FARMER IMPLEMENTATION OF ALTERNATE WET-DRY AND NON-FLOODED IRRIGATION PRACTICES IN THE SYSTEM OF RICE INTENSIFICATION (SRI)

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ABSTRACT

Competition for limited water resources and low rice yields in developing countries has renewed the interest in finding better ways to grow more rice with less water. In recent years alternate wet-dry (AWDI) and non-flooded (NF) irrigation have shown promise for reducing water consumption without significant effect on rice grain yield. In 2001, a survey of 109 farmers was conducted in four rice producing areas in Madagascar to investigate farmer implementation of AWDI and NF irrigation as part of the recently introduced System of Rice Intensification (SRI). SRI recommends aerating the soil during the vegetative development period and transplanting young seedlings (8-12 days old) at low plant hill density (25 hills per m^{-2} or fewer) and with one plant per hill. The survey showed that farmers have adapted their AWDI practices to fit the soil type and their availability of water and labor. The primary drawbacks reported by farmers with implementing AWDI and NF were the lack of a reliable water source, little water control, and water use conflicts. SRI was associated with a significantly higher grain yield of 6.4 t-ha^{-1} compared with 3.4 t-ha^{-1} from traditional practices. On SRI plots, the grain yields were 6.7 t-ha^{-1} for AWDI, 5.9 t-ha^{-1} with NF, and 5.9

t-ha^{-1} for CF. The results of the study suggest that by combining AWDI with SRI cultivation practices, farmers can increase grain yields while reducing irrigation water demand.

INTRODUCTION

Historically rice is cultivated under continuously flooded conditions in Madagascar. However, currently there are several thousand farmers throughout the island who practice alternate wet-dry (AWDI) and non-flooded (NF) irrigation during the vegetative stage of crop development. Some of these farmers practice AWDI or NF in combination with traditional cultivation methods due to periodic water shortage at the beginning of the rainy season. However, many farmers have adopted these water saving irrigation practices as part of a new strategy of rice intensification, called SRI (System of Rice Intensification), which was developed in Madagascar in the 1980's. SRI recommends farmers combine these new water management practices with transplanting younger (8-12 day-old) seedlings at a lower plant density (25 hills per m^{-2} or fewer) and with fewer plants (one plant) per hill compared with traditional cultivation methods. The primary reason farmers apply SRI is to increase grain yields. Farmers have reported 50-200 % increase in yields without the use of chemical fertilizers (Uphoff 1999; Vallois 1996). Water saving is a secondary motivation.

The SRI irrigation recommendation is that farmers avoid keeping their paddy soil saturated during the vegetative growth period, making efforts to introduce some soil aeration, and then maintain continuously flooded conditions during the reproductive and grain-filling stages to promote better plant growth and increase grain yield. During the dissemination of SRI, extension agents recommend to farmers that they practice either AWDI or NF irrigation during the period of tillering until panicle initiation, after which they should keep the plot continuously flooded until 10-14 days before grain maturity and harvesting. In experimental trials conducted concurrently with the study reported here, this set of irrigation practices was found to require up to 55% less irrigation water compared with the traditional practice of continuous submergence during all periods (McHugh 2002). The productivity of water for SRI was twice for AWDI (0.30 kg m^{-3}) compared with continuous flooding (0.13 kg m^{-3}) on the highly permeable (>5 cm/day) terraced paddies used for the study.

This paper presents the results of a survey that examined farmer adaptation, grain yields, and difficulties with AWDI and NF irrigation in Madagascar. Farmer implementation of these water saving practices is compared for the cases of SRI vs. traditional cultivation methods. For more detail on the SRI system, see Stoop et al. (2002).

METHODS

A survey was conducted during the rainy season February-June 2001 in Ambatondrazaka, Imerimandroso, Antsirabe, and Fianarantsoa with 40, 30, 28, and 11 farmers, respectively. Ambatondrazaka and Imerimandroso are located in the eastern province of Toamasina, while Antsirabe and Fianarantsoa are in the central highlands within the provinces of Antananarivo and Fianarantsoa, respectively. These sites were selected because of their importance for rice production in Madagascar and because of the significant number of farmers (but, nevertheless, a small fraction of the total population of farmers at these sites) who practice SRI.

Farmers were selected from among those practicing both traditional (conventional) and intensive (SRI) rice cultivation. In the initial selection process, only farmers using the same rice variety for both systems were included. However, in the final number, a few farmers who used different varieties for their traditional and SRI plots (n = 7) were included in the study. The selected farmers were interviewed with a formal questionnaire about cultivation details and irrigation practices. Interviews were conducted in Malagasy by agricultural extension agents and university agronomy students during a minimum of three visits with each farmer. The interviewers were trained during pre-testing of the questionnaire at each location.

Most farmers had several plots on which they practiced numerous variations of traditional and intensive rice cultivation. The survey collected agronomic and irrigation data on one selected plot cultivated with traditional and one with intensive practices for each farmer. The plots were selected based on meeting at least two of the three criteria for classification of traditional and intensive (SRI) cultivation, the criteria being formulated after conducting preliminary interviews. Traditional methods were: transplant seedlings older than 20 days; three or more seedlings per hill; and with random plant spacing. For the intensive cultivation the criteria were: transplant seedlings less than 12 days old (not including direct seeding), one plant per hill, and planted in evenly spaced rows with plants in a square grid pattern. Water management practices were thus not made a defining characteristic of either traditional or intensive cultivation, but could vary within the sample. Where farmers had more than one plot that satisfied these criteria, the interviewer selected the one considered most representative of crop growth and plot size of that farmer.

In addition to the formal interviews, grain yield was measured from 2 x 2 meter quadrats during harvest time. All reported yields are calculated for paddy rice at 14% moisture content.

Statistical Analysis. The general linear model analysis of variance and Tukey's simultaneous test were used to analyze the association between farmers' irrigation practice and grain yield. These tests were chosen because they account for multiple factor variation. The analyses included geographic location, cultivation system, irrigation type, transplant age, plant hill density, plants per hill, nutrient additions or none, number of weedings, and soil type as factors that varied between plots. Medians are reported instead of means in cases where data are highly skewed and the median better represents the average.

RESULTS

Sites and Environmental Conditions

Ambatondrazaka and Imerimandroso. Both locations are in the main rice-producing plain of Madagascar around Lake Alaotra (48°43'E, 17°83'S, 750 m above mean sea level). The soils are predominantly ferruginous clayey Aquepts, Aquents, and Fluvents formed by alluvial deposits from erosion of surrounding hillsides. Inherent soil fertility is fairly poor in all locations of the survey (Total N < 0.2%, Bray II P < 10 ppm, K < 0.14 meq/100g) and was similar for both the SRI and traditional plots selected for the study (Barison 2002). Temperatures in the Lac Alaotra area are quite constant at 21-24^{o}C during the main cropping season from December to May. Rainfall amounts and distribution are very erratic from year to year. In recent years planting has been delayed due to the late arrival of rains. Average yearly rainfall is about 1025 mm (Figure 1).

Imerimandroso is situated on the northeastern side of Lake Alaotra about 60 km north of Ambatondrazaka, the main town in the region, which is on the southern side of the lake.

The area is predominantly plains, but unlike the Ambatondrazaka area, a quarter of the study fields were situated in hilly areas.

Antsirabe. This region surrounding the large city with this name is located in the highland (*haut plateau*) of central Madagascar (the city is located 48°03'E, 19°87'S, 1600 m above mean sea level). Soils in the study plots are volcanic and lowland alluvium (Aquepts). The landscape is mostly hilly with a few broad valley plains. Temperatures remain fairly constant at 18-20^{o}C during the main rice-growing season from October until April. Yearly rainfall averages 1310 mm.

Fianarantsoa. This region is located in the southern part of the *haut plateau* of central Madagascar (47°07'E, 21°45'S, 1500 m above mean sea level). Soils in the study plots are Oxisols and Aquepts with high clay content. The landscape is predominately hilly with terraced paddies. Temperatures remain fairly constant at 20-22^{o}C during the rice-growing season from December until May. Yearly rainfall averages 1070 mm.

Farmer irrigation practices during crop growth

Results of the survey show that over 80% of the SRI farmers selected for this study practice either AWDI or NF. AWDI in this paper refers to the practice of regular cyclic flooding and drying, while NF includes practices by which the paddy is kept moist or saturated with no standing water. Table 1 shows the percentage of the surveyed farmers using alternate wet/dry (AWDI), non-flooded (NF), and continuously flooded (CF) irrigation during each crop growth period. The following sections summarize farmer irrigation practices during crop development.

Seedling Stage. In the traditional nursery, farmers puddle a small plot and grow the seedlings under a layer of water, which increases in depth in proportion with plant height until time to transplant. However, a majority of the farmers interviewed in this study no longer practice CF in their nurseries (Table 1). Farmers said that AWDI and NF help with establishment of the seedling, promote better growth, and alleviate water shortage at the beginning of the rainy season. During informal discussions, farmers in Ambatondrazaka said that they use the SRI raised-bed, non-flooded nursery to supply seedlings for all their plots when they have insufficient water or seed to maintain traditional type nurseries. (SRI requires fewer seedlings than traditional cultivation because of lower transplant density.)

Vegetative Growth. Most of the surveyed farmers practiced AWDI or NF irrigation on their SRI plots (Table 1). 17 % of the farmers also practiced AWDI or NF on their traditional plot. In some cases this was due to water shortages while in other cases farmers said that they observed better tillering and plant growth during drainage of their SRI plots, so they also adopted the practiced for their traditional plots. AWDI was used predominately in the Lac Alaotra area (Ambatondrazaka and Imerimandroso) while NF irrigation was the most common practice for SRI plots in Antsirabe and Fianarantsoa.

AWDI irrigation schedules varied greatly between farmers. The schedules ranged from more frequent irrigation with 1 day flooding followed by 1 day drying to less frequent with 10 days flooding followed by 7 days drying. The median AWDI schedules for all farmers were 4 days flooded and then 5 days drying, with means of 4.4 days flooded and 4.8 days drying. On average, the farmers who practiced SRI in Antsirabe had a lower ratio of days flooded to days dry (1:2.4) compared with the Lac Alaotra area (1.1:1). During informal discussions farmers said that they developed their AWDI irrigation schedule based on their own time availability, soil type, observed rice response, water availability, and recommendations from extension agents.

In the Lac Alaotra area, many farmers decide their AWDI irrigation schedule based on observed soil cracking. Soils with higher clay content tend to crack faster. The differences in soil types could explain in part the large variation in AWDI irrigation schedules. Some SRI experts have recommended that farmers flood their plots every night and drain them the next morning. However, this study did not find any farmers implementing this schedule. During informal discussions farmers said that the amount of labor required to irrigate and drain daily makes that schedule impracticable. Farmers developed their own irrigation schedules that they felt produced the best rice growth and fit their labor and water availability.

Non-flooded irrigation (NF) was practiced on most of the SRI plots in Antsirabe and Fianarantsoa. Farmers said that they kept their soil moist or saturated with no standing water during the vegetative growth period. Moist soil conditions were maintained by passing water through the paddy without building up a layer of water. One farmer controlled soil moisture with a peripheral ditch around the edge of the paddy. This enabled him to regulate soil moisture by supplying and draining water from the peripheral ditch. Although this practice has been recommended by SRI experts, we found only one farmer implementing it.

Reproductive and Grain Filling Stages. Continuously flooded (CF) irrigation was practiced by more than 90% of the farmers during the reproductive growth and grain filling stages on both SRI and traditional plots (Table 1). Farmers said that these are the periods when the rice plant “needs the most water” and that it is essential to keep a layer of water on the paddy to produce high grain yield. Some farmers were not able to maintain flooded conditions because of lack of water availability and/or due to long water-sharing rotations.

Grain Maturity. Irrigation practices during grain maturity (yellow ripening) were similar for both traditional and SRI plots. Farmers prefer to dry their plots during this period to homogenize grain ripening. However, it is not always possible because so much irrigation is plot-to-plot. In this type of setup all available land area is placed in production with minimal or often no space saved for irrigation and drainage channels. Due to differences in planting time and rice variety, it is not possible for the rice in all the plots of the irrigation chain to reach maturity simultaneously. In order to maintain flooded conditions for plots that have not yet reached maturity, all the plots in the irrigation chain remain wet or flooded.

Cultivation Practices

There was a large variation in cultivation practices between farmers and between locations (Table 2). A comparison of practices by location shows similarities between Ambatondrazaka and Imerimandroso in the Lac Alaotra area and between Antsirabe and Fianarantsoa in the highlands. This was expected because of similarities in altitude, environmental conditions, landform, and geographic location. As seen in Table 2, there was more variation in traditional practices between locations than for the intensive (SRI) practices. This can be expected because SRI practices were recently introduced into these areas and have not had sufficient time for farmer modification and adaptation to differences in climate, soils, and socioeconomic conditions. In this study, average farmer experience with SRI was 2.3 years compared with an average of 16 years experience with traditional rice cultivation.

On average, the traditional cultivation practices for farmers in this study consisted of transplanting 33-day-old seedlings with 3 plants per hill and 40 hills per m^{-2}, and one weeding during the season. Plots with SRI practices had younger transplants (10 days old), fewer plants per hill (one), fewer hills per unit area (24), and more weedings (2-3) during the season compared with the traditional plots. There was no significant difference in the number of farmers applying nutrients and growing off-season crops on their SRI plots compared with the traditional (Table 2).

The SRI method of cultivation recommends application of compost and manure rather than chemical fertilizer. This study found, however, that only a quarter of farmers who practice SRI were applying any nutrients to their fields; 9 farmers in Antsirabe and one in Ambatondrazaka used fertilizers while 19 used cattle manure and/or compost with their SRI crop. Most of the farmers applied the nutrients to their off-season crop and not directly for their rice crop. The common off-season crops were potatoes, beans, garden vegetables, and wheat. Farmers in this study used 13 different rice varieties, mostly improved indica and some japonica varieties. All except 7 of the farmers used the same variety for both their traditional and SRI plots.

Over half of the surveyed farmers used chemical herbicides for weed control in the Lac Alaotra area. The widespread application of chemical herbicides is a clear example of how few farmers still practice truly traditional practices. In this paper, traditional refers to conventional variations of traditional practices. Information gathered from informal interviews with older farmers suggested that 'truly' traditional practices consisted of transplanting plants 45 days or older with very high plant hill density, and up to 8 plants per hill. However, this study shows that contemporary traditional practices are conventional variations of past traditional practices.

On average, farmers allocated 29% of their total cultivated rice area (average total area per farmer was 0.8 hectares) for SRI practices. The difference in area cultivated with SRI and traditional practices could be due to the relative inexperience of farmers with the more recently adopted SRI practices. The high labor demand and higher risk associated with SRI may also limit the area that farmers can afford to cultivate (Barison 2002; Moser 2001).

Grain Production

Analysis of grain yields indicated a large difference between the traditional and SRI plots (Table 3). The average SRI yield of 6.4 $t\text{-}ha^{-1}$ was significantly higher at the 1% level (paired t-test) than the 3.4 $t\text{-}ha^{-1}$ observed on traditional plots. There was no significant difference at the 5% level in yields between the four locations comparing yield from traditional and SRI plots. The mean yield of 3.4 $t\text{-}ha^{-1}$ with traditional practices for farmers in this study is considerably higher than the national average of 2.03 $t\text{-}ha^{-1}$ for paddy rice in Madagascar (FAO 1998-2000). This indicates that the farmers selected for this study who have adopted SRI and the water-saving practices of AWDI or NF are above average in their skills, their means of production, or possibly their soil quality.

Table 4 presents the grain yields measured according to alternate wet/dry (AWDI), non-flooded (NF), and continuously flooded (CF) irrigation at each location. The plots with AWDI irrigation produced the highest average yield in both the traditional and SRI plots. The highest mean yield of 7.37 $t\text{-}ha^{-1}$ was produced with AWDI and SRI cultivation practices in Ambatondrazaka. In the case of Antsirabe, AWDI produced a lower mean yield than both continuous flooding and non-flooded irrigation, however. This difference from what was observed at the other locations could be due to the soil type or difference in AWDI irrigation frequency (discussed above).

Table 5 presents the statistical analysis of the combined grain yields for both traditional and SRI cultivation to look at the effects, ceteris paribus, of the different variables measured. MINITAB's General Linear Model analysis of variance was used for the analysis. The analysis included geographic location, cultivation system, irrigation type, transplant age, plant hill density, plants per hill, nutrient additions or none, number of weedings, and soil type as factors that varied with plots. The model produced an R-squared value of 67%. The results indicate that irrigation method had a significant relationship at the 5 % level with grain yield. Tukey's simultaneous test indicated that the least squares mean grain yield for AWDI was significantly higher at the 5% level than for the NF plots. However, CF was not significantly different from AWDI or NF.

DISCUSSION

Considerations for farmer adoption of alternate wet-dry and non-flooded irrigation

The infrastructure and labor requirements for alternate wet/dry (AWDI) and non-flooded (NF) irrigation present difficulties for wide-scale adoption by farmers in Madagascar. In this study, 37 % of the farmers said that they have difficulties with AWDI and NF irrigation (Table 5). It is important to note that this figure is probably lower than would be found for the population as a whole since only farmers who are practicing SRI and thus are more likely to have the necessary conditions for its implementation were included in the study. Some of the special requirements for wide-scale adoption of AWDI and NF include a reliable water source, good water control, good social structures for water sharing, and available labor.

Reliable Water Source. Unreliable water source was the most common problem reported by farmers in the survey (Table 6). With AWDI, plots are drained and left to dry with the assumption that water will be available when needed at the end of the drying period. However, as seen in Table 7, most of the farmers in this study rely on stream flow as their irrigation source. At the beginning of the rainy season, which is during the vegetative growth period, stream flow is not reliable due to irregular rainfall, low base flows, and high demand of water for land preparation and crop irrigation. Farmers in Antsirabe and Fianarantsoa reported long periods when there was insufficient water to meet irrigation demand. This could be expected considering that over 75% of the farmers in those locations depend on direct rainfall and small stream flow for irrigation (Table 7). Construction of water storage devices is a possible means for creating more reliable water supplies.

Water Control. Lack of water control is another factor that prevents implementation of AWDI and NF irrigation in many parts of Madagascar. Large areas around Lake Alaotra are susceptible to flooding due to seasonal increase in the water level of the lake and to erosion and siltation of drainage canals. The broad valley plains and valley bottoms of Antsirabe and Fianarantsoa are also susceptible to seasonal flooding. Infrastructure needs to be built to control flooding and to permit drainage of Madagascar's major rice-producing areas before AWDI or NF can be widely adopted.

Water Sharing. A large percentage of farmers in Antsirabe and Fianarantsoa reported conflict over water use as a difficulty with AWDI and NF irrigation (Table 6). Over 60% of the plots in Antsirabe and Fianarantsoa are hillside terraces. Traditional irrigation for these is by cascade irrigation where water flows directly from plot to plot. This often leads to conflicts of interest in water management. Good social organization and/or construction of irrigation and drainage channels that allow for independent irrigation and drainage of individual plots are necessary to successfully implement AWDI and NF irrigation in such situations.

Installation of irrigation and drainage channels in the hillside system could change the dynamics of the system because the sequential water-storage function of flooded paddies in plot-to-plot irrigation will be modified. Construction of on-farm reservoirs and coordination between farmers of the timing of flooding and drainage cycles are possible solutions to this problem. If SRI methods can augment yields by as much as 3 $t\text{-}ha^{-1}$, these investments can be justified in financial terms.

Labor Requirements. It is worth noting that farmers did not list labor shortage as a primary difficulty with AWDI or NF. However, labor availability was a significant factor affecting farmers' decisions about the frequency of drying and flooding. With traditional continuous flooding, farmers in most cases simply adjust the outlet vane height to the desired flood depth and do not have to devote much time to irrigation after the beginning of the cropping season. However, AWDI requires that the farmer adjust and readjust the vane height to drain and irrigate on a regular basis. This can require a significant amount of labor depending on the number of plots that a farmer owns and how far apart the plots are from the farmer's home. NF may require even more frequent adjustments.

Another labor consideration for AWDI and NF is the extra weeding operations needed to control weed growth when there is no continuous flooding. CF is widely used to suppress weed growth. In Table 2, SRI cultivation was associated with an average of one to two more weeding operations during the season compared with continuous flooding. The labor required for the additional weeding operations could be difficult for farmers to commit during periods of labor shortage. Farmers need to take this into consideration when implementing AWDI or NF irrigation. For the farming operations covered by this study, Barison (2002) determined that the extra labor and costs for SRI compared with traditional cultivation are more than compensated for by the higher yields.

CONCLUSIONS

A survey of 109 farmers was conducted in four locations in Madagascar to explore farmer irrigation practices for traditional and intensive systems of rice production. Information was collected during formal and informal farmer interviews. Grain yield was also measured from one traditional and one SRI plot of each farmer with also some assessment of soil differences. Results of the study revealed a wide variety of irrigation practices of farmers. With an average of 2.3 years of experience with alternate wet/dry (AWDI) and non-flooded (NF) irrigation, farmers have developed their own irrigation schedules.

Farmers base their irrigation schedule on many factors including rice plant response, soil type, and water and labor availability. Farmers reported lack of a reliable water source as the primary difficulty with practicing AWDI or NF. Inability to control water and conflicts over water use were also reported by many farmers. There was a significant association between irrigation practice and overall grain yields as AWDI produced higher grain yield than NF irrigation while continuous flooding was not significantly different from AWDI or NF irrigation.

Some of the solutions for wider-scale adoption of AWDI offered in this paper included developing more effective structures for water sharing, constructing irrigation and drainage channels, installing on-farm reservoirs, and building infrastructure for flood control. The 2-3 $t\text{-}ha^{-1}$ increase in grain yield observed in this study when AWDI is practiced in combination with SRI cultivation methods can justify these financial investments.

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Table 1. Percent of Surveyed Farmers Using Alternate Wet-Dry (AWDI), Non-Flooded (NF), and Continuously Flooded (CF) Irrigation during each Period of Crop Growth

Growth Stage	Traditional			SRI		
	NF	AWDI	CF	NF	AWDI	CF
Nursery*	27	49	24	90	8	2
Vegetative*	1	16	83	30	53	17
Reproductive[ns]	0	5	95	2	5	93
Grain Filling[ns]	0	4	96	1	6	94
Maturity[ns]	45	0	55	43	1	56

* Irrigation practices significantly different for Traditional vs. SRI (p = 0.01, contingency table chi-square test).
ns = Not significantly different at 1% level

Table 3. Mean Grain Yield for Traditional vs. Intensive Practices ($t\text{-}ha^{-1}$ paddy rice)

Location	Traditional Grain Yield	SRI Grain Yield	Difference in Yields*
Ambatondrazaka	3.4	6.7	2.4 - 4.2
Imerimandroso	3.4	6.7	2.8 – 3.8
Antsirabe	3.2	5.5	1.5 – 3.1
Fianarantsoa	3.4	6.3	1.3 – 4.6
Overall Mean	**3.4**	**6.4**	**2.6 - 3.4**

* 99 % confidence interval for difference in means; paired t-test

Table 4. Summary of Yields by Irrigation Practice and by Location ($t\ ha^{-1}$)

Location	Traditional Plots			SRI Plots		
	CF	NF	AWDI	CF	NF	AWDI
Ambatondrazaka	3.38	-	3.79	6.40	5.44	7.37
Imerimandroso	3.38	-	3.46	6.15*	-	6.74
Antsirabe	3.23	2.38*	-	5.61	5.62	5.12
Fianarantsoa	3.38	-	-	3.00*	6.69	-
Overall Mean[a]	**3.34a**	**2.38*a**	**3.52a**	**5.89ab**	**5.91a**	**6.74b**

* Only one plot
a = Yields followed by different letters are significantly different

Table 2. Farmer Cultivation Practices

Cultural Details	Ambatondrazaka		Imerimandroso		Antsirabe		Fianarantsoa		**Overall Mean**		
Cultivation System (Sample size, # of farmers)	SRI (40)	TRAD (40)	SRI (30)	TRAD (30)	SRI (28)	TRAD (28)	SRI (11)	TRAD (11)	**SRI** (109)	**TRAD** (109)	**Difference** (109)
% Who Applied Manure/Compost/Fertilizer Within Past Year	13	5	0	3	50	68	91	18	**25**	**24**	**1**
Age of Transplant (DAS)[a,b]	9-11	26-31	9-11	29-33	9-12	41-48	7-13	18-33	**10**	**33**	**20-26****
Average Plant Hill Density m^{-2}	26	44	26	42	18	35	24	30	**24**	**40**	**11-21****
Average Seedlings per Hill[c]	1	3 .3	1	3.5	1	2.8	1	2	**1**	**3**	**1.9-2.3****
Median Number of Times Weeded	2	1	2	0	4	2	2	1	**2.7**	**1.2**	**1.2-1.8****
% Who Applied Herbicide	38	48	0	93	0	0	0	0	**16**	**48**	**32***
% Cultivating Off-Season Crops within Past 3 Years	10	8	0	0	71	82	73	27	**29**	**27**	**2**

a = Days after seeding pre-germinated seeds
b = 95% confidence interval for mean
c = All farmers used 1 seedling per clump SRI practice except for one farmer in Antsirabe who used an average of 2.5 seedlings per clump
* Difference significant at p = 0.05; chi-square test with contingency table
** 99% confidence interval for difference in means; paired t-test

Table 5. General Linear Model Statistical Analysis of Grain Yield for All Plots, All Locations

Factor	**Adj SS**	**Adj MS**	**F**	**p-value**
Cultivation System (SRI vs. traditional)	47.796	47.796	31.65	<0.001
Geographic Location	20.005	6.668	4.42	0.005
Irrigation Type	**9.440**	**4.720**	**3.13**	**0.046**
Soil Type	16.345	4.086	2.71	0.032
Nutrient Additions	6.965	6.965	4.61	0.033
Transplant Age	6.302	6.302	4.17	0.043
Plants per Hill	0.220	0.220	0.15	0.703
Plant Hill Density	0.145	0.145	0.10	0.757
Number of Weedings	8.508	1.215	0.80	0.584

Table 6. Problems that Farmers Reported with Applying SRI Water Management (AWDI or NF)

Location	Do you have difficulties with SRI water management?	Listed Reasons[a]		
		Little Water Control[b]	Unreliable Water Source	Conflict in Water Use[b]
	% (yes)	%	%	%
Ambatondrazaka	43	18	65	6
Imerimandroso	7	50	50	0
Antsirabe	46	8	31	61
Fianarantsoa	73	38	62	38
Total Average	**37**	**20**	**53**	**30**

a = Reasons given by farmers who say have difficulty with SRI water management
b = Includes both irrigation and drainage

Table 7. Irrigation Source Characteristics for Farmers in the Study

Location	Type of Irrigation Source (% of farmers in study)				Farmers with Water Shortage	Duration of Period of Water Deficit[a,b]	Months of Water Deficit[a]
	Stream	Dam	Reser-voir	None[c]	%	Days	Mode
Ambatondrazaka	47	47	3	3	45	30-41	Dec, Feb-March
Imerimandroso	60	30	10	0	30	0-31	Oct-Dec
Antsirabe	85	7	4	4	25	33-128	Oct-Dec, March
Fianarantsoa	23	13	14	50	82	31-44	Oct-Nov, Jan-Feb
Total Average	**54**	**24**	**8**	**14**	**45**	**37**	

a = Period during main rice growing season when water shortage is common
b = 95 % confidence interval for median
c = Irrigation from rainfall and direct drainage from other paddies that receive irrigation from rainfall

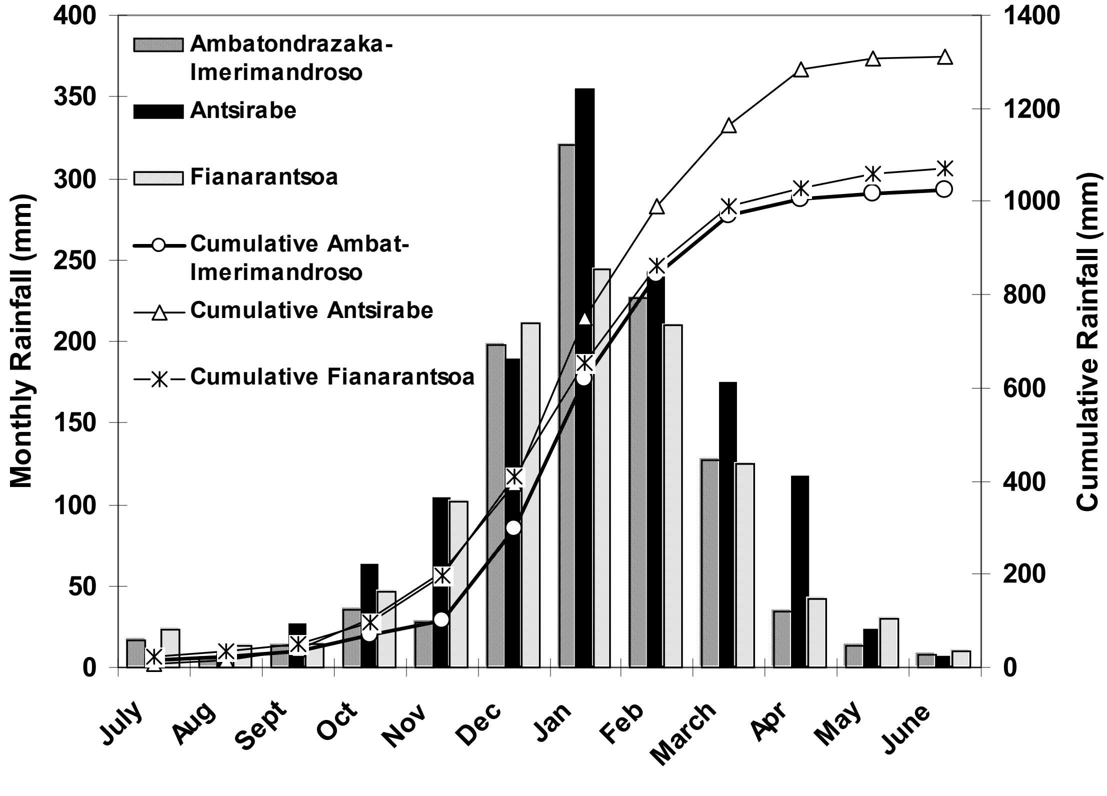

Figure 1. Average Monthly and Cumulative Rainfall, 1990-1999
(Source: Fofifa and Centre Metéorologique d'Ampasampito)