Current Research and Evaluation Efforts of the System of Rice Intensification in the Senegal River Valley

Above: A farmer showing his SRI crop grown using Sahel 202 in Guédé, Department of Podor.

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Background

The System of Rice Intensification (SRI) is a collection of cropping strategies and production principles reported to boost yields while reducing external agricultural inputs. Developed in the highlands of Madagascar, the components of SRI are hypothesized to have synergistic effects that lead to an increase in yield and resource use efficiency by capitalizing on ecological processes. Promotion by NGOs has resulted in the expanding popularity of the system in over 30 countries, some of which have made SRI public policy.
The components of SRI are as follows:

(1) The careful transplanting of young rice seedlings, preferably less than 15 days old;
(2) Wide spacing of the rice crop, generally 25 x 25 cm or more;
(3) The transplanting of a single seedling per pocket;
(4) The use of organic material to improve soil fertility, for example rice straw, compost or manure, although mineral fertilizers are often used where such material is not available. Mixtures of organic and inorganic fertilizers are also commonly employed;
(5) Alternate wet and dry irrigation (also termed intermittent irrigation) and the maintenance of semi-aerobic soil conditions during the crop's vegetative stage followed by shallow flooding (less than 5 cm of water) after panicle initiation;
(6) Manual weed control, preferably with a mechanical push weeder, although herbicides may be used in tandem with manual weeding.

Such conditions are thought to release rice plants from excessive intra-specific (rice-rice) competition while fostering an aerobic soil environment, thereby increasing root growth and health, nutrient acquisition, tillering, grain filling and yield. SRI gained notoriety when the system's proponents reported extremely high yields ranging from 15-24 tons/ha on infertile soils managed by resource-poor farmers in Madagascar. These numbers are most likely the consequence of measurement errors, as they exceed all scientific evidence of 12-14 tons/ha as the current physiological yield limit for modern rice varieties grown under of optimal management, isolation and climatic conditions.

SRI, however, is still in its infancy in West Africa, and members of the international rice research establishment remain critical or ambivalent about the utility of the system as an agricultural development strategy. Furthermore, in the Senegal River Valley (SRV), rice farmers' production practices are already quite intensive, and very high tropical yields can be attained given conventional management and the rational use of agochemicals. Production approaches such as the *Integrated Crop Management* (ICM) system developed by the The Africa Rice Center (WARDA/ADRAO), the Société Nationale d'Aménagement et d'Exploitation des Terres du Delta et des Valées du Fleuve Sénégal et de la Falémé (SAED) and the Institut sénégalais de recherches agricoles (SRA) have already been validated in the SRV. When ICM is properly implemented, significant boosts in yield and profitability have been observed.

In contrast, the SRI approach seeks to attain the same yields and profit margins demonstrated with ICM practices, although with a reduction in the use of agrochemicals, seeds, water and other resources. In this sense, SRI could improve upon already well-optimized ICM practices. Nonetheless, the system is also likely only to be applicable in areas of the SRV where farmers are already familiar with transplanting practices, which comprise about 10% of the cultivated rice surface of the valley (around 4,000 ha). These areas are concentrated in the Departments of Podor and Matam, rather than the Delta region where broadcast seeding is common. Yet given the interest of the Senegalese State in improving and intensifying rice production per unit of surface area, transplanting practices present a number of important agronomic advantages. As a consequence, further experimentation and evaluation of systems like SRI remains justified.

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Above left to right: A meeting of the "Programme Gestion Intégrée de la Production et des Déprédateurs" (Programme GIPD, a FAO supported Farmer Field School) to discuss crop spacing in SRI with farmers (Guédé, Podor), SRI Trials by the Programme GIPD at N'Diaye (ADRAO Research Station), meeting with farmers from the Périmètre Privée Oumar Youness (Podor) to discuss crop development in on-farm experimental trials of SRI.

Proponents of SRI generally argue the agronomic and economic justification for each component as follows:

(1) Careful, early transplanting reduces transplanting shock and optimizes tiller development;
(2) Wider spacing encourages enhanced root development, interception of solar radiation and tiller production while reducing transplanting time.
(3) Transplanting one hill per pocket reduces seed requirements considerably. Intra-specific (rice-rice) competition is also reduced thereby allowing each rice plant to express fully its production potential.
(4) Nutrients in organic amendments are quickly made available to the rice crop when soils are intermittently flooded and dried. Organic materials help to build the soil's inherent fertility level over time thereby facilitating high levels of crop productivity even when mineral fertilizers are lacking. This strategy is thought of as beneficial to resource-poor farmers. Organic materials also improve the functioning of the soil agroecosystem by increasing soil carbon content, water retention potential and by fostering a diversity of soil micro and macro fauna, many of which may be important to optimizing crop nutrient supplies.
(5) Aerobic soil conditions are also thought to enhance root and tiller development while saving valuable water and diesel (in the case of pump irrigation systems) resources.
(6) Manual weed control reduces farmers' exposure to agrochemicals that are potentially harmful to their health. This point is very important in Africa where farmers rarely have access to the proper protective equipment necessary to safely apply such chemicals. Farmers' awareness of proper herbicide dose mixtures and application procedures are often similarly poor, which can reduce the efficiency while increasing the danger of these products once applied. This underscores the need to develop non-chemical weed management alternatives. Moreover, in SRI, manual weed control is reported to incorporate weeds into the soil surface thus cycling nutrients *in situ* while aerating the soil to facilitate enhanced root growth.

This system contrasts with conventional rice farming practices reliant on flood irrigation, dense plant populations, and the liberal use of fertilizers and pesticides. Nonetheless, where farmers cannot enact all of these principles, they are encouraged to adapt and alter parts of the system to fit site-specific agronomic, economic and cultural needs. Projects like the FAO's Integrated Pest and Production Management Farmer Field Schools or researcher supported on-farm trials of provide a useful forum in which farmers can learn from and experiment with combinations of these principals and decide which, if any, might be of use under real on-farm conditions. SRI should consequently not be thought of as a pre-packaged technology; rather it represents an integrated rice production approach that encourages farmers to experiment with and optimize their management of soil,

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nutrient, water and biological relationships while attempting to maximize the efficient use of scarce natural resources. ICM approach has similar objectives, and the integration of SRI with ICM practices may consequently be very beneficial.

Above left: A "Cono" rotary hoe push-weeder developed at the WARDA Sahel Station for use in SRI fields. Right: The weeder in use in an SRI field in the cuvette of Nianga, Podor.

Debate on the System of Rice Intensification

The System of Rice Intensification has gained equal critique as it has popularity from rice scientists. For example, the reports of "super-high" rice yields have been widely condemned as faulty by researchers at a number of international institutions. Other critics highlight the risks and disadvantages that should be considered along side the potential benefits of SRI's principles:

(1) Where water is difficult to control or where drainage is impossible, transplanting small, young seedlings increases the risk of prolonged submergence and mortality. Some farmers may also report that transplanting small seedlings in lines is tedious work, or that it is difficult to find labor for transplanting in the relatively scarcely populated Senegal River Valley.

(2) While wide spacing may encourage root development, there is debate regarding whether such root biomass per surface area is superior to that obtained in densely planted crop communities. Further, not all rice varieties respond equally to SRI practices, and some spacing may be too wide to assure optimal leaf canopy closure. Crop density recommendations should thus be flexible and implemented according to variety, soil, management and climatic characteristics.

(3) While tiller development resulting from the use of one plant per pocket can be impressive, whether this results in significantly more fertile tiller production per surface area and enhanced grain filling than denser configurations remains hotly debated.

(4) While the ecological benefits of using organic matter in crop production are widely acknowledged, its short-term effect on yield in comparison to the use of mineral fertilizers remains controversial. The use of organic matter can also be labor intensive, especially when farmers need to transport and apply materials by hand. Finally, it is questionable if biomass is available in sufficient enough quantities in the Sahel to be used on lower-value crops like rice.

(5) Intermittent irrigation techniques come in tandem with a number of social and agronomic trade-offs. While such practices can improve water use efficiency, in order for them to be practiced under real-farm conditions, all farmers within an irrigation perimeter will have to be in consensus regarding the implementation of these methods. Otherwise, spill-over effects resulting from deep flooding in one field into another field will be common. Pumping schedules may also have to be altered and adequate drainage facilities installed. Farmers may also have difficulty leveling larger-sized fields where adequate farm machinery, tools or labor are lacking. Thus, like other water saving technologies (for example aerobic rice

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and saturated soil culture) changes in perimeter engineering and improved collective action/social relations between farmers will be necessary to fully realize the advantages of this technology. Because farmers in the Senegal River Valley pay blanket rates for water by the season, rather than by volume used, changing these conditions will be prerequisite to achieving economic advantages from water conservation. This arrangement could change, however, as diesel and electricity prices for pumps and pumping stations are increasing in tandem with soaring oil prices. These constraints are therefore not inherent to SRI, but instead indicative of wider problems in rice irrigation management. Nonetheless, they should be considered in planning any extension efforts regarding water saving systems.

(6) Although intermittent irrigation can to some degree improve nutrient availability, notably for phosphorous or nitrogen mineralized from organic matter, subsequent flooding periods could also result in the loss of nitrogen through conversion to atmospheric gasses that exit the rice agroecosystem. Intermittent irrigation is also never advisable in salt-effected soils, as it can exacerbate salinity toxicity. SRI, aerobic rice and other alternate wetting and drying production systems are consequently ill advised in parts of the Senegal River Delta where salty marine deposits are present in the shallow sub-soil horizons.

(7) Reduced irrigation can also increase weed abundance, thereby necessitating additional weeding. And while manual weed control certainly alleviates farmers from the risk of exposure to toxic agrochemicals, it also increases labor requirements. Although we are currently testing rotary weeder prototypes, such technologies are not yet widely available in Senegal. Because farmers in the Senegal River Valley face significant weed and labor constraints, it is unlikely that such technologies can completely replace herbicide use. Rather, careful and judicial use of least-toxic herbicides and manual weeding technologies could serve to optimize crop production while maintaining environmental health.

(8) Lastly, despite mounting evidence that SRI can improve upon farmers' otherwise sub-optimal rice production practices, the SRI approach remains poorly understood from the perspective of rice research and development. Further research efforts are consequently needed to adequately evaluate SRI, especially under on-farm conditions where producers may not be able to include all of the system's elements and where management may be sub-optimal. More detailed studies on research stations are also required to better understand the functioning of the SRI agroecosystem and the potential agronomic trade-offs noted above.

While the scientific establishment remains ambivalent about SRI, the system is nonetheless rapidly gaining popularity. Still, little peer-reviewed research has not yet been published on SRI in the Sahelian context, nor have studies critical of the system been made available in the Francophone literature. This has provided us with an unparalleled opportunity to evaluate both the advantages as well as disadvantages of SRI in Senegal.

Current SRI Activities in West Africa and Senegal

Although detailed research examining the agro-ecological and socio-economic aspects of the System of Rice Intensification (SRI) was initiated in Senegal in the Wet Season of 2007, field trials conducted by the FAO *Champ École Producteur* "Programme Gestion Intégrée de la Production et des Déprédateurs" (Programme GIPD) have been ongoing in Senegal, Mali, Benin, Burkina Faso since 2002. The accompanying map displays the 22 villages in 3 agricultural departments in Senegal where the Programme GIPD has already introduced SRI. The research discussed below is a collaborative effort of the Department of Environmental Studies at the University of California, Santa Cruz, the Programme GIPD, the Société Nationale d'Aménagement et d'Exploitation des Terres du Delta et des Valées du Fleuve Sénégal et de la Falémé (SAED) and the Africa Rice Center (ADRAO/WARDA). Much of the resulting data will form the basis for Timothy J. Krupnik's Ph.D. thesis in Environmental Studies/Agroecology.

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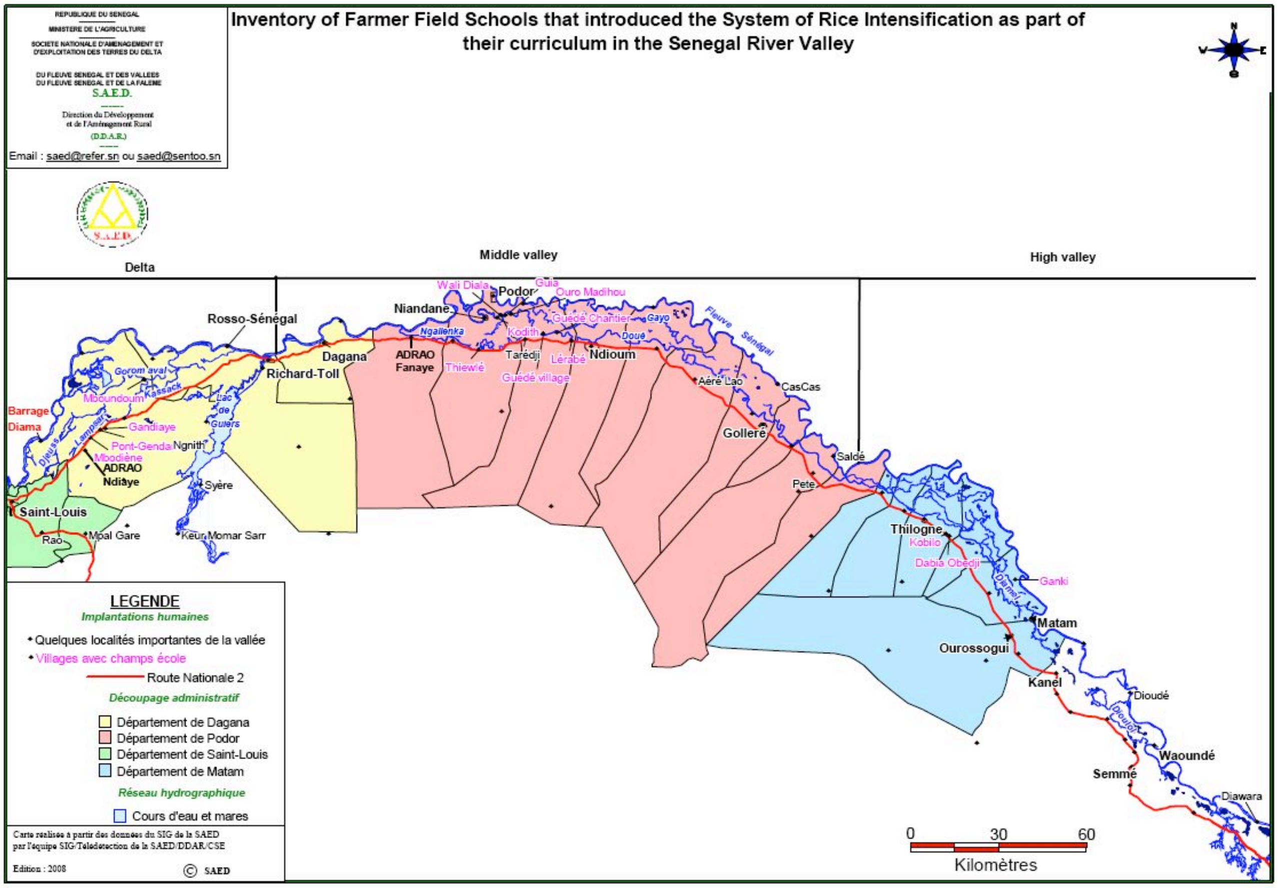

The major motivation for our work is to conduct a thorough and unbiased assessment of SRI from a variety of research angles, namely agronomic productivity, soil, water management and pest management, farmer adoption and modification of the system's components and associated socio-economic trade-offs. Part of our emphasis on SRI and ecologically based agricultural techniques in comes from a wider effort by the Programme GIPD to use low external-input agricultural techniques as a practical means to tackle increasing water quality problems (insecticide and herbicide contamination) resulting from intensive cropping in the Senegal and Niger River Basins. This offers us a unique opportunity to study adoption and innovation (adaptation) pathways of the system with farmers that have been exposed to and that have experimented with SRI.

The major accomplishment of this years' work has been the implementation of three carefully controlled experimental trials on research stations (one replicated both 36 and 149 km inland from the mouth of the Senegal River, at the WARDA Sahel Stations at N'Diaye and Fanaye, respectively) to examine SRI compared to conventional cropping systems. Another success has been the installation of side by side cropping system comparison trials in 12 farmers' fields in the Podor region. Unfortunately, we are not yet at liberty to provide data or results from our efforts at this early stage.

While the performance of SRI has been encouraging to date in our research station experiments, we have yet to harvest the first of our on-farm cropping systems trials to better judge how the system functions under producer rather than researcher management. For the moment what we can say is that although we have not found any evidence of extraordinary yield advantages under SRI, we have observed that when carefully managed, SRI can be

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quite productive and has the potential to out-yield conventional practices while improving resource use efficiency. *Nonetheless, before making any recommendations regarding SRI, the system must be evaluated under a wide range of research station and on farm conditions, and for multiple seasons. Furthermore, it should ne noted that results from research stations may contradict results from our on farm experiments, the latter of which are subjected to logistic constraints such as labor availability and management timing which are rarely an issue in the research station environment.* The research program described below will therefore continue for another 2-3 growing seasons, through 2009.

1. Experiments focused on assessing resource use efficiency:

We have implemented a nutrient (N, P) and water use efficiency trial at the ADRAO research station in N'Diaye, Senegal. Main treatments include SRI (one 13 day old plant/hill, 25cm² spacing, manual weed control and intermittent irrigation) and conventional practices (three 23 day old seedlings/hill, 20cm² spacing, chemical weed control and flooded soil conditions) and 4 sub-treatments (applications of fertilizer, fertilizer and rice straw, rice straw alone and no external nutrients), replicated four times using the variety Sahel 108. Observations focus on changes mineral nitrogen availability as a function of intermittent soil wetting and drying in SRI. N and P uptake by crop plants are being determined, as are water balances in order to assess nutrient and irrigation water use efficiency.

Left to right: A mature SRI crop, a visit to the experimental trials by Programme GIPD Farmer Field School Facilitators and directors. Since initiating these trials in 2007, we have hosted over 130 visiting farmers, researchers, extension agents and state officials from 14 countries in West Africa, North America, Asia and Europe.

This experiment will continue for another three seasons, but tentative results indicate that SRI has some yield advantage over conventional practices with improvements in water productivity. Nonetheless, these results must be confirmed for multiple seasons before any solid conclusions can be made.

2. Variety trials, weed competitiveness and weed community dynamics:

At both of ADRAO's research stations (N'Diaye in the Senegal River Delta and Fanaye in the Middle Senegal River Valley), we have implemented a variety trial focused on screening for weed competitiveness in SRI compared to conventionally flooded and managed rice production systems. Our goal is to assess changes in weed community dynamics as a function of cultivar characteristics and system management. This will help to assess the potential for reductions in herbicide use in the agricultural systems described above, while pinpointing the most problematic weed species to be managed. Cultivars include Sahel 108 (*Oryza sativa)*, Sahel 202, (*O. sativa)*, Jaya (*O. sativa)*, IR 64 (*O. sativa)*, TOG 5681 (*O. Glaberrima)*, and varieties of "New Rice For Africa" (NERICA), numbers 43 and 55. The interspecific variety WAS 161-B-9-2 is also being evaluated. Treatments include unweeded plots to

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determine weed inflicted yield losses in SRI compared to conventionally managed rice. Results from the first season of these trials are still currently under analysis.


Above: SRI experimental plots just after transplanting in the variety-weed competitiveness screening trial at N'Diaye. The same trial is shown during transplanting on the right at Fanaye.

3. Crop resilience to simulated pest damage:

At N'Diaye, we have implemented a pest control trial examining crop resilience to simulated stem borer damage in both SRI and conventional farming systems. Lepidopteran stem borers, particularly *Chilo zacconius* (Pyralidae)*,* *Maliarpha separatella* (Noctuidae) and *Sesamia calamistis* (Pyralidae) and the Dipteran *Orseolia oryzivora* (Cecidomyiidae) reduce panicle fertility or cause reductions in grain weight. While they do not present an immediate threat in the Senegal River Valley, they are a persistent problem in other parts of the Sub-Region including rice producing areas of the Cassamance, Burkina Faso, Mali and Côte d'Ivorie. They cause highly apparent plant damage symptoms (desiccated tillers and panicles/grains called "dead hearts" and "white heads"), which can amplify farmers' fears of crop losses and encourage heavy pesticide applications.

Nonetheless, it has been documented that rice plants can readily compensate for tiller loss through production of new tillers. This trial thus serves as a model system allowing careful experimentation on crop compensatory responses to simulated pest damage given differing agronomic practices like SRI, which are reported to produce a large number of tillers per plant. This experiment is managed by simulating stem borer damage by injecting tillers with a chemical called *toluene*, which slowly kills tillers without killing entire plants, thereby mimicking stem borers. This is done at 4 dates during the crop growth cycle of the variety Sahel 108 (which has recently been brought to the cassamance region as part of GOANA, the "Grand Agricultural Offensive for Food Security") and at 4 different levels of damage. The results will provide farmers with improved threshold criteria for stem-borer control in both conventionally and SRI managed crops.

4. On-Farm Evaluations:

In collaboration with the Programme GIPD and the SAED, we have implemented on-farm comparative trials of farmers' practices, SRI and recommended rice production practices based on integrated crop management principles in the Podor Region. It is in this area where farmers readily use transplanting techniques and where we expect SRI to have the highest potential.

Although SRI trials have already been conducted in a number of villages in the Senegal River Valley through the FAO, they have always been implemented in farmer field schools and managed by groups of farmers as part of learning exercises. While useful pedagogically, such trials can over-estimate the utility of a production system because labor and other inputs are rarely lacking. Management timing is also unusually precise. Production can thus be artificially optimized in comparison to a family farm where management may be constrained by social and economic factors.

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Right to left: Instillation of experimental plots in Guia-4 (Podor), testing rotary weeders and a fully mature SRI crop.

Our on-farm experiments are designed, therefore, to examine how SRI can perform under farmer, rather than field school or researcher, managed conditions. A group of four farmers in three different irrigation schemes in the Podor region are participating in the trials (for a total of 12).

Farmers and extension agents visiting our on-farm experiments in the Cuveete de Nianga, Podor. July 2008

At the end of this first season, we plan to hold focus groups where farmers will be asked to evaluate and redesign the SRI system to make it more locally compatible with the farmers' agronomic and economic conditions. After this, we will implement a 4th treatment in a separate experimental plot (modified SRI) for another two seasons, to see if any of the elements of SRI hold promise for farmers after they are locally adapted. The importance of adaptively modifying and managing SRI can not be understated; it is only after the system is thoroughly evaluated and rendered more locally appropriate by farmers that SRI and its principles could truly be implemented as an agricultural development approach in the valley. We expect farmers to pick and choose the most interesting priciples of both SRI and the recommended (ICM) system and hybridize them, ideally creating a high-yielding, yet resource efficient rice cropping system that reduces agrochemical inputs. An additional 6 farmers are also expected to begin participation in the trials next season, totaling 18. Two of the initial farmers have already adopted and modified SRI practices and are now using them on their own farms.

5. Socio-economic Evaluation:

Our on-farm research also forms the basis of a cost – benefit analysis of the systems under study by providing real-time estimates of labor inputs and potential water (and thus fuel and electricity savings) for each system Bioeconomic modeling of these systems will be conducted to analyze the potential long-term socio-economic ramifications of each cropping strategy, especially the modified SRI systems described above. This area of research has just begun but will be much more seriously developed over the next year, using tools like participatory crop calendar planning to collect data.

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A farmer field day held in Podor to visit and discuss the on-farm experimental trials on June 8, 2008. Over 65 people participated in this event sponsored collaboratively by ADRAO, the University of California, SAED and the Programme GIPD. Right to left: Discussing grain filling in experimental plots, comparing rice pockets, farmers counting tillers to compare stem productivity, participating farmer Souleymane Diaw explaining his SRI experiments to the media. Finally, we use traditional board games where farmers can participate in scoring and ranking their adoption preferences for each agricultural system, a method we have found to be far more effective than conventional surveys.

Collaborators and Project Funders

- As noted above, this research is primarily designed yet collaboratively implemented by Timothy J. Krupnik, PhD Candidate with the Department of Environmental Studies, University of California. Tim's focus is on agricultural ecology and he serves as the contact for this document (see below).
- Jonne Rodenburg, on site advisor to Tim Krupnik and Weed Scientist, Africa Rice Center (WARDA/ADRAO). Drs. Carol Shennan (Tim Krupnik's Major Professor in Agroecology), Deborah Letourneau (Insect Ecology) and Alan Richards (Development Economics) at the University of California (Santa Cruz). Dr. Bill Settle, Agricultural Biodiversity Officer at the FAO's Global IPM Facility in Rome, is another thesis committee member.
- In Senegal, we work closely with the Regional Sub Director of the FFS program, Dr. Mohamed Hama Garba and Dr. Makhfousse Sarr (based at FAO's regional headquarters in Dakar). More locally, we collaborate with a number of FFS facilitators in the Senegal River Valley, most notably Alassane "Long" N'Diaye, who also works in extension at the SAED Regional Offices in Podor.
- El Hajj BA, Koly KIETA and Doudou SAÉ are SAED/GIPD extension agents who are responsible for supervision of the on-farm trials in Podor. Doudou M'BAYE and Hamsatou SOW are ADRAO technicians who oversee the on-station research trials.
- SAED and Institut Sénégalais de recherches agricoles (ISRA) representatives have provided considerable technical and logistical assistance for our SRI research activities, especially those who maintain Programme GIPD links, notably Salif Mbaye Diack (SAED-Saint Louis), Alassane Ba (SAED-Podor), and Souleymane Diallo (ISRA).
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