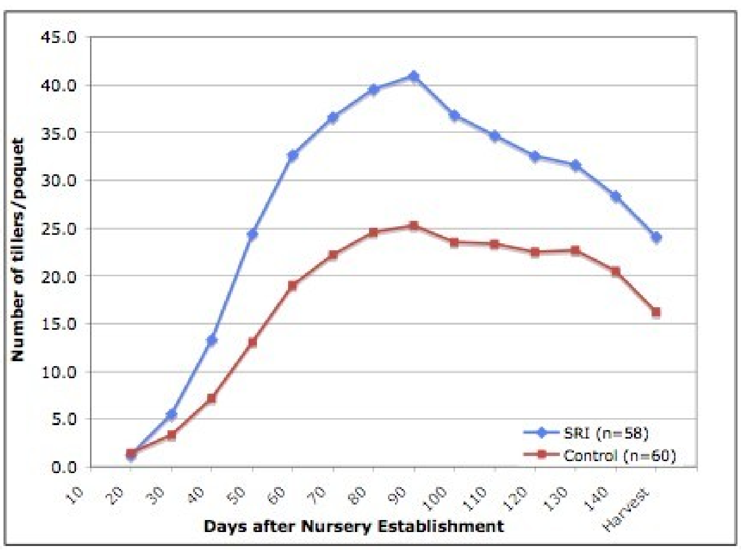


Figure 8: Tiller development for SRI and control from 20 days after seeding until harvest (average of 58 and 60 farmers)

Figure 9: SRI plant in the process of reabsorbing some of its tillers (index finger of right hand points to a brownish tiller that is being reabsorbed)

3.7.4. Rice Variety Performance

Farmers, free to choose their own seeds, used seven different varieties in this evaluation. The farmers supplied all seeds, as Africare did not provide any. The most popular variety was BG90-2, used by 20 farmers, followed by Adny-11, used by 14 farmers. Agane, Wassa, RPKN2 and D52 were each used by 5 to 8 farmers, and Kogoni by one farmer only. A similar distribution was observed in the farmer practice plots. Yields are reported in Table 8.

Table 8: Rice grain yield (t/ha) for 7 varieties in SRI, control and farmer practice plots.

Variety	Yields SRI t/ha	SE (n)*	Yields Control t/ha	SE (n)	Yields Farmer practice t/ha	SE (n)	Increase of SRI over control %	Increase of SRI over farmer practice %	Crop cycle ** SRI/control Days
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	116/133
Agane	**9.29**	0.79 (5)	**4.54**	0.29 (5)	**3.62**	0.45 (4)	105	157	127
Adny 11	**8.75**	0.53 (14)	**4.44**	0.37 (14)	**4.39**	0.42 (12)	97	100	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
Kogoni	**x**	x (1)	**3.77**	x (1)	**5.81**	x (1)	x	x	119

* SE: standard error, n: sample size

** average of harvests (days after germination)

Best performing varieties under SRI were BG90-2, Wassa and Agane, each producing on average more than 9 t/ha, followed by Andy-11 with 8.75 t/ha, D52 and RPKN2 with 7.73 t/ha and 6.95 t/ha, respectively. Compared to the control, Agane and Adny-11 doubled yields under SRI. RPKN2, D52 and Wassa achieved yield increases from 57 to 76%, whereas for BG90-2 it was less than 50%.

Malian Government reports show yields of 6 t/ha at the research station for BG90-2, Wassa, Adny-11, and RPKN2 (personal communication from Mr. Attaher, Regional Direction of Agriculture, Timbuktu, January 2009); these yields were all widely surpassed by SRI. In the control plots, BG90-2 and Wassa achieved this yield level, but not the other two varieties. In the farmer practice plots, all yields were below 6t/ha.

- This again underwrites the observations made under paragraph 3.7.1. that SRI practices allow the rice crop to achieve a much higher level of production independent of the variety!

Agane, a traditional variety, achieved the highest yield increases with SRI. No official information is available about this variety and its yield potential. These findings are worth exploring further in the upcoming season. We already noticed highly increased tillering and yields of indigenous varieties in the SRI plots compared to the control plots. These indigenous varieties, belonging to the African rice (*Oryza glaberrima*), are not usually grown under irrigation, but planted in low-lying areas under rainfed conditions. Some individual plants of these varieties were found in the SRI plots and the control plots, as they had been inadvertently mixed with the improved seeds (belonging to the Asian rice (*Oryza sativa*).

Observations on 16 randomly harvested plants from the African indigenous variety within the SRI and the control plots showed an average of 79 tillers/plant in the SRI plots, compared to 46 tillers in the control plots. The same variety produced under traditional rainfed cultivation only 22 tillers/plant. The grain yield was 1785 grams/16 plants for SRI and 926 grams/16 plants for the control, which is a 93% yield increase of SRI over the control. See more details on this story described in the blog entry on Indigenous Rice Varieties. These findings call for further evaluation of local and indigenous varieties under SRI.

Indigenous varieties (*Oryza glaberrima*) planted under the traditional rainfed cropping system in shallow landscape depressions. A farmer holds up two harvested plants.

Africare field agent Ibrahima holds up two indigenous rice plants harvested in the SRI plot. Notice the difference in tillering and plant vigour between traditional plots and SRI plots.

3.7.5. Shortening of crop cycle with SRI

SRI plants showed faster crop development and growth. We estimate a one to two week advance of the SRI crop to the control crop. For instance, in the village of Morikoira, using Wassa as variety, maturity of SRI rice was reached at 116 days after nursery establishment, whereas for the control plot it was at 133 days (see also Table 8 for crop cycles of all varieties). This is a 17 days difference. We were able to observe this phenomenon in all 12 villages, which has some important implications:

Farmers prefer medium duration varieties because the yields are higher. In villages where water is available early in the season, BG90-2 is the most cultivated variety. BG90-2 was planted in the first four SRI villages of Hara Hara, Horogoungou, Douegoussou, and Katoua. Villages where water arrives later in the cropping season are obliged to use short-cycle varieties in order to complete the cycle before the cold season starts, and the rice will no longer grow well.

Africare technicians Hamidou and Haruna show an uprooted SRI plant (left) and control plot plant (right). Panicles emerged in SRI plant, but not yet in the control plant. Notice profuse root development of the SRI plant. Bagadagji village, RPKN2 rice variety

SRI plots (right) compared to the control plots (left), in the village of Kessou-Korey, rice variety Adny-11. Control and SRI seeds were germinated the same day, nevertheless SRI plants show remarkable advance in their crop cycle.

With the shorter crop cycle under SRI of up to two weeks, intermediate and late season locations may be able to switch to longer-cycle varieties and thus increase production. We were able to observe such a situation in the village of Kessou-Koreye, which is in an intermediate position as to when it can start the rice season. One of the five SRI farmers used BG90-2, producing a SRI yield of 10.26 t/ha. The other four SRI farmers used the slightly shorter cycle variety Adny-11 achieving only 6.49 t/ha. If adopting SRI, farmers in this village may be able to switch to BG90-2, which under conventional practice is likely to be a risky undertaking.

The late-season locations face a number of threats as experienced in Adina, Niambourgou and Donghoi villages. All three suffered from a cold spell at the end of the cropping season. At that point, SRI plants were already in the grain-filling stage, whereas in the control plots, panicles had not yet emerged. In Niambourgou and Donghoi, flocks of birds, which migrate into the region towards the end of the season, caused great damage to the rice crop.

- Again, with a shorter cropping cycle through the practice of SRI, these hazards can be better avoided.

3.7.6. Efficiency of chemical fertilizers

The efficiency of chemical fertilizers on yield improvement can be observed by comparing control and farmer practice plots. The control used 53% more chemical inputs compared to the farmer practice plots (Table 3), but the yield increase amounted to only 13% (from 4.86 t/ha to 5.49 t/ha) (Table 6).

- Applying chemical fertilizer did not translate into a proportional increase in yields, suggesting limits for increasing production through the use of higher chemical inputs.

3.7.7. Equal fertilization of SRI and control plots.

Farmers were free to decide on how much fertilizer and manure they would use, which varied from farmer to farmer and for the control and SRI plots. In order to control for the effect of fertilization, we asked farmers if one or two volunteers per village would use identical amounts of fertilization inputs on the SRI and control plots. Ten farmers agreed to use the same amount of manure and fertilizer on their evaluation plots, and three farmers tested the use of manure alone without applying fertilizer. Unfortunately, one 'manure-alone' test plot had to be disqualified due to bird damage. The yields and inputs used are reported in Table 9.

Table 9: Yields and fertilization inputs for 12 farmers who applied same fertilization to SRI and control plots: a) 10 farmers applying manure, urea and DAP fertilizer, and b) two farmers applying manure only.

a) Manure and fertilizer

	Yields		Inputs		
Farmer	SRI t/ha	Control t/ha	Manure t/ha	Urea kg/ha	DAP kg/ha
1	12.08	7.08	8.7	173	0
2	11.84	10.21	8.5	235	118
3	11.34	8.44	9.6	166	0
4	10.88	9.56	8.3	148	0
5	10.34	7.95	6.4	153	0
6	9.39	5.15	8.0	230	0
7	9.35	7.00	8.9	153	0
8	9.35	6.13	6.4	153	0
9	8.54	5.41	11.5	140	92
10	7.47	3.47	16.5	120	120
Average	**10.06**	**7.04**	**9.3**	**167**	**33**

b) Manure only

1	8.86	4.11	19.0	0	0
2	5.76	3.77	15.5	0	0
Average	**7.31**	**3.94**	**17.3**	**0**	**0**

The results are clear: with same use of fertilization, yield increases of SRI compared to control were more than 50% for the ten farmers using both manure and chemical fertilizers, and 86% for the two farmers using only manure.

- These results indicate again that within the SRI system there are synergies at work that cannot be attributed to a single factor. Or in other words: the expression of production increase in SRI compared to conventional practices is not dependent on fertilization alone, although it certainly is supported by it. This stands in contrast with the paradigm of conventional agriculture, where fertilization is a main pillar for increasing production.

SRI field (dark green field in the middle of the picture) and control plot (front of picture) of Hamadoun Baba, village of Donghoi: he applied same amount of manure to both plots, and no fertilizer. He used the cono-weeder three times on the SRI plot. The effect was immediately apparent: the SRI plants are much greener and developed much more vigorously than those in the control plot. SRI yields were more than double (see Farmer 1 in Table 9b).

3.8. Considerations on labor

Data on labor required for SRI compared to the control remain preliminary. Data on labor and costs were collected during the cropping season by monitoring the time required to carry out the various tasks, and by doing a small survey in each of the 12 villages. We expect that SRI labor requirements will change in the future as farmers get used to SRI practices. It is important to continue collecting data on labor and production costs for the next season. The data from this first season should therefore not be considered as conclusive. Labor data for SRI and for conventional cultivation are reported in Table 10.

We observed changes in how labor was used for most of the field and crop management tasks under SRI compared to the conventional farming practices. We assume that harvest time will be the same, and the increased time for threshing is proportional to yield increase (+66% for SRI compared to control or the here reported conventional data).

<u>Plot preparation:</u> Before planting, SRI plots require some preparation, consisting of a superficial tillage and leveling. Traditionally, farmers do not till the soils before planting. In recent years, plowing by tractor, for a fee, has become available, and some farmers, have this done. Other farmers till their fields by hand, as explained in section 3.1. These three scenarios, with and without land leveling, create different labor costs, which are shown in Table 10.

Table 10: Labor needed for the various rice cropping activities (person day/ha) for SRI and the conventional system, taking into account different soil preparation options.

	SRI Tractor Person day/ha*	**SRI** Manual tillage Person day/ha	**Conventional** Tractor Person day/ha	**Conventional** No tillage Person day/ha
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		
Harvest	31	31	31	31
Threshing	56	56	34	34
Total	**265**	**246**	**183**	**156**

* 1 person day = 8 hours of work, is paid 1000 CFA

Although tractor plowing may seem to be an attractive alternative to manual plowing, on these hard and dry soils, the resulting tillage work was very irregular, because the tractor can only break the soil into large chunks and does a poor job of leveling the plot. It took the SRI farmers considerable time and manual labor to break up the big soil chunks created and to level their plots. By contrast, manual tilling created only small soil chunks, better allowed the farmer to level the field during tillage, and required overall less time. In the tilled control plots, even if tractor plowing was done poorly, farmers did not spend much time leveling their fields. In non-tilled plots, labor required for preparation was much reduced, but increased for planting, as farmers needed to dig planting holes in the hard soils.

Done early in the season, on dry and hard soils, the uneven plowing creates deep furrows and untouched ridges

After uneven plowing by tractor, villagers are breaking up the big chunks of soil and leveling the field in Asseydou Alhassane's SRI plot, Hara-Hara village.

Ibrahim Hamidou's plot has a good soil texture. After having pre-irrigated and hand-plowed it, the SRI plot is already fairly well levelled. (Hara-Hara village).

Land levelling is not practiced in the area. Using a hardwood beam, the soil was sufficiently levelled after a few passes. Techniques of levelling need to be improved, especially if SRI is widely adopted.

Farmer's plot, which was plowed by tractor. Without additional leveling of the soil surface, soil and irrigation conditions will be inconsistent for the rice crop.

Nurseries: SRI nurseries require less labor time than conventional nurseries for several reasons: i) SRI nurseries have a much smaller surface area, ii) they require attention for only ten days, compared to 30 days for conventional nurseries, and iii) SRI seedlings are harvested quickly and easily with a hoe by cutting through the light textured soil below the roots. By contrast, in conventional nurseries, people (nearly always women) must sit for hours at a time in flooded plots to pull seedlings one by one out of the ground, a very unpleasant and unhealthy task; and iv) transportation of the seedlings is also more labor-intensive for conventional nurseries, as seedlings are heavier, and more of them are needed per rice field.

Traditional nurseries are flooded before plant harvest. People sit in the water for hours at a time to pull out seedlings plant by plant from the ground, a very unpleasant and unhealthy task. The roots are washed in the water and all soil is removed.

SRI seedlings are harvested with a hoe, cutting easily through the light textured soil below the roots.

Transplanting: Transplanting SRI plots took about three times longer than in 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 other people from the village would show up, perhaps out of curiosity or wanting to help, and take part in the planting. Often these events were difficult to keep well organized, and people's labor was not used very efficiently. It can be foreseen that farmers will reduce planting time considerably once they are used to handling the small seedlings, and once they gain expertise in the techniques for planting in line.

Weeding: As discussed under the weeding section, SRI weeding took about half the time required for conventional weeding.

Evaluations of SRI in other countries have shown that initially, SRI is more labor-intensive while the new methods are being learned. Once the farmers have gained skill and confidence in the methods, however, SRI does not require more labor than before (labor neutral), and over time can even become labor saving. (Anthofer, 2004; Uphoff, 2007). SRI labor requirements should be further monitored, as farmers get used to the different practices. SRI farmers tell us they will continue practicing SRI and increase the area under SRI, even though they perceive at the moment it takes a bit more time. They also mentioned that they do not mind spending more time on SRI because of the significant yield increases.

3.9. Revenue calculations

In Table 11, input costs, production value, and the net revenue are shown for SRI, control, and farmer practice plots, based on the data presented in this report and on information from farmers in the 12 villages.

Net revenue for SRI farmers this season was more than 1 million CFA/ha, compared to 490,000 CFA/ha for the control plots and 426,000 CFA/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 revenues were 2.1 and 2.4 times higher compared to the control and farmer practice plots, 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 this was 46% and 47%. Measuring the cost to produce one kilo of paddy rice, SRI production costs were reduced by one-third. The calculated costs of production were 76 CFA/kg in the control plots and 77 CFA/kg for the farmer practice plots. For SRI, the costs were 52 CFA/kilo.

These figures help us to understand why farmers in the Timbuktu region who participated this year's SRI evaluation are so excited and enthusiastic about it, and plan to expand the area under SRI cultivation next year.

Table 11: Rice production costs, production value and net revenue for SRI, control and farmer practice plots (CFA/ha)

Inputs	**SRI** Quantities	**Control** Quantities	**Farmer practice** Quantities	**SRI** CFA/ha	% of total cost	**Control** CFA/ha	% of total cost	**Farmer practice** CFA/ha	% tot cost
Irrigation (gasoil 200 liter * 550 CFA)	90%	100%	100%	99,000	21	110,000	27	110,000	29
Amortization of moto pump (yearly)	90%	100%	100%	40,500	8	45,000	11	45,000	12
Seeds (380 CFA/kg)	6 kg	50 kg	50 kg	2,280	0.5	19,000	5	19,000	5
Urea (350 CFA/kg)	120 kg	145 kg	97 kg	42,000	9	50,750	12	33,950	9
DAP (350 CFA/kg)	8 kg	34 kg	20 kg	2,800	0.5	11,900	3	7,000	2
Manure (300 CFA/100kg)	13 t	3 t	0	39,000	8	9,000	2	0	0
Labor* (person day *1000 CFA)	251	169	161	251,000	53	169,000	41	161,000	43
Total input costs				476,580	100	414,650	100	375950	100
Production (paddy) (165 CFA/kg)	9.1 t	5.49 t	4.86 t	1,501,500		905,850		801,900	
Net Revenue (CFA/ha)				**1,024,920**		**491,200**		**425,950**	
Production cost for 1 kg paddy (CFA)				52		76		77	
Input costs as % of total production value				32		46		47	

* Labor was calcuated with Table 12: For SRI: 40% tractor, 60% hand; Control: 33% tractor, 15% hand, 52% no till, Farmer practice: 20% tractor, 80% no ti

4. Conclusions and Recommendations

When we discussed SRI with farmers at the end of the growing season, they listed many advantages of SRI: reduced seed use, reduced water use, less weeding time, better and faster plant development, and most important, increased yields. Overall, farmers did not find any real disadvantages with SRI, although there were constraints, mostly to do with the increased labor for land preparation, increased labor for transplanting, and as SRI becomes more popular, the likely lack of sufficient animal manure for all the fields. The challenge is now to address the constraints and to make SRI accessible for interested farmers in the region.

- **Soil preparation:** SRI land preparation, which includes applying organic matter, tilling, and field levelling, requires more time at the beginning of the cropping season. At present, farmers are not accustomed to commit much time to land preparation, although this is changing since plowing has been introduced in the past few years. It is recommended that all soil preparation work be done before the nurseries are installed in order to avoid rushed soil preparation. As tractor plowing has not proved efficient for this work, it would be helpful to test some small machinery for tilling and levelling. Such machinery is available in the Office du Niger Zone (a large rice-growing area further south in Mali), but not yet introduced to the Timbuktu region. Use of appropriate small equipment should reduce the amount of time for soil preparation and help farmers to expand the land area under SRI.

- **Nursery and planting:** As SRI nursery areas are small, farmers could share larger nurseries at the PIV, and help each other to water the seedlings. A staggered seeding schedule would allow farmers to easily access 8 to 12-day-old seedlings, while transplanting their fields over several days. Transplanting techniques can be optimized, as farmers traditionally are used to planting in line. This year we used a knotted string to mark the SRI plots for transplanting, but based on existing skills and local methodology, improved methods of transplanting in line can be developed that are more efficient.

- **Fertilization:** Availability of sufficient animal manure may become a constraint as SRI is widely adopted, and it will be necessary to develop composting in order to obtain sufficient organic matter to add to the soil. It is recommended to work on on-site composting with compost pits, using rice straw, animal manure, and other organic matter (plant biomass of all sorts) as components. A practical calendar for making compost should be developed to coincide with labor availability and take advantage of seasonal availability of various organic materials. Within SRI villages, cattle kraaling strategies should be improved to produce higher quantities and better quality of manure, an important compost ingredient. Application techniques of chemical fertilizers should be improved, especially for urea. Where it is used, incorporating urea into the soil during cono-weeding will preserve the nutrients better and over a longer time period than the current practice of broadcasting urea into the irrigation water, which is linked to significant nutrient losses.

- **Irrigation:** SRI requires a different irrigation schedule than conventional practice, which is difficult to implement within the predetermined irrigation schedules of a PIV. It is therefore recommended to group SRI plots together, to designate an entire section within a PIV for SRI, or to eventually practice SRI on an entire PIV. In order to better understand the water savings potential for the Timbuktu region, a test could be run next year, perhaps using a washbore well irrigation system that irrigates 1 to 2 hectares. Thus, one could measure the exact amount of water and its associated pumping costs.

- **Rice varieties:** Given the impressive tiller development and associated yields under SRI of indigenous rice varieties (*O. glaberrima*) that are usually not used under irrigation, it is recommended to test locally-available indigenous varieties under SRI. Other improved varieties, such the new NERICA varieties, should be tested as well.

- **SRI and women**: In Findoukaina village there were two women among the SRI farmers. This has never been seen before in the region. As a rule, women do not cultivate rice, and are not seen in the fields except for the tedious work of weeding and threshing. But this year, two women decided to plant rice for themselves, and did all the work on their own. During the farmers' inter-village exchange meeting, these two women announced that next year, all 20 women from their women's group will be doing SRI. It is recommended to follow up and strengthen this woman's group within its leadership role of cultivating rice, and encourage the dynamics that would allow other women's groups to do SRI.

In conclusion, experience across the 12 villages is quite varied, as SRI plots have been established on a number of different soil types, different rice varieties were used, different fertilization strategies applied, and farmers practiced different weeding intervals. Many lessons have been learned from this evaluation, but the most important is that the yield and economic differences of SRI compared to the control are significant. Most farmers say they are ready to adopt SRI at an increased scale in the future, and would like to see SRI adopted by more villagers. The challenge remains to assist all interested and willing farmers to carefully apply the SRI techniques, in order to take full advantage of the synergies and the production potential of SRI.

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6. Portraits of 60 SRI farmers, Goundam and Dire, Timbuktu, Mali, 2008/2009

Legend to portraits: each line regroups the five SRI farmers in one of the 12 villages: Village and farmer names from top to bottom and from left to right:

Village of Hara Hara: Daouda Aboubacrine, Asseydou Alassane, Mahamane Houssa, Ibrahim Hamidou, Makiou Asseydou

Village of Horogoungou: Youssouf Aboubacrine, Alkalifa Ag Insaye, Alassane Abassadji, Agaly Alhassane, Almoulou Abakari

Village of Douegoussou: Kaga Oumar, Mahamoudou Imam, Hamadoun Mahamane, Mahamoudou Oumar, Mahamane Abdoulaye

Village of Bourem: Fihroun Elhadji, Aroufaya Sideye, Ziba Assadou, Sidi Mido, Mahamadoun Sideye

Village of Kessou Koreye: Sideye Sidi, Alassane Zeinou, Assadou Adama, Issa Seckou, Mahamane Mahamadou

Village of Katoua: Ali Coulibaly, Djadje Hama, Oumar Amir, Amadou Oumar, Mahamane Ousmane

Village of Bagadadji: Haha Ag Intalla, Aguissa Ag Ibrahim, Mossa Ag Alhousseini, Oyahit Nelewat, Hama Ag Nibagar

Village of Morikoira: Bouba Boureima, Hamadoun Djadje Toure, Djadje Baber, Hamadoun Djadje Saloum, Mahamane Ahamadou

Village of Findoukaina: Hama Boury, Hamadoun Abdoulaye, Maya Abdoulaye, Maya Hama, Youssouf Abdoulaye

Village of Adina Koira: Hamad Agissa Ag Mohamed, Abdurahamane Ag Boubou, Mogasse Boubacar, Ahmed Ag Anasbagor, Mohamed Ag Ibrahim

Village of Niambourgou: Ousmane Abdramane, Oumar Aleye, Backa Abdou, Kaga Bouyaye, Hama Bouyay

Village of Donghoi: Mahamane Seckou, Gouro Almadane, Hama Boury, Hamadoun Baba, Hameye Kelly