Uganda Journal of Agricultural sciences, 2004, 9:425- 431 ISSN 1026-0919

Developing technology options for rice integrated crop management in the Sahel Zone of West Africa: Case of irrigated rice production the Senegal River Valley

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Abstract

Rice (Oryza sativa) farmers in the Sahel are regularly confronted with making input use and crop management choices, which have important consequences for farm output, incomes, and the welfare of producers. Socio-economic conditions and numerous biotic and abiotic factors affect these choices that farmers make. One important goal of irrigated rice research and development at The Africa Rice Center (WARDA) is to improve the performance of the sector by developing and adapting improved technologies for increasing irrigated rice productivity in Africa.The development of options for RICM as a means of increasing irrigated rice productivity features prominently in research and development efforts at the Center's regional station in Senegal. RICM research recognizes that irrigated rice cultivation involves an array of component factors from land preparation to harvest and post-harvest management. These factors interact in a range of complex relationships that together determine crop performance. The strategy has been to develop, evaluate and adapt options for RICM, recognizing the farmer as the ultimate integrator of factors. For the options to be relevant, they must be responsive to farmers' production environments. The notion of 'options for RICM' takes the heterogeneity of the production environment into account. Elements of the RICM options include fertilizer, weed and water management practices, and the use of improved varieties and cost-effective harvest/post harvest technologies. Fertiliser management strategies focus on the application of basal phosphorus in the form of TSP, and nitrogen in the form of urea. The timing of fertilizer application is associated with the stage of crop development. Weed management strategies combine herbicide use with manual weeding. Water management options are associated with the use of other inputs, with emphasis on maintaining optimal water levels through irrigation and drainage prior to and/or after fertiliser/herbicide application and crop harvest. The management options also include optimal timing for harvesting and threshing. Results from work in the Sahel show that rice farmers can significantly increase productivity and profitability by use of technology options for RICM. A major attraction of these options is that they emphasize better management of available resources without significant increases in input levels. Farmers at key sites realized significant increases in yields and profits by integrating the technology options into their management practices. The results confirmed earlier conclusions of high farm level impact for research and development efforts that emphasize improved crop and resource management among small scale irrigated rice producers.

Key words: Fertiliser/herbicide application, *Oryza sativa*

Introduction

Rice is a dominant cereal in West Africa, with its importance felt among rural and rapidly expanding urban populations. The increasing demand and consumption of rice in the region cut across the socioeconomic spectrum: from poor rural and urban households, to middle class households in urban areas. Among the 17 member states of the Africa Rice Center (WARDA), annual rice consumption per person nearly doubled during the last 25 years leading up to 1995, from 14.7 kg in 1970 to 25.1 kg in 1995. With current high population growth rates, it is realistic to expect rice demand in the region to continue increasing in the short to medium term. Although there have been moderate increases in rice production in the region, the growth rate in rice production has not kept up with increases in demand and consumption. The average annual growth rate for rice production between 1973 and 1993 was 5.2%, compared to an annual consumption growth rate of 6%.

One undesirable effect of this is that the region continues to rely heavily on imports to meet its rice consumption requirements. The average annual growth rate in rice imports between 1973 and 1992 was 8.4%. It is estimated that rice imports in Africa now exceed US $1 billion (Director General of The Africa Rice Center: March 2004 issue of cgiarNEWS), placing tremendous pressure on economies in a region characterized by poor economic performance and persistent balance of trade deficits. But the problem is not just economics; access to adequate rice supply is a basic survival and food security issue for millions of African households. Nowhere is this more apparent than among poor rural and urban households for whom rice is the primary source of food.

During the last three to four decades, governments and aid agencies in the Sahel have made massive investments in the development of irrigation schemes for rice production. This was partly in response to the devastating droughts that hit the region in the early seventies. Irrigated rice now occupies more than twelve percent of the total rice area in West Africa. With very high yield potentials, irrigated rice systems can make significant contributions to efforts aimed at mitigating the rice deficit situation in West Africa. Mean paddy yields in regions such as the Senegal River Valley and the Niono valley in Mali are in the range of 5.5 to 6 tons per hectare. A major challenge, however, is that these yields still remain significantly lower than potential yields of 8 to 10 tons per hectare in the region. The relatively low yields of irrigated rice-based systems have been attributed to the use of inappropriate input management practices, the use of low yielding varieties, and a number of socioeconomic and biophysical factors.

Irrigated rice research and development efforts at the Africa Rice Center (WARDA) over the last decade have focused on increasing resource use efficiency and mitigating soil degradation as a means of improving productivity and enhancing the sustainability of irrigated rice-based production systems. Work during this period has concentrated largely in the region referred to as the Sahel. The Sahel region covers the arid and semi-arid regions of West Africa (including large parts of Senegal, Mauritania, Mali, Burkina Faso, Gambia and a host of other countries), and is characterized by erratic and low rainfall (below 400 mm per year). Specific activities have included the development, evaluation, adaptation and dissemination of improved irrigated rice technologies in collaboration with national research and development institutions, producer groups and other partners in the rice sector. Through these efforts, improved fertility, weed and water management strategies have been adapted for use by farmers in the region. Varietal improvement efforts have resulted in the adaptation of short and medium duration cultivars that have been widely adopted by irrigated rice farmers. Harvest and post harvest research efforts focus on alleviating labor bottlenecks during these periods and improving rice grain quality.

In this paper, we present experiences and key results from efforts to increase resource use efficiency and enhance sustainability in irrigated rice production systems through the concept of 'rice integrated crop management and the technology basket option'. A definition and some key concepts of rice integrated crop management are presented in the section that follows. We then present the various components of the options for rice integrated crop management developed and adapted with small and medium-scale farmers in the region. This is followed by a case study of work undertaken in the Senegal River Valley, where we present an overview of the approach used and highlight some key results. The paper concludes by defining a way forward for rice integrated crop management in the region.

Rice integrated crop management and the technology basket option: giving farmers choice

In the irrigated rice production sector in West Africa, medium and small-scale farmers are regularly confronted with making farm production and input use choices based on the availability of resources and numerous biotic/abiotic factors that characterize their production environments. The choices producers make have important consequences for farm output, incomes, and the general welfare of producers and consumers alike. One important task of irrigated rice researchers at The Africa Rice Center has been to develop technologies and decision-making tools that respond to the needs of these groups of producers. To meet this goal, researchers at the center's regional station in Senegal have made extensive use of the concepts of 'rice integrated crop management (ICM) and the technology basket option'. The target is to increase the productivity and profitability of irrigated rice by use of improved integrated crop management practices. The approach stresses the importance of providing management options that enable farmers make choices based on their production objectives, and existing socioeconomic and biophysical environments.

Rice integrated crop management recognizes that rice cultivation is a production system involving a range of component factors, from land preparation to harvest and post harvest management. These factors interact in an array of complex relationships that together determine crop performance. A change in the management of one factor can affect the performance of other factors, subsequently influencing crop performance. RICM seeks to develop and promote a management approach at the farm level that manages cultivation of the crop as a total production system, taking into account all factors that impact yield, profitability and quality. This is done by delivering technologies as an integrated management basket, focusing on the farmer as the ultimate integrator of the management factors. This notion of providing options from a basket of technologies recognizes farm heterogeneity in terms of production objectives, resource endowment, management capacity, etc.

Components of options for RICM in the Sahel

Components of the options for rice integrated crop management include integrated fertilizer, weed and water management, combined with the use of improved varieties and post harvest technologies. The post harvest technologies are aimed at reducing the drudgery of manual labor and improving grain quality through timely harvesting and use of efficient and cost effective threshing equipment

The improved varieties are a short duration cultivar known as Sahel 108 and a medium duration cultivar released as Sahel 202. Seeding rates are 80-100 and 40-60 kg/ha respectively for direct seeding and transplanting. Simulations with the RIDEV model showed that in order to prevent cold sterility, seeding in the wet season should be done between end of June and early August. Transplanting is advised at 20 days after seeding. Emphasis is placed on good quality planting material to ensure satisfactory germination rates and good plant stands. Certified seeds are preferred, and seed selection should be made carefully in the absence of certified seed.

Fertilizer management focuses on improving fertilizer efficiency through timely applications of optimal combinations of nitrogen and phosphorus fertilizers. Nitrogen is generally applied in the form of urea (46% N) while phosphorus is applied in the form of triple super phosphate (TSP, 20% P) or Di-ammonium phosphate (DAP). Optimal fertilizer rates are 100 kg/ha of TSP/DAP and 250-300 kg/ha of urea. Alternative application rates, depending on indigenous soil fertility and availability of resources, are provided in table 1 below. In general, TSP is applied in single dose while urea is applied in two or three splits. TSP applications may be delayed by a maximum of up-to 2 to 3 weeks after transplanting and directing seeding respectively. When urea is applied in three splits, the first dose of 40% is applied at the start of tillering, and another dose of 40% at panicle initiation. A final dose of 20% is applied at the booting stage of the crop (Haefele and Wopereis, 2000**)**. In the case of two splits, equal doses are applied at the start of tillering and at panicle initiation respectively.

Weed management consists of a mixture of 6 l/ha of Propanil and 1.5 l/ha of 2,4D applied 3 days before first urea application**,** and this is complemented with one manual weeding after first urea application. In the event of financial constraints for the purchase of herbicides, an alternative option is the use of half the recommended dose in combination with two manual weedings as required. The essential factor is to minimize competition between the rice crop and weeds during fertilizer application and at critical stages of crop growth.

Because fertilizer, weed and water management are linked, it is important to enhance effective and efficient use of irrigation water. This is especially important in a system where water is ‘purchased’. Water management, directed at maximizing the efficiency of fertilizers and herbicides, consists of applying herbicides in completely drained fields and reducing water levels in the field to 3 cm for about 4-5 days at each fertilizer application. The rice field is completely drained 15 days after flowering to promote uniform ripening of the grains, but primarily to allow for a timely harvest at 80% maturity. Threshing is undertaken within 7 days of harvest, preferably with a thresher/cleaner prototype developed for Sahelian conditions by WARDA and officially released as the ASI in Senegal. Given critical labor constraints for harvest and post harvest operations, the development and release of this cost effective and efficient thresher cleaner in Senegal, Mauritania, Mali, Burkina Faso, Ghana and Cote d’Ivoire continues to receive much attention.

These technologies together comprise the component factors for rice integrated crop management developed by scientists at the Africa Rice Center in collaboration with NARS colleagues and producer groups. The result of these efforts is a basket of technology options from which farmers can make choices to suit their production environments, specific farm needs, constraints and priorities. The strategy recognizes that producers are not homogeneous. Because farm resource categories, socioeconomic and production environments are different, farm constraints and priorities are not the same even within the same region. Farmers and farmer organizations, national research and extension personnel, and development agencies have been key partners in the development and adaptation of the options for rice integrated crop management for use by irrigated rice farmers in the Sahel region of West Africa. Through these efforts, a viable partnership has been developed for enhancing the productivity and profitability of irrigated rice in the Sahel region of West Africa through rice integrated crop management.

RICM research and development in the Sahel: The Case of the Senegal River Valley

Approach

Farm level research and development on rice integrated crop management for irrigated rice systems in the Sahel started in earnest in 1995. By then it was observed that there were significant gaps between farmers’ yields and the yield potentials of improved irrigated rice varieties released during the first half of the 1990s. Initial work focused on the identification of key contributors to these yield gaps, and the evaluation and adaptation of improved technologies that would help narrow yield gaps at the farm level. From these efforts, researchers identified poor management (especially fertilizer and weed management) as a principal contributor to low yields obtained by farmers in the Senegal River valley. With these results, attention shifted to evaluating the performance of improved crop management technologies in farmers’ fields. On-farm assessments of improved fertilizer and weed management technologies were initiated at key sites in Senegal and Mauritania (Senegal River valley), Mali (Niono valley) and Burkina Faso (Kou and Sourou Valleys). At the same time, technologies were being adapted to address important harvest and post-harvest constraints faced by irrigated rice farmers in the region. Here, WARDA initiated collaboration with IRRI, NARES and local artisans in Senegal to adapt a thresher-cleaner prototype for use in the Senegal river Valley. Results from these efforts showed significant gains from the use of improved crop management practices by irrigated rice producers in the Sahel. The ASI thresher quickly became a household name among irrigated

Table 1. Optimal fertilizer rates for the Upper Senegal River Valley based on available resources and indigenous soil fertility

Scenario	Fertilizer Dose (kg per hectare)		
	Urea	TSP or DAP	KCL
Optimum dose	250	100	0
Minimum dose (for low resource groups)	150	50	0
Medium dose (intermediate resource groups)	200-250	100	0
Maximum dose (continuous double cropping)	250	100	50

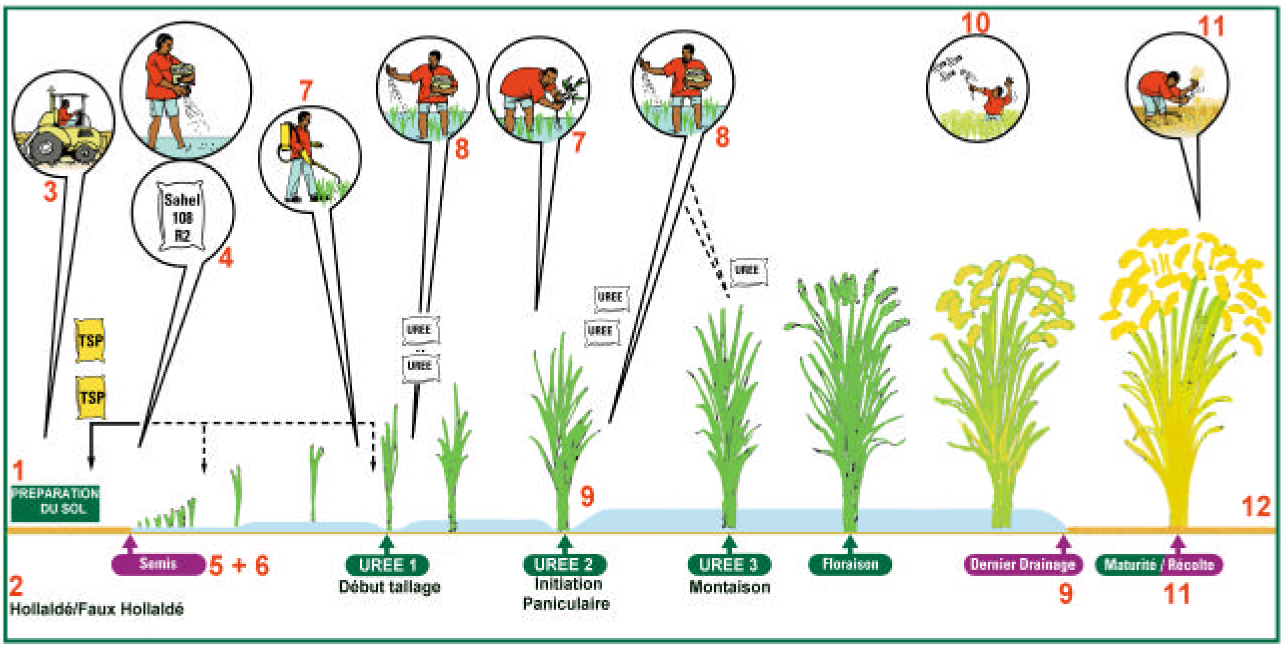

Figure 1. Flyer for rice integrated crop management in the upper Senegal River Valley developed in collaboration with NARES and farmer groups in the region

rice producers in the Senegal River valley. Initial work in these areas was the foundation for developing the technology basket options for rice integrated crop management in the Senegal River Valley and other parts of the Sahel.

In the late 1990s, on-farm research activities were undertaken with farmer organizations and research/ development partners in the Senegal River Valley (Senegal and Mauritania). Emphasizing integrated crop management principles, field trials were set up to evaluate and adapt improved irrigated rice technologies to farm conditions as a means of increasing rice productivity in the region. Initial trial results showed significant increase in productivity and profitability by the use of improved management technologies among farmers. Paddy yields were increased by 1 ton per hectare from the use of either improved fertilizer or improved weed management practices. Combining improved fertilizer and weed management resulted in a 2 ton per hectare increase in farm yields. These results, suggesting that producers could increase farm yields by up to 2 tons per hectare by better management of inputs, had important implications for efforts aimed at improving the productivity and profitability of irrigated rice.

Encouraged by these initial results, scientists at the Africa Rice Center initiated an innovative on-farm program in collaboration with small-scale farmers and NARES in the Senegal River Valley in 1999. The goal was to make available improved irrigated rice technologies with the potential to increase farm output and income. The work combined conventional and innovative approaches to better understand the intrinsic linkages between farmers' socioeconomic settings, their choice of crop and resource management practices, the productivity and profitability of irrigated rice production systems, and the quality of the natural resource base. Large plot trials were set up at key sites to evaluate the performance of improved varieties and crop management practices on farmers' fields. Farm surveys were undertaken determine differences in farm management, and explain the consequences of these differences. In addition, formal and informal socioeconomic surveys were conducted in order to further characterize the production environment, identify key production constraints and opportunities, and determine farmers' perceptions on the performance of the improved technologies. Farmer field visits were undertaken to facilitate exchanges between producers, researchers and their development partners. Collaborating producers took center stage during these visits, discussing their roles and participation in the on-farm activities.

Outputs of RICM project

Yield and productivity effects of RICM

Results from fieldwork at three key sites confirmed initial evidence of significant yield gaps on farmers' fields. Mean paddy yields from farmers' plots and RICM demonstration plots are presented in figure 2 below. The figure shows significant yield increases from the use of options for RICM at all sites. Yields from the RICM demonstration plots are 2 to 2.3 t/ha higher than farmers' yields. The superior yield performance of the trial plots was attributed to the use of better quality seed, TSP, and better management of fertilizer and herbicides among others. Also, timely harvesting and threshing of the trial plots resulted in lower levels of post harvest losses.

Farm management survey results showed that the significant gaps were largely explained by management factors. Although sample producers initially identified access to inputs as the primary problem, poor management of available resources (example, timing and mode of input application) emerged as a more important constraint. These results show that improving crop and resource management practices could go a long way in narrowing yield gaps and enhancing the overall performance of irrigated rice farmers in the region.

Profit effects of RICM

Benefit-cost analysis results (Table 2) show substantial revenue gains from the use of options for RICM at the study sites. RICM resulted in 39-69% increases in total revenue per hectare across sites. Additional production costs associated with RICM was negligible at all sites, partly because the different options for RICM focus on better farm management in order to increase efficiency and optimize available resources.

Net benefit analysis further confirmed the superiority of the options for RICM evaluated at the study sites. Net revenue gains per hectare associated with the various options for RICM ranged from 49 to 142%. This is partly explained by the substantially higher yields obtained from improved management without substantial increases in production costs.

An important consideration in economic evaluation is a comparison of additional benefits from adoption of a new technology to additional costs incurred. Results show that in addition to having superior net revenue per hectare across all sites, marginal rates of return of the improved technology are indeed attractive. The marginal rate of return is defined in terms of the ratio of additional net benefits to additional production costs. The minimum MRR is over 300%, indicating significant gains from investment on RICM. These results, indicating that returns to the additional cost of adopting improved irrigated rice production technologies are high, have important implications for the small farmers in the Sahel.

Farmers' perceptions the options for RICM

Key informant interviews were conducted with sample farmers at each site to determine their perceptions of the component factors, and to identify positive attributes of options for RICM. The results are summarized in table 3 below. Components most appealing to farmers were: fertilizer and weed management, use of improved varieties and harvesting/post harvest technologies. In general, farmers attributed the superior performance of RICM to management factors. Application of urea in three splits is perceived to have a yield increasing effect, while use of basal phosphorus is perceived to affect high tillering and yield. The perceived positive attribute of herbicide use is its labor saving effect. However, only half of the respondents plan to use herbicides for weed control, citing the high cost of herbicides as the main reason. Farmers also indicated that where labor is not a major constraint in the household, the need for chemical weed control is minimal. Respondents also consider the higher grain quality and good taste of the improved variety Sahel 202 as important, but cited problems of seed availability as a constraint to potential use. Most farmers indicated they would reduce seeding rates to appropriate levels only when certified seed is available.

Defining a way forward for rice integrated crop management in the region

Low productivity continues to be a problem in irrigated rice-based production systems West Africa. Low yields and poor grain quality resulting from the use of inappropriate technologies have resulted in rice deficit situations for the majority of rice producers and consumers alike. Weed competition, inadequate water and fertility management strategies, and labor intensive post harvest technologies are some of the constraints facing irrigated rice farmers in West Africa.

In the Sahel, improved technologies generated to facilitate the productivity and profitability of irrigated rice systems have been developed and assembled into component factors for rice integrated crop management. Results from work in the Senegal river valley and sites in Mali, Burkina Faso and Mauritania show that these component factors can potentially address major constraints of irrigated rice production in Africa, resulting in the narrowing of yield gaps and significance improvements in the performance of the system. However, there is an urgent need to scale-out this experience in order to benefit large numbers of irrigated rice producers

Table 2. Economic analyses of field trials at key sites in the Senegal River Valley, wet season 1999

	Mechra Sidi		Thiambene		Sinthiane	
	RICM	*Farmers' Plot*	*RICM*	*Farmers' Plot*	*RICM*	*Farmers' Plot*
Yield (kg/ha)	7559	5423	5629	3333	5985	3764
Total revenue (Euro/ha)	1226	880	913	541	971	610
Total variable cost (Euro/ha)	424	341	380	320	356	293
Net Revenue (Euro/ha)	802	539	533	221	615	317
Marginal net revenue from RICM (Euro/ha)	263		312		298	
Marginal variable cost from RICM	83		60		63	
Marginal rate of return (%)	317		520		473	

Table 3. Perceptions on contributors to yield/productivity gaps

RICM Component Factors	Percent Farmers with positive perception	Positive attributes identified by farmers
Urea application in 3 splits	100	Yield
Basal Application of Phosphorus	100	Tillering and yield
Drainage prior to chemical weeding and urea application	80	Increase in efficacy of herbicides and urea
Use of Sahel 108 and Sahel 202	80	Grain quality, taste,
Certified seed and optimal seeding rate	85	Less weeds, high tillering
Harvesting at 80% maturity and threshing with small scale thresher	90	Grain weight, less shattering, timeliness, low labor requirement
Use of Herbicide for weeding	60	Labor saving effect

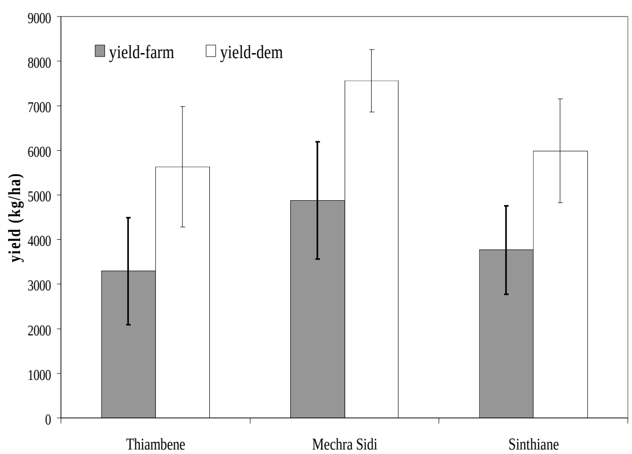

Figure 2. Paddy yields from Farmers' fields and RICM demonstration Plots at key sites in the Senegal River valley, wet season 1999

in the region. Existing shortcomings in this area are due in part to the failure to incorporate the knowledge base and perceptions of farmers and their development partners into the generation and adaptation of improved technologies. Although researchers generally recognize the value of participatory approaches for technology generation and adaptation, farmers/farmer organizations and their development partners continue to be excluded from efforts to effectively evaluate, adapt and transfer appropriate farm technologies. The result is that they often reject these technologies because they do not address their expressed needs and are not appropriate for their production environments. Until farmers/farmer organizations are better integrated into the technology generation and adaptation process, the debate on participatory technology development and transfer in sub-Saharan Africa will fail to translate into positive results and continue to be largely theoretical.

The experience of The Africa Rice Center in the Senegal River Valley and other parts of the Sahel has clearly demonstrated that rapid growth in irrigated rice productivity can be accomplished with rice integrated crop management, combining fertility, water and weed management with the use of improved cultivars and cost effective post harvest technologies. However, these technologies are only useful if and when they are adopted by producers and can significantly increase farm yields, productivity and profitability. Key issues for increasing the productivity and profitability of irrigated rice production in the Sahel are the rapid evaluation, adaptation and transfer of appropriate technologies for use by small-scale producers. The active participation of the principal stakeholders (farmer organizations, researchers and other development partners) in this process will ensure that technologies that have already been developed are adapted to address relevant constraints. Given this picture, scientists at the Center will explore partnerships for adapting and scaling-up RICM for irrigated rice-based systems in the Sahel. With the range of agro-ecological environments under which irrigated rice is cultivated in Africa, work will also explore the feasibility of adapting the experience of the Sahel to other regions such as savannah and Sudan-savannah areas. Also, it is important to recognize that irrigated rice cultivation represents a myriad of production systems, from complete to partial water control. These could be viewed from the perspective of an intensified lowland-irrigated continuum. It is important to explore how RICM developed for production systems with complete water could be adapt along this continuum. This would ensure that large numbers of small-scale farmers benefit from investments in research and development efforts on RICM in the Sahel.

This will require a participatory and decentralized technology evaluation and adaptation process. This will promote interactive processes between researchers, farmers and their development partners in order to characterize the micro-level environment, identify constraints and pragmatic solutions, examine a range of technological options, and design and implement adaptive research to address relevant constraints through rice integrated crop management. Extensive consultation and feedback from all stakeholders will be required in order to ensure that technology options and recommended interventions are acceptable, sustainable and appropriate for the production environment. Such a collaborative approach is required to facilitate the participation of producers in addressing issues that have direct effects on their welfare. Also, a consultative and investigative approach will support interpretive and perceptive reviews of relevant farm technologies, and will facilitate the promotion of rice integrated crop management by incorporating farmers' perceptions in the process of identifying and adapting solutions to their major constraints. To ensure durability and sustainability, it is extremely important to incorporate a strong capacity building component with emphasis on national research and development partners, farmer organizations and partner institutions in the private sector.

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