Research to Impact: Case Studies for Natural Resource Management for Irrigated Rice in Asia

Edited by Florencia G. Palis, Grant R. Singleton,
Madonna C. Casimero, and Bill Hardy

IRRI

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M.C. Casimero, and B. Hardy

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IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today, IRRI is one of the 15 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (www.cgiar.org).

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Mailing address: IRRI, DAPO Box 7777, Metro Manila, Philippines
Phone: +63 (2) 580-5600
Fax: +63 (2) 580-5699
Email: irri@cgiar.org
Web: www.irri.org.
Rice Knowledge Bank: www.knowledgebank.irri.org
Courier address: Suite 1009, Security Bank Center
6776 Ayala Avenue, Makati City, Philippines
Tel. +63 (2) 891-1236, 891-1174, 891-1258, 891-1303

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Foreword

The lives of resource-poor farmers who grow irrigated rice in Asia can no doubt improve if innovative agricultural technologies are tailored to their needs and carried out collectively. Establishing synergy among various rice stakeholders, including scientists and farmers, is a key to helping resource-poor farmers increase food security, profitability, and environmental sustainability.

To facilitate the journey from research to outcome to impact, the third phase (2005-08) of the Irrigated Rice Research Consortium (IRRC) of the International Rice Research Institute (IRRI) provided an international partnership platform for adaptive research for impact in 11 countries in Asia. The IRRC, with funding support from the Swiss Agency for Development and Cooperation, has the role as IRRI's facilitator of working with various rice stakeholders in the intensive irrigated lowlands to foster multistakeholder partnerships, bridge the gap between research and extension, and together address the regional and country-specific needs and problems in irrigated rice production. In September 2008, the IRRC organized a regional workshop at the Philippine Rice Research Institute in Nueva Ecija to synthesize field experiences and distill the lessons learned from Phase III. I understand that this workshop provided a dynamic sharing of experiences that are rarely well captured in the literature. So, I am especially pleased that the presentations have been documented in this book.

I congratulate the editors and authors of the book for their dedicated effort in bringing out this volume. This book is a key resource for scientists, extension workers, and students who are interested in overcoming the research and extension divide for effective scaling up and scaling out of agricultural technologies. The various case studies presented emphasize the important role of research along the research-to-impact continuum. A telling finding of this book is that, for innovative research on natural resource management to make a significant change in the lives of farmers—men and women farmers, their households, and consumers—strategic partnerships are essential among a range of actors.

Robert S. Zeigler
Director General
International Rice Research Institute

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Lastly, thanks go to the men and women rice farmers across Southeast and South Asia for graciously allowing the scientists and researchers of IRRI and ICOP partners to work and learn with them in making technologies more adaptive to the field and in improving and sustaining rice livelihoods in the region.

Strengthening research and extension partnership for impact: lessons from case studies

F.G. Palis, G.R. Singleton, and M.C. Casimero

Background

Rice is the staple food of about half of the world's population, the majority of which is located in Asia. Rice supplies as much as 80% of the daily caloric intake of the teeming population of Asia, where two-thirds of the world's impoverished population lives. It is estimated that 2.3 billion farmers and their households depend on rice as their main source of livelihood (Mohanty 2010). In Southeast Asia alone, about 24 million farmers depend on lowland rice agriculture, whereas, in South Asia, the figures are two to three times higher. Irrigated rice is grown on approximately 50% of the rice area in Asia and generates approximately 75% of the total rice production.

Rice also plays a major role in all facets of peoples' lives in Asia. This is evidenced in their cosmology (i.e., calendar, time perception, etc.), language, community structure, rituals, songs, material culture, and perception of the landscape, among others (Conklin et al 1980). The term "eating" is often synonymous with "eating rice." The Chinese word for rice is the same as the word for food. In Thailand, when you call your family to a meal, you say, "eat rice." In Japan, the word for cooked rice is the same as the word for meal. For many Asians, meals are incomplete unless they contain rice, as it "uniquely sustains the human body in a way no other food can" (Hamilton 2003: 23). Also, in the Philippines, rice is associated with an abundant life. After wedding ceremonies, the bride and groom are showered with rice to indicate more blessings from God. Further, social and economic activities are also directly related to preparing and irrigating the land, planting, maintaining the crops, irrigation, harvesting, drying, and storage (Conklin et al 1980). Hence, rice is not only nourishment to the body but it also has high significance to the social, economic, and cultural aspects of Asian people that are deeply woven into the fabric of Asian cultures and civilization.

Agriculture remains an economic backbone in most Asian countries. Rice, being the staple food of Asia, and hence a political commodity, has remained a major component of Asian agriculture. Since, in recent history, rice has become a primary element in the agricultural component of the gross domestic product (GDP) of many Asian countries, Hamilton (2003) observed that rice may be the key to unity in a culturally diverse Asia.

The recent global rice crisis in 2008 stimulated Asian governments to allocate more investment in rice research and extension to increase the rice supply and achieve rice self-sufficiency for the importing countries, and a rice surplus for the exporting countries. With its political, economic, social, and cultural significance, a continued increase in rice productivity is critically important for increasing food security, reducing poverty and hunger, and enhancing environmental sustainability. However, the sustained productivity of this critically important irrigated rice ecosystem is challenged by declining water availability, conversion of prime lands to alternate uses, the increasing shortage of labor, climate variability and climate change, and widespread concern regarding the environment.

Thus, research and extension in agriculture continue to play important roles in agricultural development to bring about impacts on the lives and livelihoods of Asian farmers and consumers. Research generates technologies and good agricultural practices or best practices for natural resource management (NRM) for increasing resource-poor farmers' productivity and income. Extension provides mechanisms by which these NRM technologies are disseminated for wide-scale adoption by farmers.

Impacts of NRM technologies can be realized only when the end-users—rice farmers—are practicing them. However, adoption of agricultural technologies has always been a challenge. The adoption of best practices for NRM is even a greater challenge because most are knowledge-intensive technologies that cater to local adaptation by farmers, and not physical products. This book documents cross-country learning, through case studies on the processes and methodologies employed from research toward the achievement of impacts by addressing the challenges of generating wider-scale adoption of NRM technologies in lowland irrigated agroecosystems.

IRRI, the IRRC, and ICOP

The International Rice Research Institute (IRRI) started its work in 1960 with a primary mandate of increasing food production. To date, the Institute's mission is to reduce poverty and hunger, improve the health of rice farmers and consumers, and ensure environmental sustainability through collaborative research, partnerships, and strengthening of national agricultural research and extension systems (NARES) to bring hope and improve the lives of men and women farmers and their households and consumers as well.

To effectively help rice farmers achieve increased profitability, food security, and environmental sustainability, the Irrigated Rice Research Consortium (IRRC) was established in 1997 with funding from the Swiss Agency for Development and Cooperation (SDC). The IRRC is an international platform for adaptive research for impact. Phase I (1997-2000) developed a region-wide multidisciplinary approach to irrigated rice; Phase II (2000-04) developed problem-oriented work groups based on regional needs assessment and began to develop research-extension partnerships; and Phase III (2005-08) continued the work group approach and made strong progress in integrating technologies across disciplines and in strengthening linkages between research and extension to address effective technology delivery to achieve impacts. The consortium had activities in 11 Asian countries during Phase III. Now in its fourth phase (2009-12), the IRRC has placed greater emphasis on strengthening research-extension networks to facilitate delivery of technologies to improve the lives of Asian farmers and communities (for a brief history of the IRRC, see Box 1). The activities in Phase IV focus more on seven countries in Southeast Asia but also include China, Bangladesh, and Sri Lanka.

In contrast to the traditional top-down or linear approach for the production and use of knowledge, the IRRC has adopted the recent thinking of an innovation system as an evolving system of actors involved in the production, dissemination, and use of knowledge (Freeman 1987, Dosi 1988, Lundvall 1992). Starting in its third phase, the IRRC shifted its focus to strengthening the multistakeholder partnership to bridge research and extension for efficient technology delivery and achievement of impacts.

The "IRRC Country Outreach Program" or ICOP was launched during Phase III to facilitate the partnership in-country, ensure technology integration, generate social learning among the members of the partnership, and thereby speed up the scaling up and scaling out of NRM technologies and processes for rice production in Asia. The stakeholders include various organizations from research to extension, government and nongovernment organizations, the private sector, and farmer organizations/groups. The ICOP, which is primarily NARES-led, was initially and formally established in three countries: Myanmar and the Philippines in 2006, and Indonesia in 2007. The model has been generating many exciting results (see Part 1 of the book). The ICOP approach, however, was less formal in countries where only a couple of work groups were situated and where an effective research-extension mechanism was already in place for the delivery of IRRC technologies.

The implementation of ICOP has strengthened research-extension linkages, developed important policy advocates, and enabled IRRI to respond to policy initiatives in Indonesia, Myanmar, and the Philippines, and this has been extended to Thailand and Vietnam in Phase IV of the IRRC. Technology development is now being led by IRRC working partners and farmers in the respective countries. Also, technology verification and demonstration are being conducted jointly by the IRRC work groups, in-country partners, primarily NARES, and farmers at the selected field sites across Southeast and South Asia. Through ICOP, the IRRC hopes to realize greater research impacts, moving from innovation and technology adoption toward attaining food security, poverty alleviation, social stability, and environmental sustainability.

Overview of the book

In September 2008, the IRRC coordinated and sponsored a regional workshop—"Research to Impact: Case Studies for Natural Resource Management in Irrigated Rice in Asia." Held at the Philippine Rice Research Institute in Nueva Ecija, the workshop aimed to document the progress and lessons learned during Phase III of the IRRC. The major output of the workshop is this book.

Box 1. A Brief History of the Irrigated Rice Research Consortium

The IRRC has become and is continuously being recognized as one of the leading consortia in agricultural research and extension. From its conception, it has greatly strengthened and developed the delivery of appropriate rice technologies in Asia. The consortium has also helped identify and address regional research needs in irrigated rice. Further, through its partnerships and collaboration with NARES, IRRI scientists, and other stakeholders, the IRRC has directly and indirectly contributed to making progress toward the Millennium Development Goals.

Phase I, 1997-2000

Realizing the need for a platform for IRRI and NARES partners to exchange knowledge, plan joint activities, and collaborate at a project level, the IRRC was established in 1997 with the goal of integrating disciplines and institutions, and to effectively manage resources to build national capacity and ultimately improve rice production. With funding from the Swiss Agency for Development and Cooperation (SDC), Phase I was implemented from 1997 to 2000. It started with three projects: (1) Integrated Pest Management Network (IPMNet), (2) the Reversing Trends in Declining Productivity (RTDP) Project, and (3) linkage with the Integrated Nutrient Management Network (INMNet).

Realizing the potential and relevance of a regional agricultural research and extension consortium that focused on the interdisciplinary and interinstitutional activities in addressing integrated rice farming needs and problems, the SDC agreed to provide funding for Phase II of the IRRC. However, it was evident by the end of Phase I that improvement in the IRRC's structure was necessary to include extension systems and an effective mechanism in which national programs could put into use their research outputs.

Phase II (2001-04)

IRRC Phase II started in 2001. Taking a step forward from its previous phase to facilitate more impact from national programs, the general objectives of Phase II were to (1) identify and address regional research needs in irrigated rice, (2) promote research collaboration, (3) support the integration of research, (4) leverage researchers from consortium members, and (5) facilitate technology delivery for impact.

This time, the IRRC was structured into work groups. Each work group was formed on specific research needs to solve problems with high potential impact at the collaborating sites and regions. In addition, the work groups were composed of interdisciplinary teams of research and extension workers at sites in three or more countries. The problem-based work groups were (1) Nutrient and Integrated Nutrient-Pest Management (Reaching Toward Optimal Productivity), (2) Hybrid Rice, (3) Water Saving, (4) Weed Ecology, (5) Rodent Ecology, and (6) Postharvest Management (in the last year). A work group in impact (technology communication, dissemination, and evaluation) linked all problem-based activities and facilitated the delivery of technologies.

The new and improved IRRC proved to be very successful in strengthening regional and NARES-driven multidisciplinary research collaboration, access, and capacity. The consortium also developed environmentally and ecologically sound rice production technologies through improved resource efficiency and input management.

Phase III, 2005-08

Phase III began in January 2005 with continued strong support from SDC. During its third phase, the IRRC secured funding from a number of additional agencies. These included the Australian Centre for International Agricultural Research (ACIAR), the Asian Development Bank (ADB), the Department for International Development (DfID) (UK), the International Fertilizer Industry Association (IFA), the International Potash Institute (IPI), and the International Plant Nutrition Institute (IPNI).

During this phase, the work groups were reduced to four based on the themes that link directly or indirectly with the Millennium Development Goals. These were (1) Productivity and Environmental Sustainability (Productivity and Sustainability); (2) Increased Productivity under Water-Scarce Conditions (Water Saving); (3) Improved Labor Productivity (Labor Productivity); and (4) Improved Postproduction Techniques and Diverse Rice Markets (Postproduction). Similar to previous phases, the work groups were composed of interdisciplinary research and extension teams. They were formed based on research priorities identified from farmers' problems for rice production within irrigated rice ecosystems.

The work groups were armed with mature technologies that include site-specific nutrient management (SSNM), alternate wetting and drying (AWD), direct seeding of rice (DSR), integrated weed management (IWM), ecologically based rodent management (EBRM), and the IRRI Super Bag. The IRRC provided farmers with a "basket of options" for natural resource management of irrigated rice.

A coordination unit of the IRRC was formed, which facilitated interdisciplinary approaches to improved rice production, and also provided the work groups with skills in social sciences and development communication.

In order for the knowledge-intensive NRM technologies to be validated, scaled out, and their impacts realized in the context of specific countries and localities, the IRRC launched the IRRC Country Outreach Program (ICOP) in 2006. Although the implementation of the ICOP was led by the NARES partners, the program placed a strong focus beyond the NARES level and established strategic partnership with local governments, policymakers, extension workers, farmers, the private sector, nongovernment organizations, and donor agencies.

Phase IV, 2008-12

Now in Phase IV, the IRRC is active in 11 countries in Asia: Bangladesh, Cambodia, China, India, Indonesia, Lao PDR, Myanmar, the Philippines, Sri Lanka, Thailand, and Vietnam. A fifth work group (Crop Health) was added to the previous four work groups and the coordination unit of Phase III. The consortium's five work groups aim to further enhance its research-extension partnerships in order to better identify the natural resource needs of rice farmers, formulate some solutions to their problems, and facilitate the adoption of appropriate technologies. The current phase of the IRRC has a stronger focus on food security and reducing poverty, as it aims to (1) increase rice production by 10% and household income by 15% for smallholder families, which has the potential to improve the livelihood of 500,000 people; and (2) foster innovative research on natural resource management of irrigated rice-based cropping systems. The IRRC realizes that this can be achieved only through strengthening the capacity of its NARES partners and other partners.

This book aims to share lessons and experiences and document cross-country learning in 11 countries from bridging research and extension to fostering multistakeholder partnership for "research to impact." More specifically, it seeks to (1) document the different strategies and processes for dissemination and assessment of impacts of NRM technologies in Asia, (2) provide a platform for effective research-extension-impact pathways for lowland rice in Asia, (3) capture the dynamics and different mechanisms for ICOPs, and (4) assess different dissemination methods adopted for bridging research and extension, with the aim of developing future strategies and models for scaling up (policy advice) and scaling out (diffusion on a spatial scale) best practices for NRM in Asian rice production.

The book is divided into four main parts. Prior to the first part is a keynote chapter by Cees Leeuwis (Chapter 2), which sets the tone of the book. He discusses the changing views of agricultural innovation, from linear models toward nonlinear and multidirectional models. It sees innovation as a process, adoption as a collective process within nested networks of interdependent stakeholders, and diffusion starting during the design of the study, with scaling out often requiring contextual redesign. The chapter offers a perspective on the need for the reordering of multiple social networks in society through communicative interventions. Special attention is given to the broader role of communicative intervention (including extension) and scientists in supporting development and agricultural innovation. Leeuwis also presents new roles for scientists in performing social learning and negotiation, leading them to effectively acquire and disseminate new knowledge.

Part I presents the experiences of the IRRC Country Outreach Programs (ICOPs) in the Philippines (Chapter 3), Indonesia (Chapter 4), and Myanmar (Chapter 5). These chapters highlight the importance of using participatory approaches and forging partnerships among rice stakeholders in disseminating integrated NRM rice-based technologies. The case studies highlight the role of NARES and extension organizations in the success of ICOPs despite their limited resources, as well as the importance of engagement with policymakers for policy support in scaling out technologies.

Part II illustrates the various processes of putting science into practice through the documentation of 14 case studies. There are contributions from Bangladesh (Chapters 6 and 18), China (Chapter 14), India (Chapter 7), Indonesia (Chapters 8 and 12), Myanmar (Chapter 16), the Philippines (Chapter 9), Sri Lanka (Chapter 10), Vietnam (Chapters 11, 13, and 17), and Thailand (Chapter 15). The case studies underscore the role of partnerships among the various stakeholders in the dissemination, capacity building, and scaling out of NRM technologies. Vital to this partnership is the link between research organizations and the private sector (NGOs and the business sector), the role of local champions, and the participation of policymakers in the spread of innovation. Success stories include the upscaling of IRRC technologies to the National Rice Program in the Philippines, the promotion of flat-bed dryers and the scaling out of the 3 reductions, 3 gains (3R3G) technology in Vietnam, the integration of SSNM into a national crop management program in Indonesia and into a provincial program in China, and the benefits of direct-seeded rice together with integrated weed management for alleviating hunger in Bangladesh.

Part III focuses on the assessment of impacts of NRM technologies adopted by farmers in Vietnam (Chapters 19 and 20) and China (Chapter 21). It also presents methodological perspectives on how to assess the impacts of the adoption of NRM technologies as well as the enabling and constraining factors for the adoption and scaling out of technologies.

Part IV consists of reflections from a renowned sociologist, Dr. Gelia Castillo (Chapter 22). Other reflections from biophysical and social scientists and a major donor of the IRRC can also be found in Appendix 1. The reflections emphasize the role of the IRRC and ICOP in the broader context of agriculture. It also presents some assessment of the various approaches used in all of the case studies from an Asian perspective. These reflections place more emphasis on specific innovations and general trends as components for developing new models for up-scaling and out-scaling of best practices of NRM for improved and sustainable rice production.

Common themes generated

From all the cases presented in this book, the following common themes emerged.

Farmers' participation in the innovation process

Recognizing farmers as one of the key stakeholders, and hence engaging them in the development process, has brought their voices or perspectives in modifying or adapting technologies suiting their local conditions. Several case studies highlighted the appreciation among scientists of local knowledge and technological innovations following their interactions with farmers (Heong et al, Sibayan et al, Sudarmaji et al, Zhong et al). Through participatory approaches and tools (e.g., participatory experiments for technology validation, demonstration farms, focus group discussions, key informant interviews), local context was integrated in the design and refinements of NRM technologies, and in the formulation of doable strategies to address the complex problems in lowland rice production.

In the same vein, the value-addition of farmers' participation in developing an appropriate technology, as well as their role in research and extension, is underscored. As such, farmers became an active part of the research and development initiatives in their respective communities, where the "emic" (the farmers' point of view) is reconciled with the "etic" (the scientists' point of view). Considering that farmers are well informed about their own situations—what works and does not work—farmer knowledge has much to contribute to how a new technology will be useful for them. Further, building on farmer knowledge, for which the "emic" is integrated with the "etic," encourages farmers to use the technology because of its location-specificity and applicability (Palis et al 2007).

Moreover, participation of farmers in developing an appropriate technology fostered ownership and sustainability. In the scaling out of technologies in various cases, farmers and other stakeholders tended to treat the project or technology as their personal achievements. This sense of ownership was found to be beneficial in sustaining a project or use of technology, including the sustainability of partnerships and linkages among the various stakeholders in the rice supply chain. Although sustainability is not an intrinsic property of any technology, it entails continuing change and a "fit" between the technology and the multifaceted context in which it is used (Uphoff 2002).

Multistakeholder partnership

Agricultural research and extension have always been embedded in the social and political context (Killough 2005). Likewise, success in research and extension is influenced by a wide range of institutions and actors operating within the rice supply chain (Hall et al 2005). The active involvement of researchers, extension specialists, and policymakers in comprehending the needs of farmers is a key to ensuring technical backstopping and policy support to bolster the dissemination of information and adoption.

Experiences from the case studies showed that localization and contextualization of knowledge-intensive technologies (e.g., Corales et al, Hien, Huelgas and Templeton, Santosa et al, Nga et al, Tuan et al) could be achieved only through active partnerships with local sectors (e.g., local fabricators of the technology, community-based organizations, local NGOs, local government units, and farmers' organizations). Tapping into these organizations is important in the partnering process because, aside from them having their own extension networks, they may have comparative advantages (e.g., capacity and experience) in knowing the most pressing needs of farmers.

Multistakeholder partnership (MSP), however, is not easy to establish as this requires appropriate strategies, lots of effort, resources, and time. One needs to build on the existing social capital in place and understand the culture and subcultures in each society (Palis 2006, Palis et al 2005). As shown in the case studies presented, existing research and extension networks, both public and private, were used for speeding up social learning and the dissemination process. Notably, the use of farmers and farmer groups for efficient farmer-to-farmer extension was capitalized on in the case of SMART farmers (Soitong) and hamlet facilitators (Tuan et al). Further, the experience in Vietnam with World Vision's Area Development Program stressed the importance of time for partner institutions to become familiar with the technologies and in promoting these to the farmers (Tuan et al). In addition, rice-based technologies require suitable environments that would enable stakeholders to put their knowledge into use (World Bank 2006). One variable that can greatly influence and create an enabling environment is policy. Effective innovation not only requires one policy but also a set of policies working together and considering the relationship of attitude and practice in order to shape innovative behaviors (World Bank 2006).

MSP is also an avenue that fosters interdisciplinarity and multiple realities (Ramirez 2001). This form of diversity among various stakeholders uncovers varying interests and perspectives that can provide many options for finding doable solutions to help farmers increase their yield and profit. Several case studies in this book highlighted the crucial involvement of policymakers, local champions, and the private sector in achieving impact and sustainability of the IRRC-ICOP projects.

A. Involvement of policymakers

The IRRC-ICOP projects underscored the value of involving policymakers. In the scaling up and scaling out of technologies in the Philippines, Indonesia, Myanmar, and Vietnam, adoption and diffusion of innovations were highly influenced by government policies (Corales et al, Sarwani et al, Yi et al, Tuan et al). These policies are in the form of incentives for adoption, government support and subsidies, and accreditation. These case studies also highlighted the impacts of having support from policymakers, as well as the consequences of its absence.

The involvement of policymakers and government officials fosters the synergy of government policies at different levels, especially in countries in which the agricultural extension system is fragmented and pluralistic. As shown by the experience in Indonesia, the participation of policymakers influenced the formulation of a standard procedure for information dissemination and building technical capacity among partner agencies. Also, it averted any replication of related projects or activities and information overload (Sarwani et al).

B. Role of local champions

All the contributors in this book have acknowledged the indispensable role of local champions in the development, scaling up, and scaling out of NRM best practices and rice technologies. They included the village heads, community elders, seasoned farmers, large farm owners, local technology fabricators, and local government officials and staff.

Local champions are instrumental in mobilizing the community when research-oriented activities are implemented in their respective places. Organizing farmers to participate in a farmer field school (FFS), demonstration plots, farm laboratories, and other development-related intervention projects is easier because of the facilitative help extended by the local champions. Partnering with local champions provides project teams, researchers, scientists, NGOs, and extension staffs much-needed credibility, especially when they are introducing or testing a new technology in a community. The local champions can also link farmers to NGOs, civil society organizations, and local leaders. Each can help to sustain the innovation activities, especially when donors or outside funding would no longer be available (Killough 2005).

As discussed in the case studies, the local champions have not only created opportunities and expanded the reach of farmers to other networks; they have also served as an inspiration or model among farmers in the adoption process. Since the prevailing belief of farmers is “to see is to believe,” evidence of technology use by local champions often determines adoption (Gallentes 2005). Most farmers don’t usually risk trying a technology if no one in their networks has used it successfully. With limited resources, risk could prevent farmers from adopting a recommended practice or technology.

C. Public-private partnerships

Successful adoption is not guaranteed even if technologies are appropriate to the needs of end-users. First, technology and innovation solutions should consider the ability of a technology to be locally reproduced, especially in the case of equipment and machinery. Second, technology adoption depends not only on the motivation of stakeholders to learn about it but also on the price, relevance, profitability, adaptability, and replicability of the technology for wider use (Douthwaite et al 2001).

Because of this, the participation of the local production sector in research, development, and dissemination of technologies is vital. However, local fabricators must have the technical capacity to manufacture the technology (e.g., flat-bed dryer) at an affordable price for wide-scale promotion and commercialization. Partnership between the public and private sector is designed to meet this challenge and help farmers gain income and profits.

Public-private partnership is a business-oriented approach in which both farmers and the private sector can have leverage to benefit from rice farming as an enterprise. In Vietnam and Myanmar, the involvement of local fabricators of dryers was necessary for the scaling out of flat-bed dyers (Hien; Kyaw and Gummert). The availability of equipment and farm inputs in the market is another factor to consider when scaling out input-intensive technologies.

Participatory monitoring and evaluation

Participatory monitoring and evaluation (PM&E) activities are mechanisms for the refinement of approaches and features of the technology to further enhance its impacts and for it to achieve sustainability (Vernooy 2005). However, ensuring proper feedback requires building capacity among partners—research and extension organizations, NGOs, community-based organizations, farmer groups, and the private sector—to monitor and evaluate a project or the adoption of a technology.

The reasons for enhancing capacity among government research and extension organizations are obvious as they are traditionally tasked with the development and diffusion of knowledge and technology. PM&E is not well integrated in the development framework, which is a weakness because PM&E usually creates instructive feedback. As shown by the case studies, transmission of feedback from farmers is not properly captured and brought to the concerned organizations or individuals. In the Red River Delta of Vietnam (Nga et al) and North Anhui in China (Ding et al), for example, a lack of capacity to transmit and acquire feedback has remained a limiting factor in the adoption of technologies. A good PM&E scheme can strengthen the learning, accountability, and effectiveness of the research effort (Vernooy 2005).

Feedback provides important input for refining approaches, strategies, and the features of the technology itself in order to improve and widen its applicability and impacts. Since feedback is most effective if documented regularly, the case studies highlighted that regular meetings and sharing of results are the most common and most effective mechanisms for acquiring stakeholder and end-user feedback. This, however, would require commitment and initiatives from the partners to address timely issues and enhance the likelihood of creating sustainable solutions.

Communicative intervention

The use of appropriate communication channels, which aimed at changing farmers' perceptions, attitudes, and practice toward a particular technology, has proven to be effective. The case study on the 3R3G campaign in Vietnam exemplified the appreciation of local context in the framing of simple messages to improve farmers' decision making about insecticide use. Integrating the local context has minimized or eliminated misperceptions and misinterpretations of information during the campaign. A well-planned communication strategy, as the authors of the case study argued, is a key for framing and simplifying technical information for a wide range of audiences (Heong et al).

Furthermore, other case studies illustrated that the effective flow of information and knowledge through the research-extension continuum could aid farmers and other stakeholders in managing their resource base. Information and knowledge on crop management practices are valuable inputs that would help farmers in making sound judgment on how to best manage their limited available resources.

The presence of NGOs in the community, being a part of the information network, widened the accessibility of knowledge and provided technical support to farmers. Also, this enhanced the extension system in crafting a tailored response to the needs of farmers, as well as in disseminating KITs through field demonstrations, field days, and training activities in the community.

Toward a regional platform for learning

The primary motivation for establishing partnerships is to enhance performance in problem solving (Gilmour et al 2007). Since problems encountered in rice production have been taking a more regional scope, such as the outbreak of pests and diseases in Southeast Asia during 2007-10, climate change, and the 2008 food crisis, a more regionally oriented partnership approach is needed.

The IRRC has pioneered an Asian-wide initiative for both the development of rice technologies in the region and a cross-regional learning platform for a wide range of rice networks in the irrigated areas. Through these networks, innovation and information about rice can be shared by stakeholders, as well as their experiences in validating and modifying the use of technologies based on local conditions. More importantly, as a regional platform for learning, the IRRC presents a unique venue for different stakeholders in the region to share their best practices as templates for improving others' practices.

This book is a documentation of the IRRC as a learning platform. The information, knowledge, and experiences shared in this book might not have been possible if the contributors of the book had not had a platform for shared learning and experiences such as the IRRC.

References

Conklin HC, Lupāih P, Pinther M. 1980. Ethnographic atlas of Ifugao: a study of environment, culture and society in northern Luzon. New Haven, Conn. (USA): Yale University Press. 124 p.

Dosi G. 1988. The nature of innovative process. In: Dosi G, Freeman C, Nelson R, Silverberg G, Soete L, editors. Technical change and economic theory. New York (USA): St. Martin Press. p 221-238.

Douthwaite B, Keatinge JDH, Park JR. 2001. Why promising technologies fail: the neglected role of user innovation during adoption. Res. Policy 20:819-836.

Freeman C. 1987. Technology and economic performance: lessons from Japan. London (UK): Pinter.

Gallentes J. 2005. Lessons in hybrid rice technology promotion. PhilRice Magazine 18(2):16.

Gilmour DA, Drust PB, Shono K. 2007. Reaching consensus: multi-stakeholder process in forestry: experience from the Asia-Pacific Region. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific. Bangkok. Available online: www.fao.org/docrep/010/ai390e/ai390e00.HTM. Date accessed: 1 September 2010.

Hall A, Rasheed Sulaiman V, Clark N, Yoganand B. 2005. Innovation systems perspective: from measuring impact to learning institutional lessons. In: Gonsalves J, Becker T, Braun A, Campilan D, de Chavez H, Fajber E, Kapiriri M, Rivaca-Caminade J, Vernooy R, editors. Participatory research and development for sustainable agriculture and natural resources management: a sourcebook. Volume 1: Understanding participatory research and development. International Potato Center-Users' Perspective With Agricultural Research and Development, Laguna, Philippines, and International Development Research Centre, Ottawa, Canada. p 87-93.

Hamilton RW. 2003. The art of rice: spirit and sustenance in Asia. Los Angeles, Calif. (USA): UCLA Fowler Museum of Cultural History. 552 p.

Killough S. 2005. Participatory approaches to agricultural research and extension. In: Gonsalves J, Becker T, Braun A, Campilan D, de Chavez H, Fajber E, Kapiriri M, Rivaca-Caminade J, Vernooy R, editors. Participatory research and development for sustainable agriculture and natural resources management: a sourcebook. Volume 1: Understanding participatory research and development. International Potato Center-Users' Perspective With Agricultural Research and Development, Laguna, Philippines, and International Development Research Centre, Ottawa, Canada. p 23-31.

Lundvall B. 1992. National systems of innovation: towards a theory of innovation and interactive learning. London (UK): Pinter Publishers.

Mohanty S. 2010. The global rice market: Where is it going? Rice Today 9(1):42-43.

Palis FG, Buresh RG, Singleton GR, Flor RJ. 2007. Adoption of fertilizer best management practices: the need for a sociological approach. Proceedings at the IFA International Workshop on Fertilizer Best Management Practices (FBMPs), Brussels, Belgium, 7-9 March 2007. p 99-110.

Palis FG. 2006. The role of culture in farmer learning and technology adoption: a case study of farmer field schools among rice farmers in central Luzon, Philippines. Agric. Human Values 23(4):491-500.

Palis FG, Morin S, Hossain M. 2005. Social capital and geography of learning: roles in accelerating the spread of integrated pest management. J. Agric. Educ. Ext. 11(1-4):27-37.

Ramirez R. 2001. Understanding the approaches for accommodating multiple stakeholders' interests. Int. J. Agric. Res. Gov. Ecol. 1(3/4):264-285.

Uphoff N. 2002. The agricultural development challenges we face. In: Uphoff N, editor. Agro-ecological innovations: increasing food production with participatory development. London and Sterling, Va. (USA): Earthscan Publications Ltd. p 3-20.

Vernooy R. 2005. Monitoring and evaluating participatory research and development: some key elements. In: Gonsalves J, Becker T, Braun A, Campilan D, de Chavez H, Fajber E, Kapiriri M, Rivaca-Caminade J, Vernooy R, editors. Participatory research and development for sustainable agriculture and natural resources management: a sourcebook. Volume 1: Understanding participatory research and development. International Potato Center-Users' Perspective With Agricultural Research and Development, Laguna, Philippines, and International Development Research Centre, Ottawa, Canada. p 104-112.

World Bank. 2006. Enhancing agriculture innovation: how to go beyond the strengthening of research systems. The International Bank for Rural Reconstruction and Development, Washington, D.C. Available online: http://siteresources.worldbank.org/INTARD/Resources/Enhancing_Ag_Innovation.pdf. Date accessed: 1 September 2010.

Notes

Authors' address: International Rice Research Institute, Los Baños, Philippines. Email: f.palis@cgiar.org.

Changing views of agricultural innovation: implications for communicative intervention and science

Cees Leeuwis

In the last decades, we have seen many new developments in innovation studies. Discussions no longer center around "adoption and diffusion of innovations." New themes include the co-evolution of social and technical developments, and the survival (or not) of different innovation initiatives that are competing with each other and with an "external" selection environment. It will be argued that we need to broaden considerably our view on the types of intermediation and facilitation that an innovation process includes and requires. Special attention will be given to the implications this has for the role of communicative intervention (including extension) and scientists in supporting development and agricultural innovation.

Communication has been an area of interest in innovation studies for a long time. Early studies such as Ryan and Gross (1943) and Bowers (1938) already paid attention to aspects of communication, and this was expanded upon in later works on the adoption and diffusion of innovations (e.g., Beal and Rogers 1959, Rogers 1962, Van den Ban 1953, 1961). In those days, communication was looked upon primarily as an intermediary function between science and societal users. It was studied mainly in terms of the "sources," "media," or "channels" that provided people with "information" and the "promotion efforts" of "change agents"; all this at different "stages" of the "adoption" process (see, e.g., Rogers 1962, 1983). The interest in communication even stimulated the emergence of new (applied) academic disciplines such as "agricultural extension studies," "health education," and the like. In the last decades, the theoretical understanding of innovation has advanced considerably, and the then-dominant "linear model of innovation" has been replaced by other bodies of thought such as innovation systems thinking (Lundvall 1992, Röling 1992, Hall et al 2001, Hall 2005, Smits and Kuhlmann 2004), strategic niche management (Kemp et al 2001, Geels 2002), and actor network theory (Callon et al 1986, Law and Hassard 1999). Clearly, these changes in thinking have implications for how we must conceptualize the role of communicative intervention and research in innovation processes. Building blocks and inspirations for this can be derived from many studies and scholars in the domain of innovation studies, but since most of these authors are not centrally interested in "communicative intervention," a systematic rethinking of the role of communicative intervention in innovation processes is largely absent. This chapter makes an effort to fill this void. We start by summarizing some important changes in thinking in innovation studies and discuss the conceptual implications for understanding the role of communication in innovation processes. We then turn to what this implies for deliberate attempts to professionally use communication as a strategy to bring about innovation, whereby we touch upon the functions that communication may support, and the kinds of planning and monitoring that may be of use. Subsequently, we reflect on the implications of the changed understanding of innovation for the role of scientists and research. In our concluding reflections, we emphasize that communicative intervention can still be regarded as an intermediary process, but that we need to broaden our perspective on the types of intermediation that an innovation process includes and requires.

Changing views of innovation

Over the years, ideas about innovation have evolved considerably. Although there are clearly different strands of thinking, some widely shared shifts are listed in Table 1, and further explained below.

The linear idea that innovations are developed by scientists, disseminated through intermediaries, and then put into practice by users has been criticized by many (Kline and Rosenberg 1986, Röling 1988, 1994, Rip 1995, Leeuwis 2004). Numerous studies showed that "innovations" developed by research were often not adopted, and that successful innovations were usually based on an integration of (technological and other) ideas and insights from not only scientists but also users, intermediaries, and other societal agents. Along with this shift regarding the origins of innovations, the ideas about what an innovation actually *is* evolved as well. In the past, an innovation was regarded as a new technical device or principle—for example, a photovoltaic cell or a new seed variety. Moreover, the idea was that such an innovation was either adopted or rejected by an individual, depending on all kinds of social conditions (Rogers 1962, Van den Ban 1974). Nowadays, we recognize that innovations—even when considered solely from a technical perspective—are not one-dimensional, but must be viewed as a combination of technical components. In order to work in Dutch society, for example, photovoltaic cells became integrated in solar panels that could be used as roofing materials, and with equipment through which electricity could be measured and fed back into the electricity grid (Van Mierlo 2002). Clearly, the latter also required new contractual arrangements among dwellers and electricity companies, as well as new role perceptions and adapted policies and legal rules. Thus, innovations do not just consist of new technical devices, but also of new social and organizational arrangements, such as new rules, perceptions, agreements, and social relationships. These are no longer considered as external and static, but rather as integral parts of an innovation. This implies simultaneously that often many different stakeholders (operating in different interdependent networks) are involved in an innovation process, and hence that it is not very useful to look at "adoption" as something that happens

Table 1. Changes in academic thinking about innovation regarding different aspects.

Aspect of innovation	Linear model of innovation (dominant 1950-80)	Later modes of thinking (dominant from 1990 onward)
Origin	Science and research	Building blocks come from science, practice, and intermediaries
Nature	New technical device	New successful combination of technological devices, modes of thinking, and social organization
Social conditions for application	Are "outside" the innovation	Are an integral component of the innovation
Key processes	R&D, adoption	Interactive design, co-evolution, learning
Adoption	Is an individual process	Is a collective process within nested networks of interdependent stakeholders
Steering	Change can be engineered, predicted, and planned rationally	Change is an unpredictable, messy, and emergent process
Role of science	Designing innovations	Delivering inventions that may be turned into innovations; responding to questions that emerge in the innovation process
Diffusion	Happens after the innovation is ready	Starts already during design, while scaling out often includes contextual re-design

only at an individual level. Building on Smits (2000), we can thus conceptualize an innovation as a successful combination of "hardware" (i.e., new technical devices and practices), "software" (i.e., new knowledge and modes of thinking), and "orgware" (i.e., new social institutions and forms of organization) (adapted from Smits 2000, 2002).

Not surprisingly, the thinking about innovation as a *process* has also changed dramatically over the past decades. In former days, there was a strong belief in the possibility of planning and predicting change and innovation. In contrast, we now see that change is often affected by complex interdependencies, unintended and unforeseen developments and interactions, and coincidence and dynamics of conflicts that defy engineering and reductionist understanding (Prigogine and Stengers 1990, Holling 1995, Loorbach 2007). In connection with this, innovation processes are looked at nowadays from an evolutionary perspective. The idea is essentially that a variety of innovations and innovation processes compete in a dynamic selection environment in which the "best fitting" survives or "wins" in a given time and space context (Bijker

Box 1: Linear theory and nonlinear practice: agricultural development in the Netherlands

It is interesting to note that some innovation-oriented programs were linear in their setup, but much less linear in practice. In the 20th century, the Dutch government invested heavily in a publicly funded system of research, extension, and education. This system has been very successful and resulted in the Netherlands becoming the second largest exporter of agricultural products in the world around 1980. In its philosophy, language, and design, the system was clearly inspired by a linear model of thinking. Agricultural extension, for example, was mainly seen as an institution that needed to ensure that technologies developed in research were disseminated and adopted by individual farmers. In actual practice, however, the system often operated in a far less linear fashion. Many formal and informal feedback loops existed through which farmers exerted influence on the research and extension agenda. At the local level, for example, intensive interaction between selected farmers, extensionists, and applied researchers existed and contributed to tailoring research and extension efforts to the needs and initiatives of those who wished to embark on the modernization project (Röling 1989, Vijverberg 1997). Moreover, the technology promotion efforts by research and extension were complemented by (and in fact made successful through) many changes in the social and organizational sphere, such as the development of agricultural cooperatives for credit and marketing. Despite this history, the discourse about innovation in the agricultural sciences remained focused narrowly on the dissemination of technology for a long time.

et al 1987, Rotmans et al 2001, Nelson and Winter 1977).[1] Clearly, such "fitting" does not just involve adaptation to prevailing contextual conditions, but also the active influencing, re-design, or destruction of preexisting conditions and frameworks, respectively, the "overthrowing" of previously dominant "socio-technical regimes" (Geels and Schot 2007).

Implications for communicative intervention

From the above signaled changes in thinking, we can derive two main implications for our effort to systematically rethink the role of communicative intervention in innovation processes. First, we have seen that innovation happens in society, and involves the contextual re-ordering of relations in multiple social networks. Communication obviously plays a role in such re-ordering, but, if we want to understand its role, we can no longer think only in terms of "transferring technology" or "diffusing" a ready-made innovation. Rather, we need to think about it in terms of a process that takes place in the context of the building, design, and/or evolution of effectively re-ordered relations among "hardware, software, and orgware." Below, we discuss several aspects concerning the role of communicative intervention. We start with a general reflection

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[1] The concept of innovation proposed here implies that the selection environment is not only dynamic but can also be actively influenced, that is, can be made an integral part of the innovation. For instance, the dominant selection environment in conventional modern agriculture (in which one could include the agro-industrial sector) is not a very fertile ground for organic agriculture, which is why people with a passion for organic agriculture have, in a manner of speaking, created their own selection environment with the aid of all kinds of parallel institutions and organizational structures.

on the role of intervention, and then zoom in on specific functions of communication and implications for communication planning.

Conceptualizing the overall role of intervention: assisting evolution

As indicated earlier, the current theoretical understandings of communication and innovation imply that it is no longer useful to limit our thinking about the role of change agents (such as agricultural extensionists) and communication professionals to processes of individual adoption and diffusion. We must explore the roles that they can play in the building, design, and/or evolution of effectively re-ordered relations among "hardware, software, and orgware." This while recognizing at the same time that they cannot (and hence should not aspire to) control such processes; change agents may have an influence, amid the influences of many other actors and factors. In more conceptual terms, we would like to propose two (compatible) ways of thinking about the role of intervention. From a more evolutionary innovation perspective (Geels 2002), we would argue that the role of change agents is to enhance the survival chances of initiatives for change, by supporting—through various strategies—that they become more effectively adapted and/or linked to their dynamic selection environment (which itself can also be influenced) than other competing initiatives. When insufficient initiatives for change exist in a problematic situation, they may even do well to support multiple competing initiatives in order to create sufficient variety (Van Woerkum and Aarts 2002). In this perspective, there is much emphasis on the temporal provision of "protected space," in which the innovation initiative does not yet have to compete with the existing "regime," but gets the time to become more "mature" and better adapted through learning experiences (Geels 2002). This broad perspective on the role of intervention tends to emphasize the need to "struggle" with (e.g., influence, lift, adapt, ignore) existing constraints and regimes.

Functions of communication

From a sociological perspective, social structures, institutions, and regimes have much in common. Changing them coincides with and takes place through the adaptation of storylines and discourses through which actors order the world. Such adaptations must somehow be sufficiently complementary, congruent, or agreed upon (Grin and Van de Graaf 1996) across different actors and networks, and must at some time resonate within society. Building on different strands of literature, we argue that three (simultaneous) processes deserve particular attention and support by communication professionals in order to contribute to this. The first process is that of *network building*. We have seen that innovation inherently implies a re-configuration of relationships within and between networks, and possibly the formation of new networks and/or the demise of existing ones (Engel 1995, Callon et al 1986, Latour 1987). A second key process is *supporting social learning.* In different strands of thinking about innovation, learning is considered a critical process for developing a conducive fit between innovations and their environment (Geels 2002, Rotmans 2003, Smits and Kuhlmann 2004, Hommels et al 2007). Moreover, the development of congruent storylines and discourses (Hajer and Laws 2006, Grin and Van de Graaf 1996) requires that the parties involved slowly develop overlapping—or at least complementary—perspectives on relevant models of reality, problems, goals, and boundaries as a basis for identifying desirable, feasible, and acceptable options for change. Dialectical debate and joint learning are proposed as the main route toward achieving this (Checkland 1988); several scholars have labeled this process "social learning" (Dunn 1971, Friedmann 1984, Röling 2002, Woodhill 2002, Leeuwis 2002). The third key process that can be supported by communication professionals is the *dealing with dynamics of power and conflict*. We have seen that efforts to change the status quo are likely to lead to tensions and conflicts of various kinds. Moreover, the realization of change in one way or another involves the mobilization of power resources to overcome resistance. Our point here is not that dynamics and power and conflict must be prevented; instead, we argue that they are always at play, but that there are more and less productive ways of dealing with them.

When we mirror the perspective outlined so far with the roles for communication outlined in the linear adoption and diffusion of innovation perspective, we see important differences (see Table 2).

The theoretical and practical literature on learning, negotiation, participation, and communication provides numerous insights and suggestions on how the three basic processes indicated earlier could (depending on a specific context) be facilitated and enhanced through communicative strategies. In Table 3, we list such strategies, which can also be seen as ways to improve dialogue in the "areas of discourse" mentioned in Table 2.

As can be noted from the above, current ways of thinking about innovation and communication imply that communication professionals can usefully engage in a much wider array of activities than the (persuasive or advisory) provision of information in individual decision-making about (non-)adoption, and/or organizing horizontal exchange to support the diffusion of early-adopter experiences to a wider audience. Instead, the activities outlined in Tables 2 and 3 typically encompass multiple tasks and roles in the sphere of process preparation and facilitation.

Communication planning and monitoring in the context of an emergent process

Our widened understanding of the nature of innovation processes and the role of everyday communication and communicative intervention therein is bound to have implications for communication planning. In the past (and perhaps even still today), the dominant way of thinking was that change can be engineered and effectuated through deliberate planning, usually operationalized in the form of "projects" with variable durations (ranging from, say, 6 months to 4 years). Typically, such projects included "communication plans" based on similar assumptions and time horizons. Handbooks on (communication) planning emphasized the need to (1) formulate clear goal hierarchies (ultimate objectives, project objectives, behavioral objectives, communication objectives, etc.); (2) identify well-described target groups; (3) develop specific messages for each group; (4) choose appropriate activities, media, and methods; (5) organize budgets, staff, and other logistics in accordance with these; and (6) monitor and evaluate the achievement of stated goals at certain time intervals (Windahl et al

Table 2. Different conceptualizations of the stages/tasks to be supported by communication, and the kind of information/areas of discourse required in them.

Stages in the (individual) adoption process that require communicative support (Rogers 1962, 1983) (Information required in each stage)	Basic (iterative) tasks to be supported in socio-technical innovation processes (Leeuwis 2004) (Areas of discourse)
(1) Awareness	(1) Awareness of a problematic situation
(information clarifying the existence of a problem addressed by the innovation)	*(the problems different stakeholders experience, and their interrelations)*
(2) Interest	(2) Mobilizing interest in a network of stakeholders
(information about the availability of promising solutions)	*(availability of conducive conditions for the joint development of solutions, willingness of open-minded representatives to engage with each other)*
(3) Evaluation	(3) Socio-technical design and re-design under protective conditions, including ● Experiential (social) learning and exploration among stakeholders ● Negotiation among stakeholders
(information about relative advantages and disadvantages of alternative solutions)	*(perspectives of different stakeholders, options for widening the solution space, likely consequences of different options for different stakeholders)*
(4) Trial	(4) Gradual lifting of protective conditions
(feedback information from one's own or other people's practical experiences)	*(collection and interpretation of feedback that arises from first practical experiences with innovative solutions)*
(5) Adoption/acceptance	(5) Further socio-technical evolution and re-design or failure
(information reinforcing the adoption decision made)	*(reasons to continue/abort, adaptations needed to keep key stakeholders on board, and ways in which the learning process can be communicated/repeated in wider networks)*

1992, Van den Ban and Hawkins 1996). Clearly, such an approach to communication planning does not match well with the idea that objectives are contested, and that innovation emerges from complex, politically laden, uncontrollable, and largely unforeseeable interaction patterns in networks of stakeholders. The facilitation of such processes demands a much more adaptive approach to the professional use of communication than we thought in the past. In particular, it makes little sense to strive hard at achieving predefined and detailed substantive objectives and "deliverables"

Table 3. Examples of possibly relevant communicative strategies for enhancing the basic processes relevant to innovation support.

Network building	Supporting social learning	Dealing with dynamics of power and conflict
● Make an inventory of existing initiatives, complemented with stakeholder analysis. ● Build on existing initiatives for change and the networks around these. ● Arrange contact between disconnected networks that may have compatible interests (e.g., Chinese consumers and African farmers). ● Work toward "coalitions of the willing" and exclude actors that do not feel interdependent. ● Mobilize pressures from outside (carrots and sticks) to enhance feelings of interdependence.	● Demonstrate and visualize interdependencies among stakeholder practices. ● Explore and exchange stakeholder perspectives (values, problems, aspirations, context, etc.) through discussion, role playing, dramatization, visits, filmed interviews, informality, humor, fun, etc. ● Visualize invisible biophysical processes with the help of discovery learning tools or simulation. ● Explore past and current trends and likely futures if nothing changes. ● Use visioning tools and scenario analysis to imagine (and find common ground on) possible futures.	● Identify and propose process facilitators who are credible and trusted by the stakeholders involved. ● Work toward process agreements, including dealing with media, mandates, etc. ● Probe to explicate the interests and fears that underlie mobilized arguments and counter-arguments. ● Steer collaborative research activities (see other column) to questions relevant to less resourceful stakeholders. ● Make stakeholders talk in terms of proposals and counter-proposals. ● Ensure regular communication with constituents to take them along in the process.

Continued on next page

Table 3 continued.

Network building	Supporting social learning	Dealing with dynamics of power and conflict
• Forge contact with outsiders and outside expertise.	• Discuss institutional and other influences that reinforce existing patterns/problems. • Organize contact with others who have encountered and managed similar problems. • Elicit uncertainties that hinder change, and design collaborative investigation and experimentation to develop common starting points. • Use practical actions and experiments as a source of reflection and learning, rather than organizing discussion and reflection only. • Organize regular reflection on process dynamics and satisfaction with outcomes.	• Translate agreed-upon problems and solutions into storylines and symbols that are likely to resonate in society. • Use media and lobby tactics to influence societal agendas and advocate solutions (with the help of storylines/symbols).

Sources: Pretty et al (1995), Loorbach (2007), Smits and Kuhlmann (2004), Weisbord and Janoff (1995), Aarts (1998), Pruitt and Carnevale (1993), Leeuwis (2004).

Box 2: Representing tasks and roles in the Irrigated Rice Research Consortium

At the IRRC workshop on which this book reports, many scholars and professionals have been struggling with tasks as outlined above. However, despite the fact that the IRRC is at times defined as a "learning alliance," these struggles were not always visible and valued.

A telling example of this was a presentation in a session with the already linear title: "Water-Saving Technology: Dissemination and Impacts." A bright young scholar gave a presentation on the outscaling of water-saving technologies. Throughout the presentation, he used the language of technology transfer, adoption, and dissemination, thereby drawing upon Everett Rogers' theories on individual decision-making regarding the adoption of innovations. Only in the subsequent discussion did it appear that he actually spent a great deal of his time on solving conflicts within and between different stakeholders in the irrigation scheme, and on improving the capacity of water management institutions. This seems very appropriate since water management in an irrigation system is a collective affair, and tension and conflict are likely to occur on a regular basis, and certainly when "water saving" is on the agenda. I found it very striking that the presenter did not say anything about the very essential things he was doing in his scholarly presentation. Instead, he continued to reproduce a model of thinking that typically does not apply to irrigation systems, and not to many other problem situations that are typically collective in nature (such as, e.g., rodent control and IPM). Also at other points in the conference, I had the feeling that the IRRC learning alliance was by some interpreted as a "diffusion alliance."

I am convinced that, if we continue to look at and talk about agricultural innovation in terms of "technology dissemination," then we run the risk of overlooking crucial processes. We may, for example, end up spending money on one-sided "technology dissemination" programs, rather than on innovation trajectories in which technical and institutional issues are explicitly tackled simultaneously.

for a given project period. Doing so denies that such ends are likely to be overtaken by emerging dynamics and ever-changing conditions, which may well render them less relevant and opportune, or even obsolete, counterproductive, and self-defeating. Instead, it may be much more useful to formulate broad search directions and objectives at the process level, such as "reaching agreement on collaborative research needed to remove obstacles to alternative energy production systems." Of course, one needs to develop an initial and well-thought-out idea about the kinds of communicative (and other) strategies and activities needed to further such a process objective, but, in order to make progress, such ideas must be continuously adapted as the process unfolds. Although conventional approaches to communication planning seem to be less useful when looked at from the context of an evolving innovation process over a longer time span (as demarcated artificially by one or more "project periods"), principles of communication planning remain essential when thinking at the level of a specific event or activity in a wider process. One cannot hope to realize, for example, a productive meeting between stakeholders with diverging experiences and interests if one does not think carefully about, for example, the purpose such a meeting could or should serve at a specific moment in time, the persons present (or invited) at the meeting, the communication methods and strategies that may be of use, a conducive location for the meeting to be held, a credible hosting organization and/or facilitator, etc., etc. Thus, new understandings about innovation and the role of communication therein do not render communication planning useless altogether, but change the time horizon at which it becomes relevant. On the one hand, the time horizon needs to be much shorter than the typical project period, as one can only usefully "plan" specific activities and events in a specific time and space context. At the same time, the time horizon of more radical innovation efforts needs to be much longer than the typical project horizon since system innovations and transitions require decades rather than years to evolve (Rotmans 2003, Loorbach 2007). The ability to work with a long time horizon is primarily dependent on sustained political and organizational support (Negro 2007) for innovation efforts, and, although this is unlikely to be secured through a conventional communication plan, communication can certainly be an important ingredient for mobilizing and maintaining continued support and perseverance.

The approach to communication planning outlined here clearly needs to be accompanied by a different approach to monitoring and evaluation (M&E) than "establishing whether original substantive objectives and deliverables are effectuated in an efficient manner." It has been acknowledged widely that such a control-oriented approach to M&E may have to be replaced by an approach that can contribute to learning among stakeholders (who have diverging objectives to begin with) (Uphoff 1989, Mosse 1998, Estrella et al 2000, Guijt 1999, 2008). Such learning-oriented monitoring could allow parties in the process to identify and adapt to dynamics and changing conditions (including obstacles and opportunities) in the environment, and reflect critically on their own activities and efforts undertaken, as well as on the institutional setups that (re)produce certain outcomes (Grin et al 2004, Van Mierlo 2007). In this sense, M&E holds the promise of becoming an important mechanism for dealing with complexity and achieving innovation. In a different paper, we propose that for such purposes M&E must not just become participatory and focused on stakeholder perspectives and experiences, but that it also needs to incorporate and investigate theoretically grounded variables associated with "progress" in innovation trajectories. This implies that such M&E should explore variables related to, for example, network building, social learning, conflict management, space for change, discursive dynamics, etc. (see Van Mierlo 2007). In the absence of clearly identifiable substantive objectives at the outset of an innovation trajectory, regular theoretically inspired investigation can inform discussion among participants about whether or not progress has been achieved and on how to proceed in the light of the dynamic context.

The contribution of scientists to innovation[2]

A key conclusion to be drawn here is that—contrary to what many scientists believe—innovation is not primarily about "doing scientific research" or "developing technology" (see also Leeuwis and Remmers 1999). Scientific insight and investigation can play an important and inspiring role in social learning processes and joint fact-finding within a context of negotiation (Van Meegeren and Leeuwis 1999). But, innovation

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[2] This section draws upon Leeuwis (2004).

processes are not likely to be successful if they are scientist-owned and/or -initiated (Leeuwis 1999a, Broerse and Bunders 1999). In a learning and negotiation process, knowledge generated in various locations (e.g., research stations and farmers' fields) by different stakeholders (e.g., researchers and farmers) for dissimilar purposes (e.g., assessing the "truth" and promoting stakeholder interests) and through different procedures of validation (e.g., scientific method and farmer experience) must be creatively articulated and integrated. In innovation processes, then, scientists can be seen as *resource persons* that can play four basic roles during social learning and negotiation processes:

1. *Help explicate implicit assumptions, knowledge claims, and questions*: Discussions among stakeholders usually contain a range of implicit knowledge claims, assumptions, and questions. Frequently, progress in social learning and negotiation processes is hampered when these remain implicit and do not become a point of explicit discussion and reflection. Such explication is far from easy and can never be complete. Nevertheless, not only process facilitators but also scientists from different disciplines can play a useful role in this respect. One may expect from scientists that they have a special sensitivity for the assumptions, knowledge claims, and questions that are hidden in what stakeholders say or do not say about their specific field of expertise. Hence, dialogue between stakeholders and scientists may contribute to making explicit what was implicit previously, and result simultaneously in a coherent set of relevant natural and social science questions.
2. *Joint fact-finding and uncertainty reduction*: Research can play a role in joint fact-finding geared toward answering shared questions and reducing uncertainties that affect the innovation process. The purpose of this type of natural and/or social science research is not only to provide answers but also to build confidence, trust, and shared perspectives among stakeholders by working together on an issue in the first place (Van Meegeren and Leeuwis 1999). Depending on the questions addressed, such research may involve on-farm research, laboratory research by scientists, computer simulations, etc., as long as it remains part of a commonly agreed-upon—and preferably iterative (see Vereijken 1997)—procedure. In the context of such research, scientists also need "free space" to follow their own intuitions (see Van Schoubroeck and Leeuwis 1999).
3. *Feedback*: Results from research can serve as—more or less confrontational—*feedback* in order to induce learning, that is, through the creation of new problem definitions. Such *feedback* from natural and/or social scientists may be provided by research data on the existing situation, but may also arise from comparison with totally different situations (including laboratories) or computer-based projections about the future (Rossing et al 1999, Röling 1999). This can also include comparison with radically new technological and organizational solutions. These latter kinds of feedback may serve to enlarge the space within which solutions are searched for. Given that scientists' questions, concerns, and conclusions are never neutral, it is important that, when

giving feedback, scientists are transparent and explicit about the implicit dimensions (e.g., underlying aspirations and assumptions) of the knowledge and insights they bring in (Alrøe and Kristensen 2002). Such transparency does not imply that scientists become "politicians." On the contrary. When scientists are clear about their underlying aspirations and values, it becomes clear that clashes between interests cannot be resolved by scientists, but that it is the task of societal stakeholders, administrators, and politicians to value and appreciate the insights put forward and make choices.

4. *Process monitoring*: Research can play a role in monitoring the social dynamics of the learning and negotiation process itself in order to inform its organization and further facilitation. How are relations between stakeholders developing? Which new developments, questions, wishes, and problems emerge? How do these affect progress, and what can be done about it?

The above view on the role of scientists is consistent with what the philosophers Funtowicz and Ravetz (1993) have called "*postnormal*" science. They argue that in situations where uncertainty is high and where different values and interests are at stake, applied scientists cannot resort usefully to "normal" strategies of "puzzle solving" and/or professional consultancy. Rather, they need to play an active role in societal discussions and innovation processes. It is important to realize here that playing a role as outlined above requires different modes of operation by scientists than are currently dominant. It requires, for example, (1) intensive cooperation between stakeholders, change agents, and researchers; (2) cross-disciplinary cooperation among scientists (as the solving of problems may well involve integration of insights from various disciplines); (3) greater emphasis on on-farm experimentation; and (4) new procedures for setting research agendas, etc. (see also Bouma 1999, Van Schoubroeck and Leeuwis 1999, Vereijken 1997). Contrary to critiques that such new modes of working do not allow for "real science," we feel that they by no means imply a devaluation of scientific endeavor. It is true that "interactive science" (Röling 1996) may require changes in the type of research questions asked, their origin, and/or the objects of research, but we prefer to look at these as new academic (conceptual, methodological, and epistemological) challenges.

Conclusions

The starting point for this paper was that, despite major theoretical developments in the innovation sciences, this has not resulted in a reconceptualized view on the role of communicative intervention in innovation processes. As a result, explicit attention to communication and communication professionals is still often associated with linear terms such as diffusion and dissemination. And, although it is self-evident that communication is an essential process in more interactive, constructive, evolutionary, or system-oriented approaches, it is dealt with in a rather implicit way. In this chapter, we have made an effort to be more explicit, and to systematically rethink the role of communicative intervention in innovation processes. Our résumé of major theoretical shifts in the innovation sciences led us to establish that innovation is a collective process that involves the contextual re-ordering of relations in multiple social networks, and that such re-ordering cannot be usefully understood in terms of “diffusing” ready-made innovations. Hence, we concluded that we need to think about communication as playing a role in innovation development and design. Because of the complex nature of innovation and innovation processes, change agents and communication professionals are unlikely to be effective if they conceptualize their role as the communicative engineering and planning of predefined changes. At a more abstract level, we have argued that we may look at their role as enhancing the survival chances of existing initiatives for change by facilitating their becoming more effectively adapted and/or linked to their dynamic selection environment than competing initiatives. In practical terms, this involves applying a range of process facilitation strategies in the sphere of network building, social learning, and conflict management. While in the linear model communication was primarily seen as an intermediary function between science and practice (e.g., in the form of agricultural extension in a technology transfer mode), we now see a much broader range of intermediary roles. As indicated in Table 3, these include, for example, mediation in conflict situations; network and knowledge brokerage; facilitation of exchange, learning, and vision building among diverse communities; matching of supply and demand of innovation support services (e.g., research); etc. Moreover, the intermediary roles that we are discussing now happen at a range of interfaces that are situated within (and between) networks of stakeholders operating in different societal spheres. In terms of substance, such intermediary processes do not mainly address the qualities of given technologies in connection with assumed or proposed problems (as in the linear model), but rather center on a range of human aspects and attributes that bear relevance to the building of networks and reaching agreement, coherence, and congruence (Röling 2002, Grin and Van de Graaf 1996) within and between them. Such attributes include, for example, stakeholder characteristics, interests, perspectives, motives, agendas, fears, visions, uncertainties, questions, etc. In practice, we see indeed that such broader intermediaries have indeed emerged in present-day innovation systems (see Smits and Kuhlmann 2004, Howells 2006, Klerkx and Leeuwis 2008), and complement the activities of classical intermediaries that focus on disseminating technology. At the same time, a range of authors signal that there is still considerable scope for strengthening the quality and position of such intermediaries in innovation landscapes (Hall 2005, Smits and Kuhlmann 2004, Klerkx 2008). In the context of agriculture, an important question here is whether agricultural extension organizations are willing and able to play broader roles. These organizations have always had the mandate to play an intermediary role in innovation processes, and could in principle expand their activities to include those mentioned in Table 3. However, this would have to go along with considerable change in terms of staffing and organizational capacities (see Leeuwis 2004). Finally, we have argued that changing views of innovation also have implications for the role of scientists. In order to ensure that research contributes to societal innovation, scientists could focus on explicating implicit assumptions, claims, and knowledge gaps in social learning processes, and engaging in collaborative research with societal stakeholders on a coherent set of natural science and social science questions.

References

Aarts MNC. 1998. Een kwestie van natuur; een studie naar de aard en het verloop van communicatie over natuur en natuurbeleid. Published doctoral dissertation. Wageningen Agricultural University, Wageningen.

Alrøe H, Kristensen ES. 2002. Towards a systemic research methodology in agriculture: rethinking the role of values in science. Agric. Human Values 19:3-23.

Beal GM, Rogers EM. 1959. The scientists as a referent in the communication of new technology. Public Opin. Q. 22:555-563.

Bijker W, Hughes T, Pinch T, editors. 1987. The social construction of technological systems: new directions in the sociology and history of technology. Cambridge, Mass. (USA): MIT-Press.

Bouma J. 1999. The role of research chains and user interaction in designing multi-functional agricultural production systems. In: Leeuwis C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 219-235.

Bowers RV. 1938. Differential intensity of intra-societal diffusion. Am. Sociol. Rev. 3:21-31.

Broerse JEW, Bunders JFG. 1999. Pitfalls in implementation of integral design approaches to innovation: the case of the Dutch Special Programme on Biotechnology. In: Leeuwis C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 245-265.

Callon M, Law J, Rip A, editors. 1986. Mapping the dynamic of science and technology: sociology of science in the real world. Macmillan, London.

Checkland PB. 1988. Soft systems methodology: an overview. J. Appl. Syst. Anal. 15:27-30.

Dunn ES. 1971. Economic and social development: a process of social learning. Baltimore, Md. (USA): Johns Hopkins University Press.

Engel PGH. 1995. Facilitating innovation: an action-oriented and participatory methodology to improve innovative social practice in agriculture. Published doctoral dissertation. Wageningen Agricultural University, Wageningen, Netherlands.

Estrella M, Blauert J, Campilan D, Gaventa J, Gonsalves J, Guijt I, Johnson DA, Ricafort R, editors. 2000. Learning from change: issues and experiences in participatory monitoring and evaluation. Intermediate Technology Publications, London.

Friedmann J. 1984. Planning as social learning. In: Korton DC, Klaus R, editors. People centered development: contributions towards theory and planning frameworks. West Hartford, Conn. (USA): Kumarian Press. p 189-194.

Funtowicz SO, Ravetz JR. 1993. Science for the post-normal age. Futures 25:739-755.

Geels F. 2002. Understanding the dynamics of technological transitions: a co-evolutionary and socio-technical analysis. Twente University Press, Enschede.

Geels FW, Schot JW. 2007. Typology of sociotechnical transition pathways. Res. Policy 36(3):399-417.

Grin J, Van de Graaf H. 1996. Technology assessment as learning. Sci. Technol. Human Values 20(1):72-99.

Grin J, Felix F, Bos B, Spoelstra S. 2004. Practices for reflexive design: lessons from a Dutch programme on sustainable agriculture. Int. J. Foresight Innovation Policy 1(1-2):126-149.

Guijt I. 1999. Participatory monitoring and evaluation for natural resource management and research. Best practice guidelines, socio-economic methodologies. Natural Resource Institute/DFID, Chatham/London.

Guijt I. 2008. Seeking surprise: rethinking monitoring for collective learning in rural resource management. PhD thesis. Wageningen University, Wageningen, Netherlands.

Hajer MA, Laws D. 2006. Ordering through discourse. In: Moran M, Rein M, Goodin RE, editors. The Oxford handbook of public policy. Oxford (UK): Oxford University Press. p 249-266.

Hall A, Bockett G, Taylor S, Sivamohan MVK, Clark N. 2001. Why research partnerships really matter: innovation theory, institutional arrangements and implications for developing new technology for the poor. World Dev. 29(5):783-797.

Hall A. 2005. Capacity development for agricultural biotechnology in developing countries: an innovation systems view of what it is and how to develop it. J. Int. Dev. 17(5):611-630.

Holling CS. 1995. What barriers? What bridges? In: Gunderson LH, Holling CS, Light SS, editors. Barriers and bridges to the renewal of ecosystems and institutions. New York (USA): Colombia University Press. p 3-37.

Hommels A, Peters P, Bijker WE. 2007. Techno therapy or nurtured niches? Technology studies and the evaluation of radical innovations. Res. Policy 36(7):1088-1099**.**

Howells J. 2006. Intermediation and the role of intermediaries in innovation. Res. Policy 35:715-728.

Kemp R, Rip A, Schot J. 2001. Constructing transition paths through the management of niches. In: Garud R, Karnøe P, editors. Path dependence and creation. London: Lawrence Erlbaum Associates. p 269-299.

Klerkx L, Leeuwis C. 2008. Matching demand and supply in the agricultural knowledge infrastructure: experiences with innovation intermediaries. Food Policy 33:260-276.

Klerkx L. 2008. Matching demand and supply in the Dutch agricultural knowledge infrastructure: the emergence and embedding of new intermediaries in an agricultural innovation system in transition. PhD dissertation. Wageningen University, Wageningen, Netherlands.

Kline SJ, Rosenberg N. 1986. An overview of innovation. In: Landau R, Rosenberg N, editors. The positive sum strategy: harnessing technology for economic growth. Washington, D.C. (USA): National Academic Press. p 275-305.

Law J, Hassard J. 1999. Actor network theory and after. Blackwell Publishers/The Sociological Review. Oxford/Malden, Mass., USA.

Latour B. 1987. Science in action. Open University Press, Milton Keynes.

Leeuwis C, editor. 1999. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden.

Leeuwis C, Remmers G. 1999. Accomodating dynamics and diversity in integral design. In: Leeuwis C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 267-277.

Leeuwis C. 2002. Making explicit the social dimensions of cognition. In: Leeuwis C, Pyburn R, editors. Wheelbarrows full of frogs: social learning in rural resource management. Assen (Netherlands): Royal Van Gorcum. p 391-406.

Leeuwis C (with contributions by A. Van den Ban). 2004. Communication for rural innovation: rethinking agricultural extension. Oxford, Mass. (USA): Blackwell Science.

Leeuwis C, Pyburn R, editors. 2002. Wheelbarrows full of frogs: social learning in rural resource management. Assen (Netherlands): Royal Van Gorcum.

Loorbach D. 2007. Transition management: new mode of governance for sustainable development. PhD dissertation. Erasmus University, Rotterdam, Netherlands.

Lundvall BA. 1992. National systems of innovation: towards a theory of innovation and interactive learning. Pinter, London.

Mosse D. 1998. Process-oriented approaches to development practice and social research. In: Mosse D, Farrington J, Rew A, editors. Development as process: concepts and methods for working with complexity. London: Routledge. p 3-30.

Negro SO. 2007. Dynamics of technological innovation systems: the case of biomass energy. Netherlands Geographical Studies 356. Utrecht: Copernicus Institute for Sustainable Development and Innovation.

Nelson R, Winter S. 1977. In search of a useful theory of innovation. Res. Policy 6(1):36-76.

Pretty JN, Guijt I, Thompson J, Scoones I. 1995. Participatory learning and action: a trainer's guide. IIED, London.

Prigogine I, Stengers I. 1984. Order out of chaos: man's new dialogue with nature. New York (USA): Bantam Books.

Pruitt DG, Carnevale PJ. 1993. Negotiation in social conflict. Buckingham (UK): Open University Press.

Rip A. 1995. Introduction of new technology: making use of recent insights from sociology and economics of technology. Technol. Anal. Strategic Manage. 7:417-431.

Rogers EM. 1962. Diffusion of innovations. 1st edition. New York (USA): Free Press.

Rogers EM. 1983. Diffusion of innovations. 3rd edition. New York (USA): Free Press.

Röling NG. 1988. Extension science: information systems in agricultural development. Cambridge (UK): Cambridge University Press.

Röling NG. 1989. The agricultural research-technology transfer interface: a knowledge systems perspective. ISNAR, The Hague, Netherlands.

Röling NG. 1992. The emergence of knowledge systems thinking: a changing perception of relationships among innovation, knowledge process and configuration. Knowl. Policy: Int. J. Knowl. Transfer Utiliz. 5:42-64.

Röling NG. 1994. Voorlichting en innovatie. In: Röling NG, Kuiper D, Janmaat R, editors. p 275-294.

Röling NG. 1996. Towards an interactive agricultural science. Eur. J. Agric. Educ. Ext. 2:35-48.

Röling NG. 1999. Modelling the soft side of land: the potential of multi-agent systems. In: Leeuwis C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 73-97.

Röling NG. 2002. Beyond the aggregation of individual preferences: moving from multiple to distributed cognition in resource dilemmas. In: Leeuwis C, Pyburn R, editors. Wheelbarrows full of frogs: social learning in rural resource management. Assen (Netherlands): Royal Van Gorcum. p 25-47.

Rossing WHA, Van Ittersum MK, Ten Berge HFM, Leeuwis C. 1999. Designing land use options and policies: fostering co-operation between Kasparov and Deep Blue? In: Leeuwis, C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 49-72.

Rotmans J. 2003. Transitiemanagement. Sleutel voor een duurzame samenleving. Van Gorcum, Assen, Netherlands.

Rotmans J, Kemp R, Van Asselt MBA. 2001. More evolution than revolution: transition management in public policy. Foresight 3(1):15-31.

Ryan B, Gross NC. 1943. The diffusion of hybrid seed corn in two Iowa communities. Rural Sociol. 8:15-24.

Smits R. 2000. Innovatie in de universiteit. Inaugurele rede. Universiteit Utrecht, Utrecht.

Smits R. 2002. Innovation studies in the 21st century: questions from a user's perspective. Technol. Forecasting Soc. Change 69:861-883.

Smits R, Kuhlmann S. 2004. The rise of systemic instruments in innovation policy. Int. J. Foresight Innov. Policy 1:4-32.

Uphoff N. 1989. Participatory evaluations of participatory development: a scheme for measuring and monitoring local capacity. Cornell University, New York.

Van den Ban AW. 1953. Wie worden door de landbouwvoorlichtingsdienst bereikt? Landbouwkundig Tijdschrift 65:317-327.

Van den Ban AW. 1961. Research in the field of advisory work. Netherlands J. Agric. Sci. 9:122-133.

Van den Ban AW. 1974. Inleiding tot de voorlichtingskunde. Boom, Meppel/Amsterdam.

Van den Ban AW, Hawkins HS. 1996. Agricultural extension. 2nd edition. Oxford, Mass. (USA): Blackwell Science.

Van Meegeren RCF, Leeuwis C. 1999. Towards an interactive design methodology: guidelines for communication. In: Leeuwis C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 205-217.

Van Mierlo B. 2002. Kiem van maatschappelijke verandering. Verspreiding van zonnecelsystemen in de woningbouw met behulp van pilot projecten. Amsterdam, Aksant.

Van Mierlo B. 2007. Reflexive process monitoring. Working Document. Wageningen University, Wageningen, Netherlands.

Van Schoubroeck F, Leeuwis C. 1999. Enhancing social cognition for combating the Chinese citrus fly in Bhutan. In: Leeuwis C, editor. Integral design: innovation in agriculture and resource management. Mansholt Institute/Backhuys Publishers, Wageningen/Leiden. p 145-171.

Van Woerkum CMJ, Aarts MNC. 2002. Wat maakt het verschil. Over de waarde van pluriformiteit in interactieve beleidsprocessen. Innovatie Netwerk Groene Ruimte en Agrocluster, Den Haag.

Vereijken P. 1997. A methodical way of prototyping integrated and ecological arable farming systems (I/EAFS) in interaction with pilot farms. Eur. J. Agron. 7:235-250.

Vijverberg AJ. 1997. Glastuinbouw in ontwikkeling. Beschouwingen over de sector en de beïnvloeding ervan door de wetenschap. Eburon, Delft.

Weisbord MR, Janoff S. 1995. Future search: an action guide to finding common ground in organizations and communities. Berrett-Koehler Publishers Inc, San Francisco.

Windahl S, Signitzer BH, Olson JT. 1992. Using communication theory: an introduction to planned communication. Sage, London.

Woodhill J. 2002. Sustainability, social learning and the democratic imperative: lessons from the Australian landcare movement. In: Leeuwis C, Pyburn R, editors. Wheelbarrows full of frogs: social learning in rural resource management. Assen (Netherlands): Royal Van Gorcum. p 317-331.

Notes

Author's address: Communication and Innovation Studies, Wageningen University, The Netherlands. Email: Cees.Leeuwis@wur.nl.

Part I
IRRC Country Outreach Programs

Dissemination of Integrated NRM for Lowland Rice

Dissemination of integrated natural resource management practices for lowland rice in the Philippines

A.M. Corales, L.C. Javier, and K.E.T. Barroga

This chapter presents salient information on the Philippine rice industry, including the rice research, development, and extension situation. The focus, however, is on the implementation of the Irrigated Rice Research Consortium Country Outreach Program (ICOP) Philippines—from its evolution to the inclusion of its technologies in the PalayCheck platform of PhilRice and to its upscaling to the National Rice Program of the Department of Agriculture. The role of partnerships in adapting and promoting technologies proved paramount in the success of ICOP Philippines as it completed IRRI's partnership with PhilRice, which had mostly been on research. Highlights of the technologies identified (i.e., site-specific nutrient management, ecologically based rodent pest management, alternate wetting and drying, use of a drum seeder and moisture meter), tested, and promoted, and the strategies taken to improve their use are discussed in this chapter. How the gap between research and extension was bridged as well as suggestions on how to further improve ICOP implementation are also provided.

The Philippines has a land area of 30 million hectares, 47% of which is agricultural land (NSO 2007). Of the agricultural land, the total area devoted to rice is 2.58 million ha (NSO 2007) but only 55% of this area is irrigated. This has limited farmers' harvest because 75% of the country's total rice production comes from irrigated areas (BAS 2008). The average yield in irrigated areas in 2007 was 4.20 t ha^{-1}.

Additionally, Filipino farmers face many geographical challenges, including the country being an archipelago and having no major river deltas, unlike many of its rice-exporting Asian counterparts. Typhoons frequent the country, averaging three each month from July to October, coinciding with the main cropping season. Compounding this situation are factors such as the growing Philippine population and the high per capita rice consumption. As of 2007, the Philippines had a population of 88.6 million (NSO 2007) and an estimated rice consumption per person of 126 kg (BAS 2008).[1]

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[1] The average rice consumption in Southeast Asia was 143 kg/person/year in 2005 (IRRI 2006).

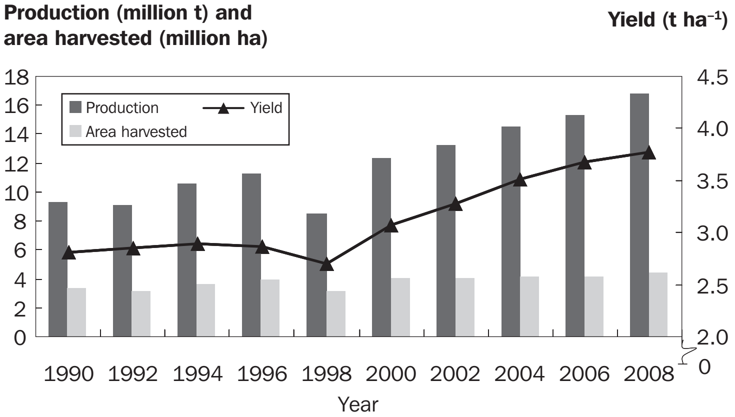

Fig. 1. Rice (unhusked) production, area harvested, and yield in the Philippines, 1990-2008 (source of data: PhilRice).

A main staple of the majority of Filipinos, rice accounts for 25% of the annual food expenditure of those in the lowest income bracket (Balisacan and Sebastian 2006). Forty-one percent of the total caloric intake and 31% of the total protein intake of the population also come from rice (IRRI 2006). These underscore the value of rice as food to a Filipino family. As a source of livelihood, 11.5 million farmers, including their family members and other parties involved in the rice industry (e.g., millers, traders, etc.), depend on rice for income and employment (Sebastian et al 1999). Hence, despite the constraints, it is imperative for Filipino farmers to produce more rice.

The country has set out a challenge to produce 21.6 million tons of rice by 2013 to achieve rice self-sufficiency (PhilRice 2008). Although Philippine rice production has increased in recent years (Fig. 1) despite these constraints, the growth rate of rice yield actually declined from 2.4% in the early 1980s to 1.7% from 1990 to 2006 (IRRI 2002, PhilRice 2007). The total area of rice harvested has not significantly changed as well. Farmers also confront a new set of production constraints. The supply of resources to rice production, including water, soil nutrients, and labor, is all under pressure. Contributing factors include increasing population, inappropriate use of purchased inputs, and economic development (Morris and Byerlee 1998, Pheng Kam 2003). In turn, the scarcity of these resources is leading many farmers to cultivate the same area of land at least twice. Intensification of land use eventually leads to a decline in rice productivity owing to undesirable ecological consequences, such as increased pest buildup, incidence of soil toxicities relating to chemical content and pollutants in irrigation water, salinity, and waterlogging (Pingali 1998, Hossain and Narciso 2004, Gollin et al 2005).

Farmers need to contend as well with the technical and economic challenges of rice production. These include the high cost of inputs, low price of paddy (unmilled) rice, lack of capital and postharvest facilities, limited labor, incidence of pests and diseases, inadequate irrigation systems, limited knowledge to correctly use fertilizers,

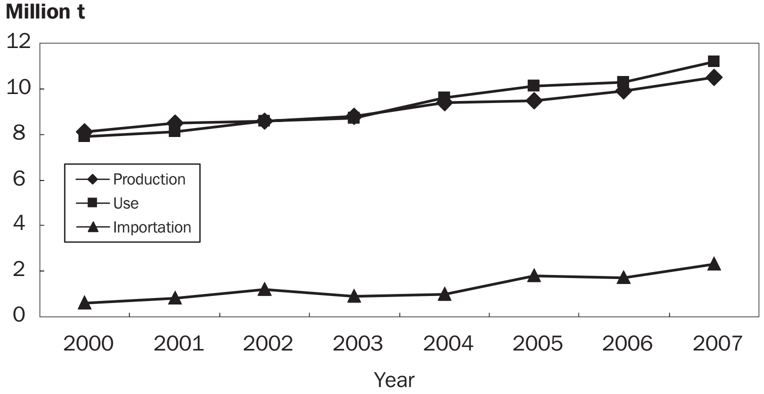

Fig. 2. Milled rice production, use, and importation, 2000-07 (source of data: PhilRice and BAS).

and postproduction losses (PhilRice 2002, 2008). Thus, the Philippines often still had to resort to importation, with average imports from 2000 to 2007 recorded at 1.2 million tons (Fig. 2). Given all this, the challenge is not just to produce more rice but to produce rice at lesser cost and in a sustainable manner.

The rice research, development, and extension system

The country's rice research, development, and extension agencies work together in helping farmers to produce enough rice for the Philippines, mainly through the development and delivery of production technologies. In 2002, rice accounted for almost 30% of the research conducted on crops (Gert-Jan et al 2007), the highest among all crops. It is the Philippine Rice Research Institute (PhilRice), a government-owned and controlled organization under the Department of Agriculture (DA) created in 1985, that leads in the planning, implementation, coordination, and monitoring of rice research and development (R&D) efforts. PhilRice accomplishes this mission through a National Rice R&D Network currently composed of 57 government organizations and a National Rice Seed Network of 115 seed centers. Annually, members of these networks meet to present and discuss their accomplishments, discuss relevant concerns affecting rice R&D, and plan how to address them.

With the International Rice Research Institute (IRRI) headquartered in the Philippines, PhilRice and IRRI collaborate in many different areas of rice R&D. IRRI used to be the main provider of rice-related research in the country until PhilRice was created. Now, every other year, a Philippines-IRRI work plan meeting[2] is held to discuss proposed, ongoing, and completed collaborative rice-related projects with IRRI. Aside from IRRI and PhilRice, the University of the Philippines at Los Baños

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[2] This used to be a tripartite meeting among UPLB, PhilRice, and IRRI until 2006.

(UPLB), the Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development (PCARRD), and the Bureau of Agricultural Research (BAR) are key participants in this meeting.

UPLB, particularly its College of Agriculture, conducts various rice R&D activities and it has bred (e.g., C4 64, UPL Ri7) and continues to breed rice varieties for various ecosystems in partnership with PhilRice and IRRI. PCARRD and BAR both act as coordinating bodies of agricultural R&D activities in the country; thus, there are overlaps in functions. BAR is more specific to agriculture and fisheries R&D while PCARRD, aside from covering agriculture, also coordinates research in forestry, marine, and natural resource management. PCARRD is under the administrative responsibility of the Department of Science and Technology (DOST) while BAR is under the DA.

Other organizations involved in rice R&D are the Bureau of Plant Industry, the National Irrigation Administration, the Bureau of Soils and Water Management, the Philippine Center for Development and Mechanization (formerly the Bureau of Postharvest Research and Extension), the Bureau of Agricultural Statistics, DA-Regional Integrated Agricultural Research Stations, the Agricultural Training Institute, and several state colleges and universities.

Although the positive impacts of rice R&D (PhilRice and BAR 2008) have been widely documented, there are acknowledged challenges to the system, such as the following (PhilRice and FAO 2001, Labios 2003, Gapasin 2005, Sebastian et al 2005):

- Weak links between R&D and extension—This could be attributed to the transitional problems (see below for examples) associated with the devolution of agricultural extension services to local government units (LGU). In addition, there is still a limited feedback mechanism between research and extension, and limited mainstreaming of participatory approaches among research organizations.
- Underfunding of R&D—Government funding has increased by only 0.28% per annum in real terms over the past 10 years (i.e., 1994-2004). Furthermore, despite the high percentage of research on rice as mentioned earlier, rice R&D is only 0.10% of the country's gross value added in agriculture over the past 10 years (Balisacan and Sebastian 2006).
- Limited capacity development and incentives for R&D workers—This has made it difficult to attract and maintain highly qualified scientists.
- Unclear accountability to clients and donors—Many scientists have tended to develop technologies based on their expertise, rather than catering to farmers' needs and their available resources.

While the rice R&D sector was consolidated and unified under the coordination of PhilRice, the government's extension system was decentralized.[3] Agricultural extension decentralization took effect under the Local Government Code of 1991. Thus, instead of one central government agency (i.e., Agricultural Training Institute

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[3] The paragraphs on the extension system draw largely on Barroga (2009).

or ATI) that would supervise and facilitate agricultural extension services, these responsibilities were devolved to the LGUs. The local chief executive of each province, city, or municipality became responsible for overseeing the agricultural situation in his/her locality. Decentralization-related issues and concerns surfaced, weakening the extension system.

Several authors (Brillantes et al 2007, Ponce 2006, Labios 2003) noted that agricultural extension became a low priority or a matter of patronage for many local officials, who seemed to have not yet fully grasped its nature and scope. This led to budget reductions or misappropriations for technology dissemination activities, thereby limiting the number of farmers that could be reached. The low or misappropriated budget allocation to agricultural extension eventually contributed to the demoralization of extension personnel. David et al (2002) reported that training courses tailored to extension workers were lacking or that LGUs either lacked the funds for staff development or did not consider this a priority. The devolution also led to highly dispersed and uncoordinated extension offices that increased transaction costs and slowed down the flow of technologies from the R&D sector (Gapasin 2005).

In addition, if data show that 2.58 million hectares are planted to rice and there are 8,000 rice ATs in the country (Cardenas 2005), then each rice AT handles 322 ha or around 160 farmers on average. Although this may not be a bad farmer-to-AT ratio, this is not usually achieved, apparently because of the reported very low level of traveling allowances (Php300–500/month) that most LGUs provide to their ATs. A Commission on Audit guideline does not provide for traveling allowances to government personnel within a 50-km radius from their official station.

On a positive note, David et al (2002) reported that LGUs with innovative leaders, who saw the opportunities in devolution, were able to initiate successful rice programs with high farmer involvement. Unfortunately, there are only a few such examples. Most LGUs have preferred to implement nationally initiated rice programs perhaps because this provides an opportunity to acquire additional funding and it means taking directives only from the DA. This arrangement suits their limited operational budget and low capability to package project proposals for external funding (David et al 2002).

Aside from devolution-related issues, Tolentino (2002) points out another major problem in the system, particularly involving DA-initiated national rice production programs. He argued that with the frequent leadership changes in the national level of the DA since 1986 (i.e., average of less than two years' term of office when the law provides for six years), programs and activities have kept changing as well. Thus, only short-term gains were experienced owing to the insufficient amount of time to fine-tune programs. This has impeded the growth of an effective agriculture-sector bureaucracy, and this has had impacts on the effectiveness and credibility of officials and extension workers operating at district and village levels according to Tolentino (2002). Needless to say, dissemination and adoption of rice production technologies integral to these programs were likewise affected.

To address some of the issues mentioned, the Agriculture and Fisheries Modernization Act (AFMA), or RA 8435, of 1997 strengthened ATI's role as the extension and training arm of the DA (Palis et al, n.d.). ATI was tasked to design and implement programs consistent and functionally integrated with the regional agriculture and fisheries development strategy and program. Five years later, the ATI, through DA Special Order No. 115, was assigned the Major Final Output on Extension Support, Education, and Training Services (MFO-ESETS) that supports the AFMA. A Work Group for the MFO-ESETS was created to harmonize all DA extension services to come up with a unified extension system for the agriculture and fishery sectors from the national up to the farmer level, in coordination with the DA-Regional Field Units (DA-RFUs), SUCs, LGUs, and all appropriate government agencies, as well as private extension service providers. The Work Group subsequently adopted the name Agriculture and Fisheries Extension Network (AFEN) in view of its expansion as a network of all agriculture and fisheries extension players of the country. Each member agency is allowed to maintain and provide for its own extension activities. For example, in the case of the rice training service, PhilRice conducts the 4-month Rice Specialist Training Course for personnel of ATI regional offices, DA-RFU, and LGU ATs. The ATI and DA-RFU conduct season-long Training of Trainers for LGU ATs, while the LGU ATs train the farmers on rice production. This confirms the nature of extension in the country as pluralistic and it is a way to cope with the extension needs of farmers, fisherfolk, as well as extension staff.

An Agriculture Extension Bill has also been proposed to transform the ATI into the Philippine Agriculture and Fisheries Extension Agency (PAFEA), thus expanding ATI's limited mandate. The PAFEA will be tasked to plan, make policies, and manage knowledge resources, as well as provide other extension services. The bill also proposes that grant aid be given by the national government to increase the resources of LGUs, especially the fourth- to sixth-class municipalities. These grants will be used to address the often-cited problem that municipalities have funds only for personnel salaries, but none for operations, thus severely limiting the productivity and usefulness of ATs.

On the other hand, PhilRice ensures that rice production technologies developed by the rice R&D network are still disseminated to the farmers by partnering with other extension providers, such as NGOs, private companies, farmers' associations, other government agencies, and even a few media groups. For these extension partners, PhilRice provides training programs, seeds, information materials, and other forms of technical assistance in a resource-sharing scheme to facilitate their services to farmers. Some partnerships proved successful, while others turned out to be short-lived and difficult to sustain, or experienced operational problems.

Implementation and dynamics of ICOP Philippines

Evolution

The appointment of PhilRice's Technology Promotion Program leader to the Irrigated Rice Research Consortium's (IRRC) steering committee in 2005 somehow facilitated the involvement of PhilRice in the establishment of the IRRC Country Outreach Program, ICOP-Philippines. Soon after her appointment, the IRRC coordinator visited

PhilRice and a plan was made to start the ICOP. The plan was to integrate the ICOP or put it into the Institute's Technology Promotion Program structure rather than having the ICOP appear as a separate project. The aim was to save on resources and avoid making it appear to PhilRice staffers as an additional load. Accommodating the ICOP activities into the Program was easy because the Program has an area-based project component. This component aims to localize and promote rice production technologies in different rice-growing areas of the country, with leadership coming from PhilRice's different branch stations.

To set the ICOP in motion, a training workshop titled "Implementing Component Technologies for Irrigated Rice" was conducted at the PhilRice Central Experiment Station, Maligaya, Science City of Muñoz, Nueva Ecija, on 23-25 January 2006. The workshop was intended to introduce the IRRC and the technologies it has developed to the project leaders of the Technology Promotion Program,[4] including selected partners from the provincial governments of Pangasinan and Nueva Ecija. The provinces of Nueva Ecija and Pangasinan were included immediately in view of favorable partnerships with them in the past and being major rice-producing provinces. In addition, their proximity to the PhilRice central station made it easy for them to participate in the training. This cuts short the need for PhilRice to explain the project to them. Scientists from IRRI and from PhilRice served as resource persons during the training workshop. From the group discussions, a work plan was developed for each area represented in the workshop. This involved identifying which among the technologies presented are needed in their area and that they would be able to evaluate and promote. The following technologies were initially identified for the following areas: site-specific nutrient management (SSNM)—Isabela, Pangasinan, and Cotabato; alternate wetting and drying (AWD)[5]—Pangasinan and Ilocos Norte; ecologically based rodent pest management (EBRM)—Nueva Ecija; direct seeding (use of human-pulled row seeder)—Cotabato; and grain postproduction (use of polyethelene plastic for palay seed storage and use of IRRI-designed moisture meter)—Isabela and Ilocos Sur. It was agreed that these would be starting or entry technologies. Thus, more technologies may be added in the future if there is a demand by farmers in their areas.

It is noteworthy that, at the time the workshop was held, PhilRice was developing the PalayCheck (Rice Check) to promote integrated crop management. Thus, the plan was to eventually incorporate successful technologies for inclusion in the PalayCheck platform to facilitate upscaling. From PhilRice experience, the DA always asks PhilRice for new technologies to promote to farmers nationwide as part of the national rice program.

To formalize PhilRice's partnership with the IRRC in the implementation of the ICOP, a letter of agreement (LOA) was signed between PhilRice and IRRI in March 2006. IRRC's work with PhilRice prior to this, specifically with the Water and Labor-

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[4] Starting in July 2006, the program was reorganized and renamed as the Knowledge Management and Promotion Program (KMP).

[5] AWD is promoted as controlled irrigation by PhilRice.

Savings Work Group, was included as well in the LOA to improve coordination and monitoring.

As earlier thought of, the ICOP technologies were eventually included in the PalayCheck platform of PhilRice. In 2007, the PalayCheck was then upscaled to the National Rice Program of the DA named FIELDS (Fertilizer, Irrigation, Extension, Loans, Dryers, and Seeds).

Partnerships

Most partnerships between PhilRice and IRRI in the past were purely on research. The ICOP is one of the major partnerships in the area of technology adaptation and promotion. The IRRC team of researchers either works with some PhilRice researchers and development specialists (technology promotion staffers) or only with development specialists. The collaborative project was forged to help farmers enhance their productivity and profitability through the use of improved and environment-friendly technologies in rice production, an objective to which both PhilRice and IRRC/IRRI commonly subscribe. Specifically, it aims to test and adapt IRRC technologies and showcase their benefits in increasing yield. In the process, the IRRC has also helped develop the capacity of development specialists and ATs, particularly those who have shown commitment to the project. The IRRC provided opportunities for these people to participate in training programs sponsored by IRRI.

Several other partnership projects branched out or were further strengthened owing to the collaboration. IRRI's presence is believed to have added more interest among local partners given its international stature. The majority of the partners in the ICOP have been PhilRice's network of reliable partners in its technology promotion activities.

PhilRice's selection criteria for its agency project partners include the following: willingness to share resources (e.g., funds, human resources, time, transportation, farm); identifies with and believes in the project goal/objective; and has demonstrated ability to get the job done. For example, PhilRice worked with the Office of the Provincial Agriculturist (OPAg) in Pangasinan to promote site-specific nutrient management and AWD. PhilRice has worked with OPAg-Pangasinan and knows that the provincial agriculturist and the staff perform well and have always been willing to share their resources. Being a major rice-producing province, it definitely wants to further improve its yield at reduced cost and with more efficient use of inputs. Together with the National Irrigation Administration (NIA), PhilRice promoted alternate wetting and drying as the technology that will work best with NIA's cooperation and NIA will benefit from the technology as well. Thus, NIA shared its resources with the project.

Additionally, PhilRice organized/facilitated meetings with IRRI and key officials in the DA, such as with the National Rice Program director. This is to gain the DA's support in the upscaling of IRRC technologies, which eventually happened.

Methodology

The technologies to be tested, adapted, and promoted in the different localities, in general, were first identified by technology promotion project leaders who were participants in the January 2006 workshop. By the nature of their work, these project leaders had a very good idea of the farmers' production constraints in their areas and thus knew what technologies were needed. For Nueva Ecija and Pangasinan provinces, the presence of personnel from their respective OPAg made it easier for PhilRice to identify the technologies that the province wanted to evaluate. This step of introducing the range of IRRC technologies available was considered critical to level off understanding and expectations about these technologies.

Identification of the specific sites as to where to test and promote the technologies in their areas was determined by the project leaders during the workshop. However, upon return to their respective areas, they had to consult this with the LGUs and explain how they could benefit from the project. In the case of Nueva Ecija and Pangasinan, the identification of a specific municipality was made by the OPAg personnel in consultation with the provincial agriculturist and other provincial ATs. After the municipalities were identified, PhilRice and OPAg officials met with the respective municipal agriculturists to discuss the project and identify the specific villages where the project would be demonstrated. The village officials, particularly the head or any of the village councilors, were approached to discuss the project. Possible sites were identified and selected, and a meeting with potential participants was scheduled to discuss the mechanics of the project. In the case of Pangasinan, since seven sites were identified, training of selected site leaders and municipal ATs was conducted with ATI and DA-RFU 1 personnel. This training again leveled off the expectations of the participants. ATI provided the training venue and management while DA-RFU 1 committed itself to monitoring the project as part of the rice program.

To facilitate the identification of key rice production constraints, a focus group discussion among farmers was conducted at each site. If one of the problems identified is technology-related and can be solved by one or all of the available technologies in rice production, that site is selected. Among the criteria in farmer selection are the following: they own and till their land to ensure that they are the decision-maker, they commit to share what they have learned about the technology so it is diffused, and they are willing to persuade other fellow farmers within their social network and sphere of influence to try the technology. For site selection for demonstration purposes, the site must be irrigated and accessible (i.e., along the road) so that more people, especially farmers, will know about the technology. Plot signs are later placed at these sites to inform passersby of the technology being used and demonstrated. The selection of agency project partners has been discussed earlier. Often, the LGU and PhilRice jointly conduct the site identification and validation.

For sites where training was considered relevant, the participatory approach was followed with about 20–25 farmer-participants per site. This number of farmer-participants is considered enough for meaningful discussion and learning, and to allow for attrition. In some cases, these farmers were organized to enable them to avail of services such as loans and subsidies. At each site, there is a farmer-partner and participating partners. The farmer-partner follows the recommended technologies of the project on his/her farm. Participating farmers, on the other hand, are not compelled to change their farm practices but they can freely adapt any practices that they think are applicable on their farms. They are both told how they could benefit from the project.

Half-day regular meetings (weekly during the first season, but less frequently during subsequent seasons) were conducted to facilitate farmer group discussions and farmer learning. The municipal AT serves as both facilitator and resource person, although OPAg personnel and PhilRice experts (i.e., development specialists and/or researchers) provide technical assistance when needed. The meetings/discussions were centered on the farming practices that would help increase a farmer's yield and income. The meetings also served as venues to formulate or give immediate action to whatever problems or issues that might arise in the implementation of the project. Farmers' field days and forums were held whenever possible before harvest time to inform the farming community about the technology's performance. Key officials/ leaders from PhilRice, the IRRC, partner agencies, and the LGU usually attended. This participatory method of evaluating technologies proceeded for three successive seasons at almost all sites. Other IRRC technologies were added when needed. Meetings are also held twice a year to report on progress, performance of technology, and constraints in implementation. These are usually attended by field implementers (from PhilRice and LGUs/partner agencies), some members of the IRRC team, and selected farmers. In the end, the technology or technologies are adapted to the locality and to farmers' circumstances. The IRRC also allowed for modification in names or use of technology and considered this part of the adaptation process, such as PhilRice's use of controlled irrigation instead of alternate wetting and drying. In some cases, the IRRC also tapped PhilRice expertise in simplifying or pretesting their information materials to facilitate adaptation. This happened with SSNM.

As the IRRC technologies were integrated into PhilRice's Technology Promotion Program, PhilRice included them in its other information dissemination activities, such as through radio, print materials, and techno clinics (i.e., rice experts go to a locality and have a facilitated discussion with farmers).

Highlights of implementation

Promotion of SSNM. SSNM was evaluated and promoted in seven provinces of the country: Kalinga, Pangasinan, Isabela, Ilocos Norte, Quirino, Sultan Kudarat, and North Cotabato. In Pangasinan, in particular, a two-day training was first held owing to the high number of participants interested in achieving a common understanding of the technology to be promoted. An action plan was drafted before the end of the training to ensure implementation. At other sites, a one-day technical briefing was usually enough. In all these provinces, nutrient management for rice was identified through FGD as one of the major concerns of the local farmers. The farmers do not usually have a scientific basis for their fertilizer application. Seeing the effect of improved yield after the first season of testing encouraged them to continue using the technology and made it easier for them to share the technology with other farmers.

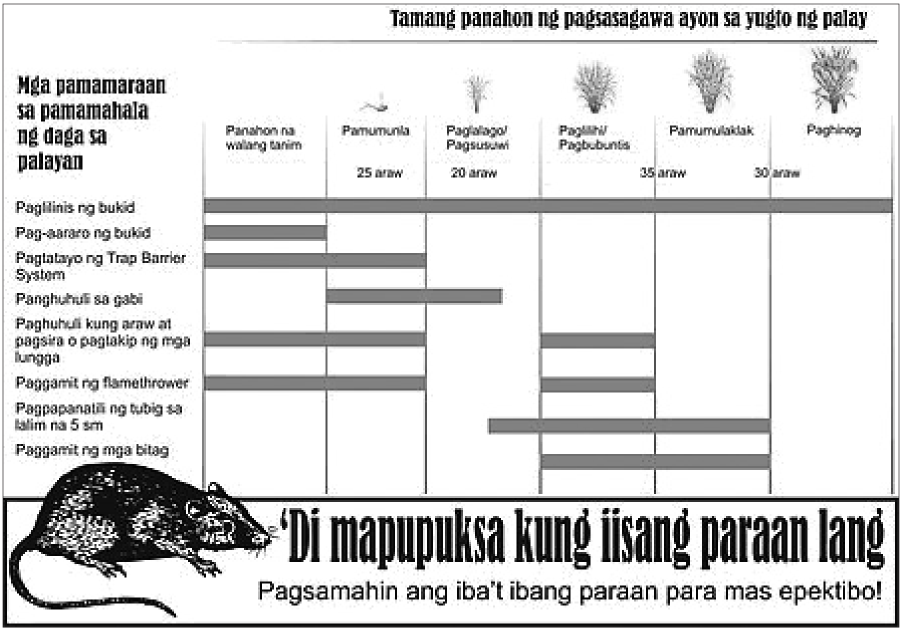

Fig. 3. A poster for ecologically based rodent pest management.

In general, results showed relatively higher yield among farmers who have used SSNM than the farmers' practice. After more than two cropping seasons of testing and evaluation, farmers have learned that using the right amount and kind of fertilizer can result in better yields and that a high quantity of fertilizer is not always equivalent to high yield. With SSNM, they are now confident of achieving better and fuller grains (PhilRice 2007) although the resulting SSNM rate was considered too high by some farmers. Additionally, they have learned not to burn rice straw because of its importance in maintaining soil fertility.

A social network and the need for farmers to organize were found important in some cases in which farmers do not have enough capital to buy the recommended inputs. PhilRice, having worked with *Alalay sa Kaunlaran*, Inc. (ASKI) before, tapped this group to provide loans to the farmers in Mangatarem, Pangasinan, who raised the issue of difficulty in testing the SSNM fertilizer recommendation because of financial constraints. ASKI usually provides a loan for small-scale enterprise development and to selected organized groups. However, it expanded its loan package to accommodate PhilRice's request for a low-interest loan for farmer-cooperators amounting to more than Php 500,000. The village captain had to organize this through the farmers involved in the project to facilitate their access to the loan. This loaning facility enabled farmers to discover the comparative advantage of SSNM against their fertilizer application practice.

Promotion of EBRM. Rodent pest management was promoted in Nueva Ecija through a community-wide information campaign (Fig. 3). This initiative came after

Fig. 4. An information needs analysis was conducted and it served as a basis for the campaign materials, information to disseminate (see below), and strategy to adopt.

the village council and the local government sought technical assistance from the OPAg and PhilRice. The campaign was named *"Boo! Boo! Rat! – Palay mo'y ligtas, 24 oras!,"* which was based on suggestions by farmers and the technical support team. It means that without the rats (through proper management), a rice field is secured for 24 hours. The campaign was well supported by the local executive who even attended the construction of the first community trap-barrier system. He also provided security during night hunting of rats. Village officials were also very supportive as well as agricultural technologists at both the provincial and municipal levels. They are graduates of past PhilRice rice specialist training courses.

An information needs analysis (Fig. 4) was conducted and served as a basis for the campaign materials, information to disseminate, and strategy to adopt. Eleven various campaign materials were developed in all as follows: T-shirts, stickers, streamers, billboards, technology poster, video, jingle, radio plugs, leaflets, bookmarks, and tricycle banners. A live interview on the campaign was done at a local radio station and several press releases came out in national dailies. All these materials carried the campaign slogan and the message of controlling rats through community work, in an integrated manner, and with proper timing. A popularity contest was also conducted as a strategy to mobilize the community into participating in a rat-hunting activity. This was done in partnership with a primary school and the local development council. In addition, to allow for knowledge push and pull, the campaign team uploaded rat management information on a Web site (www.booboorat.wordpress.com). A keyword on rats for short messaging (text *palay_daga _tanong* and send to 700RICE) was developed to allow farmers as well as other interested parties to send their questions to rat experts at PhilRice through their mobile phones.

More than 350 participants attended the main day of campaign launching. It was like a festival; thus, it created high interest among the locals. Among the activities carried out during the launching were a motorcade (with plug and jingle played repeatedly), an exhibit (displaying various rat management technologies), a video presentation (showing campaign activities), an open forum (where rat experts and farmers dialogued on concerns relating to field rats), and the conduct of some related games/fun activities. The local school band also participated, making the launching like a community affair when it is all about rats. Weekly visits to check progress of campaign activities were made and so were lectures and field practicums. Monitoring was done through filling out monitoring sheets on rat catches, open discussion, and games. Monitoring of knowledge, attitude, and practices was facilitated through dialogue, quizzes, or fun activities. The program of activities was modified based on feedback gathered.

Based on evaluation, farmers followed experts' recommendations on rat management in combination with their indigenous practices. They also learned to appreciate the importance of a community-wide approach in rat management. They invited other farmers to join them in their activities and lectures either as active participants or as observers. After a year of implementation, upscaling of ERBM promotion was conducted in six other municipalities of Nueva Ecija. The activity was incorporated in the FFS program jointly implemented by the LGUs and the Regional Crop Protection Center (RCPC). However, it was not sustained owing to a lack of resources. Community monitoring of the rat population was all that was done. A CTBS was not installed and the information campaign was not supported by other LGUs.

The *Boo! Boo! Rat!* campaign was featured in a documentary TV program with nationwide network coverage (Fig. 5). The Philippine Agricultural Journalists Inc. also awarded it the Agricultural Information or Media Campaign of the Year.

Promotion of AWD. This technology was promoted in ten provinces of the country: Pangasinan, Ilocos Norte and Sur, Nueva Ecija, La Union, Bohol, Bulacan, Tarlac, Cagayan, and Apayao. In Ilocos Norte, in particular, the sites where AWD was demonstrated showed lower yield than the farmers' practice, but also showed that production cost was higher for the non-AWD sites (see Appendix). The National Irrigation Administration (NIA) was a major partner in AWD promotion and this helped expand the AWD demonstration sites. The manager of the local irrigation system was personally approached to explain the project. The AWD team worked in close coordination with him in developing and promoting the technology. The 10% savings in water, being well supported by data, was emphasized. Farmers indeed experienced reduced cost of production with more efficient use of water. However, they also experienced weed emergence and thus used appropriate herbicides.

Since irrigation is also one of the major problems in Pangasinan, AWD was added in their rice production management practices after one season of SSNM implementation. The AWD setup was shown beside the SSNM plots. At the end of every season, a field day was usually conducted at each site to showcase the technology results to neighboring farmers.

Fig. 5. Various communication strategies were employed to inform the community of ecologically based pest management.

Promotion of drum seeder and moisture meter. Promotion of these technologies was done in Kalinga, Cagayan, and North and South Cotabato. Many became interested in using the drum seeder because, according to farmers, it reduces labor costs and facilitates weeding and other field operations since there are spaces where workers can pass through easily. Farmers also noted that it can be used best during the dry season. However, its price was an issue for some of them. Purchase of a drum seeder was facilitated by PhilRice.

The IRRC-designed moisture meter was found less useful by farmers than by seed growers. Ordinary farmers prefer to sell their palay straight from the thresher.

Strategies in bridging research and extension

According to the World Bank (1985, as cited by Toffelson and Wahab n.d.), bridging the gap between research and extension is a serious institutional problem in developing research and extension programs. Extension workers often see researchers working in an ivory tower generating technologies not applicable to the farm. On the other hand, researchers often question the ability of extension agents to perform their jobs effectively (Toffelson and Wahab n.d.).

Better communication and coordination among researchers, extension workers, and farmers are essential components in improving the transfer of technology. These, however, would continue to be enormous challenges in trying to improve the agricultural research and extension interface (Sharma 2003).

In the ICOP project in the Philippines, the following key strategies were used to improve technology transfer and thus bridge the gap between rice research and extension:

1. *Improved communication and partnership among researchers, development specialists, ATs, and farmers in technology adaptation.* Right from the start, with the workshop in January 2006, there was an effort to communicate well what the project is all about, the technologies intended for testing/adaptation and promotion, and leveling off of roles/expectations from stakeholders. This was followed by personal visits to local partners, meetings held twice a year to monitor project progress and address constraints, and joint field monitoring. Additionally, the researchers took a back seat but provided technical support when needed to development specialists and ATs in this phase of technology adaptation. This helped strengthen the capacity of development specialists and ATs, ease "turf" issues, and promote ownership and respect for each one's contribution. In the past, there was a tendency for researchers to still dominate this phase or for extension agents to be pessimistic of technologies being tested in view of issues cited earlier in this section.
2. *Shared project purpose and explaining the benefits for each.* This is related to the first point. The improved communication and partnership among stakeholders were brought about by the knowledge that the project was being done for a common purpose—one which they all subscribe to and one in which all will benefit. As mentioned, it is to help farmers enhance their productivity and profitability through the use of improved and environment-friendly technologies in rice production. Given a shared purpose and knowing that they are benefiting from the project, they were able to participate more effectively and complement each others' strengths—individually and when they work together. Integrating the work into their respective ongoing activities was made easy as well as sharing of resources as there was no conflict in purpose.
3. *Worked with right partners.* Being selective of partners is not discrimination but a matter of strategy to ensure that objectives are met and resources are managed well and go to intended beneficiaries. Working with the right partners at the national level and in the field led to a network of partners that facilitated technology delivery, dissemination, and upscaling. Again, this allowed for better resource sharing between research and extension. The decision of the IRRC to partner with the Technology Promotion Program, the development/extension arm of PhilRice, and agree on the suggestion to just build on what it was doing at that time was critical. This increased information dissemination and enabled access to a network of partners in the field and nationally (which this program has long been working with) that eventually led to the inclusion of IRRC technologies in the national rice program.

4. *Provided rewards.* The rewards were not financial but recognition in terms of invitations to participate in workshops and training programs at PhilRice and/or IRRI and also to interact with international scientists. At times, this merely meant visits of key leaders to the project sites and activities. It was mentioned that many of those in extension work are demoralized; thus, such actions helped inspire them and made them feel that their work was important and well recognized. This also helped strengthen bond and camaraderie, which facilitate development work.
5. *Employed community-based information campaign (Fig. 5).* For technologies requiring community action, such as rodent pest management, technology demonstration is not enough. A community-wide information campaign can help improve dissemination and transfer of technology, with all members of the community making a direct or indirect contribution to manage the identified field problem. This can foster partnership between research and extension as they work together in developing campaign materials, thus ensuring communicability and technical accuracy at the same time. Conducting information campaigns, however, needs to be planned more strategically to make them replicable.

Opportunities for strengthening the ICOP approach

From the experiences gained, the following are recommended to strengthen the ICOP approach in the Philippines:

1. *Continue to strengthen partnership with NARES.* Partnership with NARES should continue but it should be made more systematic and strategic. Their involvement should be right from the start of ICOP planning up to evaluation for greater project understanding and ownership and to sustain the efforts. Delineation of responsibilities should be made clear and official/formal, with respective interests considered. As there are many agencies within the NARES, it is important to be strategic in whom to partner with and to know whom to work with within an organization.
2. *Assist in building NARES capacity.* Partnerships are as strong as their weakest link. The research and extension system in the Philippines faces many challenges, as discussed earlier. Assisting in building its capacity, particularly in doing development and extension work (i.e., more opportunities are available in building research capacity), would contribute to better project implementation, documentation, and partnerships. Partners could serve as local champions. This need not come only in the form of participation in nondegree training programs but in exposure to workshops that provide opportunities for knowledge sharing or for meaningful interactions with scientists even during field monitoring/visits. In the Filipino culture, however, providing such opportunities may lead to a debt of gratitude and affect the validity of data gathered. There may be a tendency to report only positive experiences. Thus, precautions must be taken to avoid this.

3. *Document not only the performance of the technology but also the lessons in extending it.* As the ICOP also intends to learn the different pathways from research to impact, the importance of documenting the social aspects of the outreach and analyzing enabling factors of adoption must be emphasized with partners. Often, what is documented is only the performance of the technology, when it is true that many other factors contribute to successful adoption/adaptation. Proper documentation and sharing the lessons learned could result in more innovations to improve the system.

References

Balisacan AM, Sebastian LS. 2006. Challenges and policy directions: overview. In: Securing rice, reducing poverty: challenges and policy directions. The Southeast Asian Regional Center for Graduate Study (SEARCA), Philippine Rice Research Institute (PhilRice), and the Department of Agriculture-Bureau of Agricultural Research (DA-BAR), Philippines.

Barroga K. 2009. Adoption of multi-component and preventive rice production technologies: a study of complexity in innovations. Unpublished PhD thesis, University of Western Australia, Perth, Australia.

BAS (Bureau of Agricultural Statistics). 2008. Performance of Philippine Agriculture. January to December 2008. Downloaded from www.bas.gov.ph/agri_dev.php on 27 April 2009.

Brillantes AB, Ocenar RD, Tumanut MA, editors. 2007. Devolved agricultural extension services in the Philippines: trials and triumphs. Cases from Frontline Local Governments. Center for Local and Regional Governance (CLRG) in cooperation with the Center for International Economics (CIE) and the Australian Center for International Agricultural Research (ACIAR).

Cardenas VR. 2005. Revitalizing the Philippine agricultural extension system: proposed pluralistic national agricultural extension policy and program framework. SEAMEO SEARCA, Los Baños, Philippines.

David C, Hondrade R, Mascariñas A, Saz E, Vargas D, Carambas N. 2002. LGU agricultural extension services: resource and performance issues. Quezon City (Philippines): PIDS and BAR.

Gapasin D. 2005. Philippines rural growth and development revisited study: agricultural research, development, and extension. World Bank.

Gert-Jan S, Faylon P, Buendia L. 2007. Agricultural R&D in the Philippines: policy, investments, and institutional profile. IFPRI and PCARRD. Downloaded from http://maidon.pcarrd.dost.gov.ph/joomla/resources/2009/PHILIPPINES_ASTI_Country_Report%5B1%5D.pdf on 6 April 2010.

Gollin D, Morris M, Byerlee D. 2005. Technology adoption in intensive post-green revolution systems. Am. J. Agric. Econ. 87:1310-1316.

Hossain M, Narciso J. 2004. Global rice economy: long-term perspectives. FAO Rice Conference.

IRRI (International Rice Research Institute). 2002. Rice almanac: source book for the most important economic activity on Earth. Los Baños (Philippines): International Rice Research Institute.

IRRI (International Rice Research Institute). 2006. Asia and sub-Saharan Africa: rice in numbers. Rice Today 5:48.

Labios R. 2003. Integration of agricultural research and extension: Philippines. In: Sharma R, editor. Report of the APO Study Meeting on Integration of Agricultural Research and Extension. Tokyo (Japan): Asian Productivity Organization.

Morris M, Byerlee D. 1998. Maintaining productivity gains in post-green revolution Asian agriculture. In: Eicher C, Staatz J, editors. International agricultural development. Third ed. London (UK): The Johns Hopkins University Press.

NSO (National Statistics Office). 2007. Agriculture in the Philippines. Downloaded from www.census.gov.ph on 27 April 2009.

Palis FG, Flor RJ, Singleton GR. n.d. Agricultural extension: institutional pluralism and innovations worldwide. Los Baños (Philippines): International Rice Research Institute.

Pheng Kam S. 2003. Integrated natural resource management for rice production. Int. Rice Res. Notes 28:12-18.

PhilRice (Philippine Rice Research Institute). 2007. Review and planning workshop proceedings. Nueva Ecija (Philippines): Philippine Rice Research Institute.

PhilRice (Philippine Rice Research Institute). 2008. The Philippine rice masterplan 2009-2013. Nueva Ecija (Philippines): Philippine Rice Research Institute.

PhilRice and BAR (Philippine Rice Research Institute and the Bureau of Agricultural Research). 2008. An external review of PhilRice impact. Nueva Ecija (Philippines): Philippine Rice Research Institute.

PhilRice and FAO (Philippine Rice Research Institute and the Food and Agriculture Organization). 2001. In: Redoña E, Gaspar M, editors. Hybrid rice in the Philippines: progress and new horizons. 2nd National Workshop on Strengthening National Capacity for Hybrid Rice Development and Use. Nueva Ecija (Philippines): Philippine Rice Research Institute.

Pingali P. 1998. Confronting the ecological consequences of the rice Green Revolution in tropical Asia. In: Eicher C, Staatz J, editors. International agricultural development. Third ed. London (UK): The Johns Hopkins University Press.

Ponce ER. 2006. Rice extension. In: Securing rice, reducing poverty: challenges and policy directions. The Southeast Asian Regional Center for Graduate Study (SEARCA), Philippine Rice Research Institute (PhilRice), and the Department of Agriculture-Bureau of Agricultural Research (DA-BAR), Philippines.

Sebastian L, Alviola P, Francisco S. 1999. Bridging the rice yield gap in the Philippines. In: Papademetriou M, Dent F, Herath E, editors. Bridging the rice yield gap in the Asia-Pacific region. 5-7 Oct. 1999. Bangkok (Thailand): Food and Agriculture Organization.

Sebastian L, Bordey L, Alpuerto V. 2005. Rice R&D: getting hold of the future. Nueva Ecjia (Philippines): Philippine Rice Research Institute.

Sharma R, editor. 2003. Integration of agricultural research and extension. Report of the Asian Productivity Organization (APO) study meeting on integration of agricultural research and extension, Philippines, 18-22 March 2003.

Toffelson LC, Wahab MNJ. n.d. Better research-extension-farmer interaction can improve the impact of irrigation scheduling techniques. Downloaded from www4.agr.ca/resources/prod/doc/pfra…research-recherche eng.pdf on 21 April 2009.

Tolentino V. 2002. Rice policy reforms in the Philippines: a political economy perspective. Policy Notes. Makati (Philippines): Philippine Institute for Philippine Studies.

Additional references for further reading

www.agnet.org/library/eb/482c
www.agnet.org/situationer/philippines.html
www.agriculture-ph.com/2009/02/agricultural-extension-bill.html
www.bas.gov.ph/agri_dev.php
www.census.gov.ph
www.countrystudies.us/philippines/65.htm
www.fao.org.ph
www.uplb.edu.ph/ca

Notes

Authors' address: Philippine Rice Research Institute, Maligaya, Science City of Muñoz, 3119 Nueva Ecija, Philippines. Email: amcorales@philrice.gov.ph.

Appendix

Table 1. Yield performance at all sites for the wet season of 2006.

Site	No. of farmer-participants	Area covered (ha)	Average yield (t ha^{-1})	
			Techno demo	Farmers' practice
Promotion of SSNM				
A. Pangasinan				
1. Urdaneta City	24	32.10[a]	5.24	4.56
2. San Jacinto	24	25.62[a]	4.26	4.12
3. Mangatarem	28	22.45[a]	4.56	3.05
4. Tayug	1	0.25	3.50	3.25
5. Pozorubbio	1	0.14	4.18	3.76
6. Sual	1	0.33	5.13	–
7. Infanta	1	0.50	3.87	3.32
B. Isabela				
1. Alicia	1	1.00	4.00	–
2. San Mateo	2	2.00	Damaged by birds, rodents, and tungro	–
C. Kalinga				
1. Tabuk	–	–		–
			9.70	
D. Lambayong, Sultan Kudarat[b]	1	1.00	–	–
E. Kabacan, Cotabato[b]	21	–		–
Promotion of ecologically based rodent pest management				
A. Nueva Ecija				
1. Zaragosa	10	20.00	2.20	
Promotion of controlled irrigation				
A. Ilocos Norte				
1. Currimao				
	1	0.05	5.11	6.00
B. Apayao				
1. Luna				
2. Flora	1	0.30	4.82	5.20
	1	0.50	5.92	6.30
Total—16 sites	118	106.24		
Average			4.81	4.40

[a] Area includes all participating farmers. [b] Newly established sites starting in December 2006.

The research-extension linkage in the dissemination of integrated crop management for rice in Indonesia

Muhrizal Sarwani, Erizal Jamal, Vyta Hanifah, and Jovita Anggita Dewi

Much has been written about the Indonesian “success story” in relation to increased agricultural production over the past four decades, particularly in rice production. Indonesia changed from being the world’s largest rice importer in the mid-1960s to becoming nearly self-sufficient by the mid-1980s. Rice production grew by nearly 4% per annum during this period. The president of Indonesia ordered on 8 January 2007 that rice production must be increased by 2 million tons in 2007 and 5% per year until 2009. To meet this target, the Ministry of Agriculture declared in 2007 a new program, the “National Rice Production Special Program (P2BN).” During 2007-08, rice production increased from 57.1 million to 59.8 million tons, or 4.7%, and the program continues with strong emphasis on integrated crop management (ICM) over 2 million hectares. To support the program, the Indonesian Agency for Agricultural Research and Development (IAARD), through its Assessment Institutes for Agricultural Technology (AIATs) located in each province, assesses technology developed by research institutes and then tailors the technology to local needs. The AIATs bring mature technologies to end-users through developing master trainers among field extension workers at the district level. Bridging different institutions within the IAARD system and directing various R&D programs into one focal objective for timely and effective dissemination of agricultural technologies represent an innovative and challenging approach for Indonesia. An agricultural technology to be adopted by farmers would need various approaches and media for technology transfer. Likewise, it will take a couple of seasons until farmers are really convinced about innovative technologies. This paper outlines the processes implemented to facilitate the research to impact pathway for innovative natural resource management technologies and highlights how linkages with the Irrigated Rice Research Consortium have facilitated the development and delivery of these technologies.

From 1969 to 1996, Indonesia's economy grew, on average, in excess of 7% annually. Since the economic slowdown that resulted from the Asian financial downturn in 1997-98, Indonesia has resumed its strong economic growth, averaging around 5–6% per year (Jamal and Mardiharini 2009). Population growth in Indonesia has also been significant. Over the past four decades, Indonesia's population has grown at an average annual rate of around 1.8%. In 2008, the annual growth rate was 1.5% and the total population in Indonesia was around 240 million people (Population Reference Bureau 2008). Economic growth and industrialization in Indonesia have led to an increase in competition for domestic resources. As for many other developing countries in Asia, this has resulted in a reduction in the contribution of agriculture to gross domestic product. In Indonesia's economy, the share of agriculture declined from around 49% in 1970 to just over 13% in 2005. Over the same period, the percentage of the workforce engaged in agriculture fell from around 66% to 44% (Jamal et al 2008a).

Strong income and population growth has resulted in a significant increase in food demand. For the most important staple food, rice, there have been restrictive import controls in place since 2004 (imports are permitted on an ad hoc and "needs" basis, for example, during extreme circumstances such as drought). The growth in domestic rice production has slowed since the mid-1990s as the availability of arable land has become a constraint and productivity growth has slowed. As a result, there has been a gradual increase in imports of other staples, such as wheat, to meet increasing domestic food demand. Growth in per person income has also led to an increase in demand for other food products, especially vegetables, fruit, sugar, beef, dairy products, poultry, and seafood. Although Indonesia is largely self-sufficient in fruit, poultry, and seafood, imports have increased for vegetables, sugar, beef, and dairy products. Indonesia's government has pursued policies that promote agricultural production and provide protection to farmers.

Agricultural production, by volume, grew by 4% a year between 1968 and 1992. Since then, however, growth has slowed to an average annual rate of 1%. For the period 1968 to 1992, mean annual growth in agricultural productivity was 2.6%. Between 1992 and 2000, however, productivity contracted by an average 0.1% per year (Fuglie 2004). Several factors contributed to the decline in productivity in the latter period. First, significant declines occurred in expenditure in agriculture for both research and development, and infrastructure. Second, government subsidies on farm inputs such as fertilizers and pesticides declined significantly, especially in the period after the Asian financial downturn. Third, industrialization and urbanization led to increased competition for land and forced agricultural production onto marginal land. Fourth, a lack of economies of scale proved to be a barrier for agricultural productivity. Around 75% of farms in Indonesia still occupy less than 1 ha (Suryahadi et al 2006).

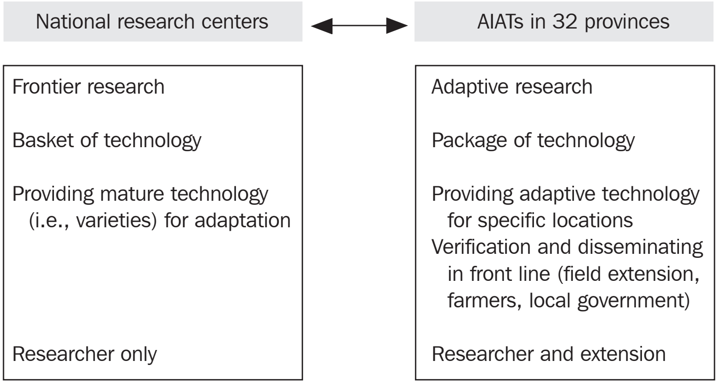

Fig. 1. Summary of the respective roles of the national agricultural research centers in Indonesia and the Assessment Institutes for Agricultural Technologies (AIATs).

Structure of the national research and extension system

The Indonesian Agency for Agricultural Research and Development (IAARD) is a top-level unit within the Ministry of Agriculture. The agency's functions are performed by 11 research centers whose main function is to manage research and development on food crops, horticulture, estate crops, livestock, veterinary, soil and agro-climate, agro-/socioeconomics, machinery development, postharvest, biotechnology, and agricultural technology assessment. IAARD also manages five institutes focusing on estate crops, grouped under the Indonesian Research Institute for Estate Crops (IRIEC). IAARD's national research centers and institutes undertake strategic research, aiming to develop policy alternatives and technology components. They then pass their findings on to the agency's Assessment Institutes for Agricultural Technology (AIATs) in each province for testing. Since the AIATs are located close to the areas they serve, they are able to adapt technology to suit each location so that farmers will be able to adopt it quickly. In 2009, 32 AIATs were coordinated by the Indonesian Centre for Agricultural Technology Assessment and Development (ICATAD). The relationship and respective roles of the national research centers and the AIATs are depicted in Figure 1.

The agricultural extension service is controlled by the Center of Agricultural Extension and Development (CAED), under the Agency for Agricultural Human Resources Development, the Ministry of Agriculture. The CAED supervises extension services at all levels through regional offices and works in collaboration with the heads of districts and villages. At the provincial level, there is an agency for extension coordination (*Bakorluh*) and, at the district level, there is an agency for extension implementation (*Bapeluh*). At the subdistrict level, there is an agricultural extension center (BPP), and 10–20 field extension workers are attached to each BPP.

The ICATAD has a coordination role nationally and is responsible for monitoring all on-farm experiments in the regions and provinces. These on-farm experiments are conducted by an AIAT at the provincial level. Staff of AIATs primarily conduct adaptive research; researchers work with subject-matter specialists to develop technology packages, which are then passed on to the extension centers. AIATs thus provide an important interface between research and extension organizations in Indonesia. The BPP, subject-matter specialists, and researchers all provide input into research needs, but the final decisions on selecting research problems and themes rest with the national researchers. The BPPs receive innovation packages from research centers through the subject-matter specialists deployed by the AIATs. Although recently interaction has increased among national research staff, extensionists, and farmers at the provincial level, this heightened interaction has not led to final decisions on linkage activities being controlled at the provincial and district levels: the management of agricultural research–extension linkages in Indonesia depends mainly on IAARD-supervised institutes.

The growth of extension activities in Indonesia flowed from a slow impact in the beginning (1945-59) to a major revitalization of the process since 2006 (Table 1).

The concept of integrated crop management (ICM) In Indonesia

Cultivated land has specific features relating to its agroecosystem and biophysical structure, socioeconomic aspects, and institutional system. This presents each farmer with a range of farming systems or cultivation practices. Therefore, it is beneficial to understand the circumstances affecting each farmer when a technology is ready to be extended. In order for farmers to benefit from a new technology, they will generally adapt the technologies offered so that they suit their specific circumstances (van de Fliert and Braun 1999). Integrated crop management (ICM) is fundamentally an approach to crop cultivation that combines environmental and socioeconomic aspects of farm management in order to achieve sustainable benefits from new technologies. In this system, it is essential to consider farmers' indigenous practices and specific circumstances, and how to integrate these with the specific technologies.

In practical terms, ICM means "integrated use of compatible technologies that meet farmers' needs and enhance their productivity and income." Two sets of options are identified for ICM: core and location-specific. Core options are those that perform similarly in multiple locations, for example, locally adapted varieties, good-quality seed, robust young seedlings, need-based nutrient application, and integrated pest management (IPM) (includes insects, weeds, and rodents). Location-specific options are those that perform differently at different locations or that can be practiced only in certain locations. These include variations in plant spacing, intermittent irrigation, and the use of organic manure. In addition, we need to improve postharvest processing to enhance the quality and market value of the produce (Balasubramanian et al 2005).

The IAARD has generated a large number of innovative technologies to support national rice production. These technologies form the platform for ICM of rice. ICM aims to enhance rice productivity and rice farming system profitability by increasing input efficiency, and to support the sustainability of production systems through the

Table 1. Historical perspective of the development of agricultural extension in Indonesia from 1945 to 2009. FEATI = Farmer Empowerment through Agricultural Technology and Information.

Period	Extension	Characteristic
1945-59	**Embryo** Part of educational institute for rural people	• Empowerment program • Slower impact
1959-65	**Start to grow** Mass guidance/campaign	• Extension program is integrated with self-sufficiency of rice
1966-90	**Growing** Extension is under agency of mass guidance "Golden time" Agricultural extension offices at the sub-subdistrict level were built, providing a place for field extension officers to gather	• Extension: horizontal exchange • Introduction of new technology • Target: intensification of rice; extension is used to solve food crisis • Practice of visit program is used by field extension officers • 1984: Self-sufficiency for rice achieved
1991-95	**Destructive time** Extension system is almost destroyed → extension is under local government unit → change profession	Agricultural extension office does not function well; cessation of "practice and visit program"
1995-2005	**Uncertainty time** Extension office is starting to be formed at subdistrict level	BPTP is formed to facilitate and accommodate extension and researcher linkages
2006-now	**Revitalization time** Extension law is released by government Extension from central government to rural centers	One village, one extension New paradigm: strategic extension → facilitate learning Process of certification is planned FEATI project implemented

conservation of land and water resources (ICFORD 2006). ICM has been developed for a large range of farming systems, which cover not only paddy rice field cultivation but also other commodities such as maize, soybean, sweet potato, and cassava.

One of the main objectives of ICM is the reduction or replacement of external farm inputs, such as inorganic fertilizers, pesticides, and fuel, by means of substitutes produced on-farm, and better management of inputs. Total replacement is not possible without a significant loss of yield, but partial substitution of inputs can be achieved by the use of natural resources, the avoidance of waste, and efficient management of external inputs. This would then lead to reduced production cost and less environmental degradation.

The ICM approach was initially developed for an international project on "Reversing trends of declining productivity of rice" coordinated by the International Rice Research Institute (IRRI) that combined the results of some component research conducted at this time. Rice yields were improved through organic fertilizers complementing inorganic fertilizers, better management of water (draining at key times), and better postharvest management. Optional technologies were the *legowo* system and improved weed management, which were adjusted to the needs of farmers. Legowo is basically a row system with planting distance of 50 × 12.5 cm instead of 25 × 25 cm, or 40 × 10 cm instead of 20 × 20 cm. ICM approaches evolved thereafter but followed four fundamental principles: (1) assessment of farmer needs; (2) integrating crop, water, land, and plant disease management; (3) appropriateness of technologies (to end-users and the physical environment) and taking advantage of the benefits from interactions and synergies among technology components; and (4) promoting active farmer participation through farmers observing, testing, and modifying new technologies, and through building the skills of farmers (Jamal et al 2008b).

The recommended technologies of ICM in rice cultivation are produced by research centers and are derived from indigenous technologies currently approved as preeminent technologies in specific locations. Component technologies adopted by farmers include (1) quality seed from good varieties (e.g., high yield, premium flavor, resistance to pests); (2) recycling rice straw and compost fertilizer if possible; (3) inorganic fertilizer application modified with regard to the level of organic matter in the soil, and the specific nutrient requirements of the growing crop (Agriculture Ministerial Decree No. 01/Kpts/SR.130/1/2006); (4) young seedlings (2–3 weeks old) and 1–3 seeds per clump; (5) intermittent irrigation; and (6) good management of harvest and postharvest, including IPM.

In 2002 and 2003, ICM was tested in 28 districts in Indonesia. The ICM approach increased farmers' income by up to 15% and increased yield up to 19% compared with existing practices of farmers. Rice yields increased by 1.0 t ha^{-1} to 2.2 t ha^{-1}, seedling-production costs decreased by about 50%, and 25–30% less water was used (Balasubramanian et al 2005).

Rice production in Indonesia and farmers' field schools for ICM

Rice is Indonesia's staple food, with an annual per capita consumption of 141 kg per year. It is a strategic commodity for the national economy and food security. For the past decade, Indonesia has on average imported 1.3 million tons of rice each year. The Indonesian government is seeking ways to bridge this gap and one key opportunity it is pursuing is to improve rice production efficiency and returns to farmers, through the "Rice Production Increase Program (P2BN)" implemented in 2007. The program aimed to produce an additional 2 million tons of milled rice in each of the next three years (2007-09). It involved technical options that required community action such as water management and rodent control, and field-specific action that required individual action, such as nutrient management, variety selection, and seed storage. Improved rice production efficiency was targeted by supplementing ICM with quality seed of the best variety, and effective seed storage. In 2009, the program was conducted in 31 provinces and 293 districts. Through this program, Indonesia was expecting that in 2009 alone the national dry rice production would increase to 63.53 million tons, an increase of 5.5% from 2008.

In 2007 and 2008, P2BN achieved its rice production target. The Minister of Agriculture announced that national rice production increased by 5% per year since it was launched in 2007. On the other hand, this program achieved a surplus of national rice production of up to 2.4 million tons.

Related to these achievements, ICM already supported and contributed 818,974 tons of milled rice (41% of the production increase target) in 2007 where ICM was operationally done by a farmers' field school (FFS) managed by potentially 66,000 farmer groups. The farmers' field school of ICM (FFS-ICM) is a strategy set by the Department of Agriculture to achieve P2BN. In 2009, the FFS-ICM began to be implemented with the aim by 2010 of covering the 2.05 million ha of irrigated rice fields, of which 2 million ha are planted with inbred rice varieties and the remainder with hybrid rice. One unit of FFS-ICM covers 25 ha planted with inbred rice varieties and 10 ha planted with hybrid rice. FFS-ICM is basically a field where the participating farmers or farmers in groups learn how to practice efficient rice production, from the selection of quality seed of the best variety, through planting systems, nutrient management, integrated pest management, including rodent and weed management, until harvesting. Within these areas, 1 hectare of a farmer's rice field is selected as a field laboratory of ICM (FL-ICM) to be used by farmers and village extension workers to learn technology adoption in a particular season. During the cropping season of 2009, 85,000 farmers' groups participated in the FFS-ICM program: 80,000 groups grew an inbred rice variety, while 5,000 groups grew hybrid rice.

Except for the "entry technologies" (e.g., quality seeds and fertilizers), rice technologies practiced in each unit of FFS-ICM were determined based on results of need and opportunity assessments (*Kajian kebutuhan dan peluang,* KKP). Through KPP, site-specific technologies were determined. No single package of technologies applied in FFS-ICM was offered through a top-down process. Seeds of rice grown in farmers' FFS-ICM plots were freely provided by the government. For rice fields assigned for FL-ICM, the government provided seeds and funds to purchase fertilizers. During the growing season of 2008, all rice crops in FL-ICM plots were fertilized with *phonska* (15-15-15), ammonium sulfate, and composted organic matter, at the rate of 200, 400, and 2,000 kg ha^{-1}, respectively. These fertilizers, in both rates and kinds, were determined by the Directorate General of Food Crops (DGFC). During the growing season of 2009, the fertilizer rate was calibrated by AIATs and extension workers, based on site-specific fertilizer recommendations (SSNM) (see http://beta.irri.org/ssnm/). Other than these entry technologies, rice technologies preferred by farmers were the *legowo* planting system, young seedlings of ≤18 days old prepared in an improved seedbed plot, and ecologically based rodent management. The latter technology consists of a 25 m × 25 m trap-barrier system with an early-planted crop within the barrier attracting rats to multiple capture traps, or a linear barrier system set to intercept mass movements of rats. The technology is underpinned by synchronized planting and mass action of rodent hunting (called locally *gropyokan*) (Sudarmaji et al, this volume). This technology requires community action.

We anticipate that in a particular area not all farmers participating in the FFS-ICM will adopt all the technologies recommended under ICM based on the needs assessment for that area. Focus group discussions were held with several district extension implementing boards, and rural extension centers of West Java. These discussions indicated that the level of involvement of the extension workers in FFS-ICM was still limited—only approximately 20% of the farmers adopted full ICM, whereas partial ICM was adopted by about 30% of the farmers. This may be due to a lack of extension staff having a good understanding of the related subjects. For example, fertilization of rice using SSNM and based on a leaf color chart (LCC) reading was still not commonly used. Some people expressed a reluctance to use an LCC, others were not confident about the result, and some did not have access to LCCs.

Collaborative research in Indonesia under the Irrigated Rice Research Consortium (IRRC) of IRRI has formed the basis of a number of ICM technologies. The two rice technologies best known by the extension specialists were nutrient management and ecologically based rodent management, but their adoption was still at the stage of initiation. Other IRRC technologies, such as direct seeding using a drum seeder, water savings using alternate wetting and drying, and seed management using an IRRI Super Bag, may need to be verified through the action research facilities of the FEATI program.

The field laboratory is a place where farmers participating in the ICM field school are able to learn the process of best management practices of rice over a cropping season, from preplanting until harvest. The "learning by doing" process starts with a meeting of a farmers' group at the village level. Farmers are familiarized with the agenda of the FFS-ICM, including the problem-solving process through participatory rural appraisals, the need for weekly meetings in the field, the location of FL-ICM, training materials, and technologies best suited to the area and the socioeconomic status of farmers. A group of farmers covers 25 ha with 1.0 ha used as a training ground. The 1.0 ha of FL-ICM could be owned and managed by two or more farmers. During the growing season of 2009, the farmers who managed the FL-ICM tried to practice technologies that had been identified through a process of needs assessment. For example, the type and rate of fertilizer, and timing of fertilizer application, were determined based on the SSNM principle. Through this arrangement, farmers can learn a specific technology with which they may not be familiar. Moreover, farmers might evaluate yields attained at harvest time in the FL areas. The FL-ICM approach has not been optimally used. It offers potential to verify some technologies such as new rice varieties and site-specific nutrient management.

To support the implementation of FFS-ICM, a 6-day national training of "master trainers" was organized by the Directorate General for Food Crops (DGFC) and conducted at the Indonesian Center for Rice Research in Sukamandi, West Java, in March 2008. The training was attended by 133 participants; 68 were from the provincial level, where the P2BN was implemented, 35 were from ICRR, and 30 were from AIATs. The alumni of this training were labeled PL-1 ("master trainers"). The plan is that the PL-1 graduates will in turn become trainers of trainers at the provincial level. The alumni of this provincial-level training are labeled PL-2, and they are expected to become facilitators for the implementation of FFS-ICM in a village (see Fig. 2). The second National Training of Master Trainers, organized jointly between AAHRD and DGFC, was conducted in 2009 in both Bogor and Sukamandi in February 2009. Operationally, the FFS-ICM began to be rolled out at the village level in 2009 in September, in readiness for the planting time for the rainy season of 2009-10 (October 2009-May 2010). In all, 80,000 FFS-ICM will be established.

Dissemination process and facilitation team

The main agricultural research dissemination at the district level is the agricultural extension service with Rural Extension Centers at the subdistrict level. Attempts have been made over past years to increase the coverage of extension officers to one person per village (or a total of about 28,000 extension officers in May 2008), but villages tend to be very large and, especially in eastern Indonesia, scattered over large and remote areas.

While the central research and provincial assessment institutes are managed by the Ministry of Agriculture, the extension service is administered by autonomous district governments. The AIATs are positioned to provide a bridge between central research institutes and the extension system (Fig. 2). Their mandate is to confirm and adapt mature technologies from research institutes under local conditions that are subsequently "handed over" to the extension system (Connell et al 2007).

To accelerate the dissemination process to end-users, the AIATs formulated in 2009 a dissemination team that consists of persons from all the centers in IAARD and the extension personnel under the management of the Agency for Agricultural Human Resources Development (AAHRD). The main task of the team is to accelerate the process of dissemination through its assessment and recommendations. In 2009, the dissemination team conducted studies in some districts in West Java together with the West Java AIAT. The recommendations from this study will be used as a model for dissemination in other AIATs. In the context of a specific program such as integrated crop management (ICM), the dissemination team will work hand in hand with other projects, such as Farmer Empowerment through Agricultural Technology and Information (FEATI) (Fig. 2). ICATAD coordinates 18 provincial AIATs that are involved in the FEATI project. The FEATI project provides a platform that enables for the first time in Indonesia a clear definition of the responsibilities of an extension office at the district level and that of AIAT. Funds were allocated to both extension offices and AIATs. Each AIAT has an obligation to provide an extension office with agricultural technologies, and to facilitate training for field extension workers.

AIATs play a strategic role for the dissemination of ICM at the provincial level (see Fig. 2). The following were identified as their key roles:

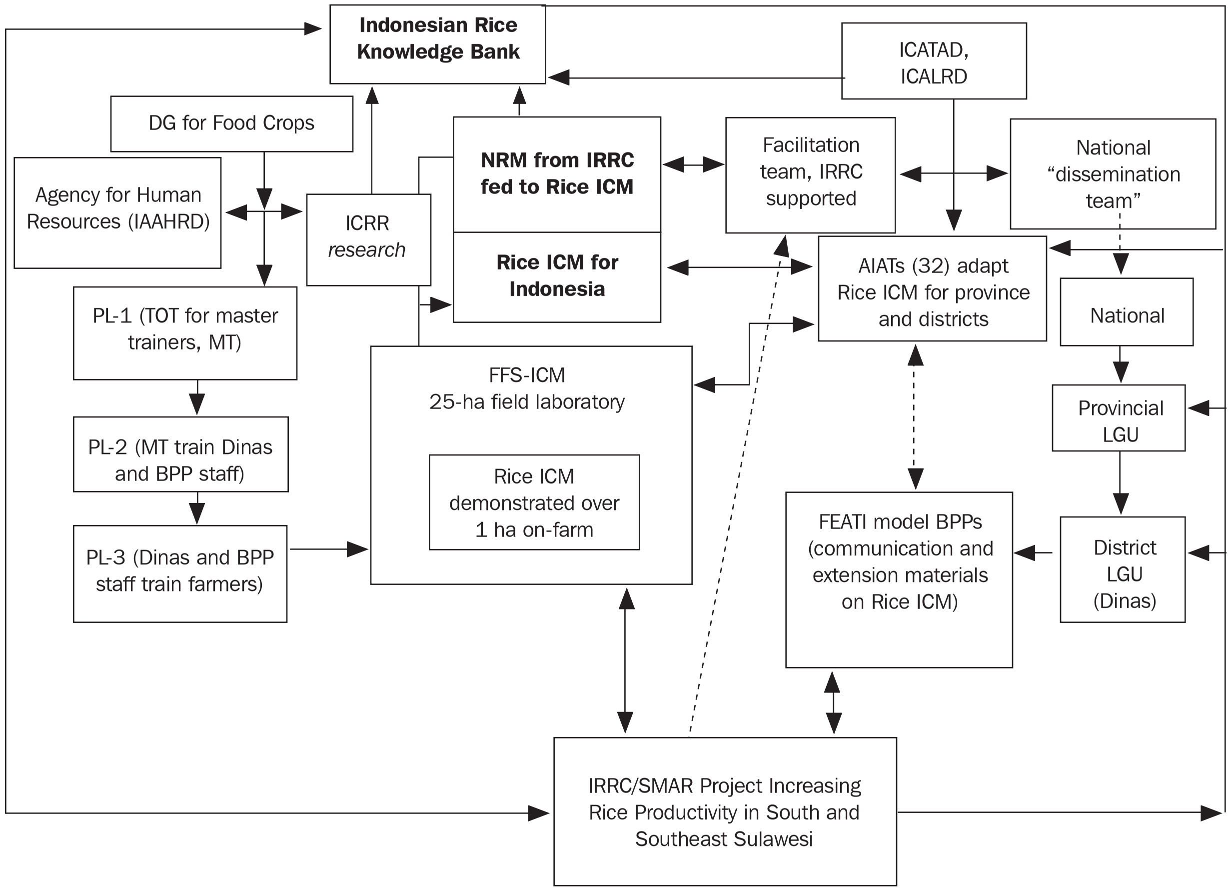

Fig. 2. An overview of the national program to facilitate research delivery to extension specialists and then to farmers at the national, provincial, and district levels; note the linkages with the IRRC and how the research and training feeds into the farmer field schools for integrated crop management (FFS-ICM). Acronyms are explained in the text.

a) As the main source of the agricultural database in a local area.
b) As a center of agricultural innovation in a local area.
c) As the main collaborative agent of the extension coordinating agency at the provincial level, and with the extension executing agency at a district level.
d) As the main supporter of information for related local agencies, at both the provincial and district levels, especially for planning, implementing, and problem solving of agricultural development needs.
e) As the main sources of high-quality seeds.
f) As an executing body for facilitating the training of extension officers and farmer groups.

To strengthen the dissemination of rice technology, the following key issues were identified:

- Collaboration involves multiple stakeholders; this requires systematic and comprehensive mapping of potential partners.
- Innovative dissemination is required in order to improve the effectiveness of our current knowledge exchange process (research to extension); this may require new uses of the media and new methods of dissemination.
- The approach should respond to the needs of end-users, such as improved livelihoods and incomes, and also recognize potential areas for impact (economic, social, cultural).
- The research should be adaptive—responding to local conditions through the employment of appropriate modules of ICM.
- We need to prevent any missed opportunities by (1) active consultation with farmers through farmer field schools, (2) documenting the adaptations made by farmers to specific technologies, and (3) improving capacity building by including communication specialists, anthropologists, and social scientists in the project.

Conclusions and recommendations

The AIATs bring mature technologies to end-users through developing “master trainers” among field extension workers at the district level. Bridging different institutions within the IAARD system and directing various R&D programs into one focal objective for timely and effective dissemination of agricultural technologies is an innovative and challenging approach for Indonesia. An agricultural technology to be adopted by farmers would need various approaches and media for technology transfer. Likewise, it will take a couple of seasons until farmers are convinced to adopt innovative technologies.

From various activities developed during the development of the dissemination of ICM, we recommend the following:

1. Participation of AIATs must be from the beginning of the dissemination project.

2. Ownership by AIATs of the new technologies, tools, and promotion materials is the key component to the success of dissemination.
3. Capacity building needs to be mandatory for researchers and extension staff of the AIATs, so as to increase their knowledge and skills.

References

Balasubramanian V, Rajendran R, Anbumani S, Stalin P, Thiyagarajan TM, Castro E, Chandrasekaran B, Las I. 2005. Integrated crop management (ICM) for sustaining irrigated rice yield and farmers' income in Asia. Los Baños (Philippines): International Rice Research Institute.

Connell J, Muktasam, Coults J, Christiana B. 2007. Strengthening province-based adaptive agricultural research and development capacity of AIATs in four provinces in eastern Indonesia. Smallholder Agribusiness Development Initiative (SADI), Support for market-driven adaptive research. Canberra (Australia): Australian Centre for International Agricultural Research.

Fuglie KO. 2004. Productivity growth in Indonesian agriculture: 1961–2000. Bull. Indonesian Econ. Stud. 40:209-225.

ICFORD (Indonesian Centre for Food Crop Research and Development). 2006. Rice production system economizing water usage. Bogor (Indonesia): ICFORD.

Jamal E, Mardiharini M. 2009. The choice of land tenure contracts in the presence of transaction costs in rice farming in West Java, Indonesia. Contributed paper at the International Association of Agricultural Economists Conference, Beijing, China, 16-22 August 2009.

Jamal E, Hendiarto E, Ariningsih. 2008a. Policy analysis for rice price in Indonesia. Journal Pengembangan Inovasi Pertanian, Volume 1. Bogor (Indonesia): Indonesian Agency for Agriculture and Rural Development.

Jamal E, Mardiharini M, Sarwani M. 2008b. The dissemination process of rice integrated crop management (ICM): a lesson learned and perspective in advance. J. Agric. Policy Anal. 6:272-285.

Population Reference Bureau. 2008. 2008 world population data sheet. Washington, D.C. (USA): PRB-USAID. 16 p. At www.prb.org.

Suryahadi A, Suryadarma D, Sumarto S, Molyneaux J. 2006. Agricultural demand linkages and growth multiplier in rural Indonesia. SMERU Working Paper. Jakarta (Indonesia): SMERU Research Institute. 24 p.

van de Fliert E, Braun AR. 1999. Farmer field school for integrated crop management of sweetpotato: field guides and technical manual. Bogor (Indonesia): International Potato Center. 266 p.

Notes

Authors' address: Indonesian Center for Agricultural Technology Assessment and Development, Jl Tentara Pelagar 10, Bogor, Indonesia. Email: muhrizal_sarwani@yahoo.com.id.

Disseminating integrated natural resource management for lowland rice in Myanmar

Maung Maung Yi, Aye Tun, Aye Aye Mar, Kyaw Yee, Than Aye, and Grant R. Singleton

Myanmar has a network of agricultural extension personnel that is centrally managed under the Myanma Agriculture Service (MAS) but has its core function at the township level. We describe the structure of agricultural extension in Myanmar and the associated linkages with institutes involved in agricultural research. Although the primary focus of MAS is on increased production, it also has a strong interest in promoting agricultural technologies that provide social benefits such as reduced drudgery, reduced use of pesticides, and improved environmental health. Effective dissemination of new natural resource management (NRM) technologies and principles that have potential to increase rice production of lowland rice is a challenge because it is knowledge-intensive. MAS has developed a collaborative outreach approach with the Irrigated Rice Research Consortium (IRRC) of the International Rice Research Institute to evaluate possible pathways to validate and extend potential new NRM technologies. An IRRC Myanmar Outreach Program (IMOP) was formed in 2005 to facilitate this collaboration. We present the general principles of the IMOP model and case studies of progress under the IMOP for specific NRM technologies from 2006 to 2008. Key strengths of the IMOP have been the development of field trials in farmers' fields, capacity building of extension personnel at a division/state and township level, extended partnerships developed with research agencies and the private sector, and regular briefings of high-level government officials. The IMOP has also provided a platform for the integration of NRM technologies, and greater farmer and multistakeholder participation. Progress thus far has been at a field level at multiple sites in five divisions and states. The challenge ahead is to successfully integrate and disseminate the technologies at a landscape scale.

Myanmar has a land area of 676,577 km^2, a population of 56.5 million (2008), and a population growth rate of 1.02% per annum. The net area under agricultural crops is 11.3 million ha (16.8% of total land area), cultivable virgin land of 6.0 million ha (8.8%), and fallow land of 0.3 million hectares (0.4%). The irrigated area sown to crops is about 2.4 million ha, which is 19% of total cultivable land (Department of Agricultural Planning 2008).

Agricultural exports and imports

Myanmar is an agricultural country, and the agricultural sector is the backbone of its economy. In 2007-08, the agricultural sector contributed 51% of the national GDP and 12.14% of total export earnings, and employed 66% of the labor force. The rich natural resource base of the country combined with abundant water in the delta regions and many of the valleys ensures that the agricultural sector will continue to be one of the leading sectors in the Myanmar economy for decades to come. Agricultural products such as rice, pulses, maize, sesame, and rubber are the main export items. In quantitative terms, peas and beans ranked first in exports, maize second, and rice third. Myanmar is now the leading country for the production and export of pulses among the ASEAN member countries (Department of Agricultural Research 2007).

Food security

Myanmar is an exporting nation for rice. In 2009-10, exports reached 1 million t. The government's long-term goal for rice production is to ensure that it is able to raise production sufficiently to feed a population of 100 million people, and still have sufficient production to become an important exporter of rice on the world market.

Farmers' landholdings

There are three basic registers: (1) the register of area: records of the area of each field; (2) register of fields: covering all the various fields within each parcel of land held by one person; and (3) register of holdings: the same as for the register of fields except it also includes noncultivable land.

Farmers have the right to till the land and they inherit the rights over the land. A cultivator who has been granted the tilling right is not allowed to divide, sell, mortgage, or transfer the land (except for inheritance purposes). In 2005, under a new system called the "Pillar Crops" policy, principal crops were identified to be grown in specific areas. These principal crops were assigned according to the needs for domestic consumption and potential for export earnings. The Ministry of Agriculture and Irrigation also assigned national targeted yields and production levels. To meet these targets, extension specialists worked closely with farmer groups to encourage the application of improved varieties appropriate for respective regions, the use of adequate fertilizers, effective pest management, the application of efficient and appropriate technologies, and the use of appropriate cropping patterns suitable for the respective regions and crops.

The ten principal crops identified in 2005-06 and their yield targets were as follows: rice, 5.15 t ha^{-1}; maize, 4.93 t ha^{-1}; groundnut, 1.40 t ha^{-1}; sesame, 1.21 t ha^{-1}; sunflower, 1.79 t ha^{-1}; black gram, 1.61 t ha^{-1}; pigeon pea, 2.02 t ha^{-1}; sugarcane, 74.13 t ha^{-1}; and long staple cotton, 1.61 t ha^{-1}.

Structure of the national research system

In Myanmar, agricultural research is entirely the responsibility of the Ministry of Agriculture and Irrigation (MOAI). Research on rice is primarily done by the Department of Agricultural Research (DAR) and the Seed Division, Myanma Agriculture Service. The Plant Protection Division conducts limited research on integrated pest management (IPM) methodologies for rice production. Other institutions that conduct some research on rice are the Land Use Division, which is responsible for research on soil conservation, management, fertility, soil-plant relations, and land use, and the Plant Biotechnology Laboratory.

The responsibilities of DAR are developing high-yielding crop varieties, generating agricultural techniques for the maximization of production benefits, the sustainable use of natural resources, conservation and use of crop genetic resources, disseminating improved crop varieties and agronomic technologies to farmers, and developing human resources in agricultural research (Department of Agricultural Research 2007). DAR has 19 research farms, which were selected based on different agroecological zones such as dry zones, hilly areas, and delta regions. DAR also conducts collaborative research with the Seed Division and the Extension Division of Myanma Agriculture Service. The Seed Division conducts field trials to test the adaptability of varieties that have been developed by DAR. Under the Seed Division are 32 seed farms, which conduct field trials, seed multiplication, and distribution of quality seed. The division also upgrades seed class and the germplasm collection for Myanmar at the Myanma Rice Research Institute in Hmawbi Township. The extension division conducts yield trials and demonstration plots for extension purposes.

Agricultural research on agricultural commodities other than rice is conducted by a large number of agencies. There is a network of agricultural research, testing, and breeding facilities throughout Myanmar.

Yezin Agricultural University (YAU) is strategically important in producing skilled scientists for strengthening the research and extension system. YAU also conducts agricultural research.

Research institutions follow the main national agricultural policies closely in defining their approaches, priorities, and objectives. The research at DAR and indeed at most other research institutions under MOAI is largely oriented toward increased productivity for individual crops and developing high-yielding varieties.

The proven technologies or new varieties developed by research institutions need to be ratified by the National Seed Committee and Technical Committee. The technologies are then validated on a large scale by relevant departments and enterprises. Once validated, these technologies are adopted and disseminated to farmers through agencies of MOAI; for rice, MAS is the main agency. The problems and constraints identified by farmers and other end-users are considered in the planning process of research and extension.

Structure of the national extension system

The Extension Division of Myanma Agriculture Service has four main tasks (Department of Agricultural Research 2007): (1) transferring appropriate technologies, (2) developing appropriate pest control and land use, (3) cooperating and coordinating with the development of agricultural research by supporting research and development activities, and (4) distributing quality seeds.

Under MAS, the Extension Division has the largest staff (Fig. 1). Every state and division has extension staff who have a clear mandate to work with farmers to improve the yields of many different crops. However, although the primary focus of MAS is increased production, it also has a strong interest in promoting agricultural technologies that provide social benefits such as reduced drudgery, reduced use of pesticides, and improved environmental health.

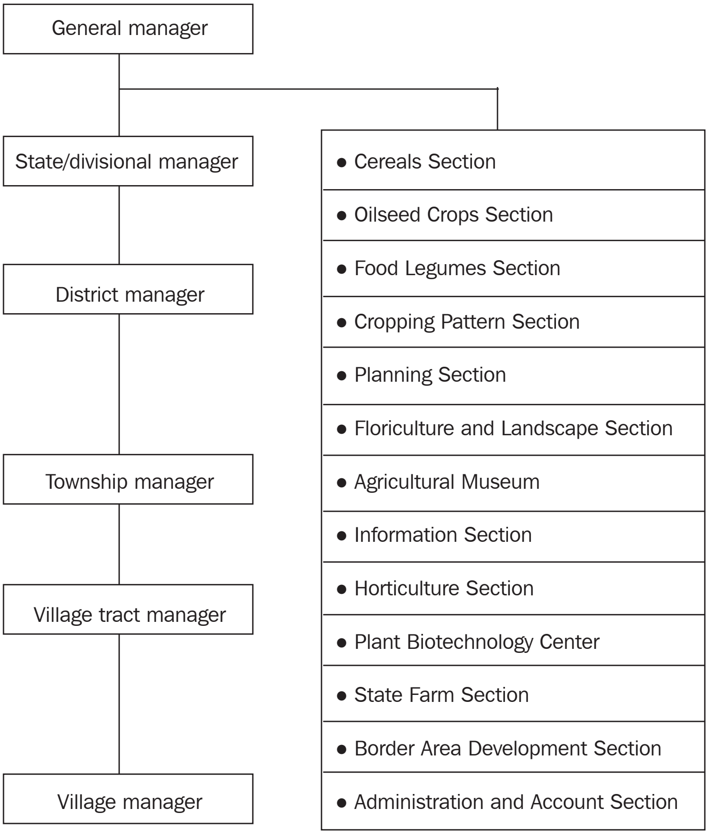

Fig. 1. The organizational structure of the Agricultural Extension Division of Myanma Agriculture Service.

Within each division are townships. Extension staff are allocated the responsibility of facilitating extension for a cluster of villages known as a "village tract." The extension staff within a village tract report to the MAS township manager. Within many of the village tracts are established "extension camps," which are typically a building at the edge of rice fields (or other commodities) where farmer meetings are held, and demonstration plots of new practices or new varieties are established in the nearby fields.

One important constraint for extension staff in the provinces is that they have only a limited budget and therefore limited mobility. This on occasion can significantly limit the rate of diffusion of new agricultural technologies.

Implementation and dynamics of the IRRC Myanmar Outreach Program

The Irrigated Rice Research Consortium of IRRI is working closely with MAS to develop effective pathways for the dissemination of new natural resource management technologies and principles that have potential to increase the production of lowland rice. An IRRC Myanmar Outreach Program (IMOP) was formed following a national rice workshop, held in Yangon in September 2005, that considered the major constraints to rice production and possible research to tackle these constraints. The IMOP approach built on earlier cooperation between MAS and the IRRC from 2002 to 2005 on nutrition management of rice, in a project titled Reaching Toward Optimum Productivity (RTOP). The workshop was attended by scientists and extension specialists from all of the major rice-growing divisions and states, DAR scientists, the private sector (e.g., MRPTA), key policy and strategy personnel from MAS, and natural resource scientists from IRRI. The IMOP consists of a coordinator (general manager of extension) and four work groups aligned with the work groups of the IRRC. These work groups are as follows:

1. Productivity and Sustainability Work Group
2. Water-Saving Work Group
3. Labor Productivity and Community Ecology Work Group
4. Postproduction Work Group

An executive committee was formed that consisted of the IMOP coordinator, the four work group leaders, and a representative of the Myanmar Rice and Paddy Traders Association (MRPTA).

The IRRC Myanmar Outreach Program began in the dry season in 2006. In essence, the IMOP consists of collaboration and cooperation between IRRI scientists, the MAS, and the MRPTA. MAS is the lead agency and the IMOP is administered under the general manager, Project Planning, Management, and Evaluation Division. The MAS project coordinator and lead national scientists highlighted the following general principles to guide the IMOP:

1. There will be a strong focus on farmer participatory research.
2. Sites will be established in at least three major rice-growing areas, with parallel activities at each of these sites.

3. Extension camps at a township level will be the focus for training of division and state extension personnel and for establishing demonstration sites.
4. The experimental design for verifying and validating an individual technology will be decided through cooperation with the respective designated expert from the IRRC of the International Rice Research Institute.
5. Sociological studies will be established through baseline household surveys and annual focus group discussions to monitor the needs of farmers and to obtain information on the response of farmers to specific technologies, including capturing adaptations made by farmers.
6. There will be annual meetings to review the progress of IMOP activities and to plan activities for the next year.

Initially, sites were chosen at five divisions, where extension staff from MAS established adaptive trials in farmers' fields to validate new IRRC technologies. The findings from these participatory field trials were disseminated to farmers and other stakeholders such as policy advisers and the private sector. The scaling out of the technologies is still at a preliminary stage, however, and the number of demonstration sites increased to 28 in 2008 (see Table 1) and effective local diffusion occurred via farmer-to-farmer contact.

Two common sites were chosen where all the work groups would have activities: Myaung Mya in Ayeyarwaddy Division, and Pyay in West Bago Division. In 2006, social scientists from IRRI coordinated baseline household surveys at each of these two sites by documenting the knowledge, attitudes, and practices of farmers for each of the main practices covered by the work groups (e.g., water use, nutrient management, pest—weeds, insects, and rodents—management, crop establishment, postproduction practices) and the inputs and outputs for rice production.

In the next section, we briefly review some of the activities and outputs of the respective work groups from 2006 to 2008.

I. The Productivity and Sustainability Work Group

The project started in the 2006 dry season with three different activities (see below for details). A site is defined as a township in a division with research teams represented by an extension unit and a research unit. In the 2007 and 2008 rice-growing season, the project sites were expanded from six to 13 townships. The original six townships continued to carry out only activity 2. The seven new townships conducted both activity 1 and 2. Detailed descriptions of the sites and locations are shown in Table 1.

Activity 1: Omission plot trials

Trials were established in farmers' fields where different plots were characterized with and without different combinations of nitrogen (N), phosphorus (P), and potassium (K) fertilizers. These plots are described as omission plots (see Buresh et al 2005). The omission research trials and demonstration plots in project areas provided clear responses to fertilizer use. The application of N increased yields by 0.5–2.7 t ha^{-1}, P by 0.4–1.7 t ha^{-1}, and K by 0.6 to 1.1 t ha^{-1}, respectively. The rice crops responded to the application of zinc in Pyay, Myaung Mya, and Taikkyi TSP, and to sulfur in Shwe

Table 1. Detailed description of sites and locations of activities of the Productivity and Sustainability Work Group of the IMOP in 2007 and 2008.

No.	Division/township	Soil type	Activities			Remarks
			I	II	III	
	Ayeyarwady					
1	Kyaiklatt—clay	Clay		*	*	
2	Kyaiklatt—loam	Loam		*		
3	Myaung Mya—clay	Clay		*		
4	Myaung Mya—loam	Loam		*		
5	Myan Aung—loam	Loam	*	*		Expansion
6	Myaung Aung—sandy	Sandy	*	*		Expansion
7	Kyaung Kone—clay	Clay	*	*		Expansion
8	Kyaung Kone—loam	Loam	*	*		Expansion
	West Bago					
9	Lepadan—clay		Clay		*	
10	Lepadan—loam	Loam		*		
11	Pyay—clay	Clay		*	*	
12	Pyay—loam	Loam		*		
13	Pyay—sandy	Sandy		*		
14	Kyo Pin Kauk—clay	Clay	*	*		Expansion
15	Kyo Pin Kauk—loam	Loam	*	*		Expansion
16	Kyo Pin Kauk—sandy	Sandy	*	*		Expansion
17	Oat Pho—clay	Clay	*	*		Expansion
18	Oat Pho—loam	Loam	*	*		Expansion
19	Oat Pho—sandy	Sandy	*	*		Expansion
	Sagaing					
20	Shwe Bo—clay	Clay		*	*	
21	Shwe Bo—loam	Loam		*		
	Yangon					
22	Taikkyi—loam	Loam		*		
23	Taikkyi—sandy	Sandy		*		
24	Kyauk Tan—Loam	Loam	*	*		Expansion
	Mandalay					
25	Mataya—clay	Clay	*	*		Expansion
26	Mataya—loam	Loam	*	*		Expansion
27	Amayapuya—clay	Clay	*	*		Expansion
28	Amayapuya—loam	Loam	*	*		Expansion

Bo and Taikkyi TSP. The response to organic matter in Myaung Mya, Letpaden, and Taikkyi TSP was 0.15 to 0.4 t ha^{-1}. The differences between sites in the response of rice crops to the respective fertilizers confirmed the need for site-specific recommendations: a strategy termed site-specific nutrient management (SSNM) (Dobermann et al 2002).

Activity 2: On-farm site-specific nutrient management (SSNM) evaluation
Evaluation of SSNM at the field scale increased rice yields by >20% (0.3–2.5 t ha^{-1}). Farmers were able to increase their net profit, ranging from 30,000 kyats to 70,000 kyats per acre. These successful field-scale demonstrations led to 70% to 90% of farmers in each project area becoming aware of the SSNM technology, with 10% to 35% of farmers adopting SSNM.

Activity 3: Combined technologies
This activity assessed the combined benefit of SSNM with other IRRC technologies. These were as follows:

(a) Integration of direct seeding using a drum seeder, and,
(b) Evaluation of the use of the modified mat nursery and younger seedlings for transplanted rice.

Both treatments were subsequently managed under SSNM.

From the 2005 dry season to the end of 2008, 14 townships realized clear benefits from adopting SSNM recommendations with either direct seeding or the use of the modified mat nursery when seedlings were transplanted. Focus group discussions at each project site indicated that 70% to 80% of farmers accepted the benefits of SSNM and the other technologies, with 10–35% of farmers adopting the recommended practices. The highest yield per hectare was 2.52 tons and the adoption of combined practices led to profits of 30,000 to 70,000 kyats above the SSNM fertilizer recommendations.

An important output of the project was the development in 2008 of a handbook on SSNM best practice and a pamphlet on the use of leaf color charts. These materials were provided to the farmers in the project areas, to extension staff, and to other people interested in transferring SSNM nutrient technologies to farmers.

II. The Water-Saving Work Group

Four divisions and five townships were selected based on the availability of water resources and the agroecological zone for water-saving activities. The four divisions were Sagaing, Mandalay, Bago (West), and Ayeyarwaddy. The townships involved were Monywa, Nyaung U, Pyinmana (Yezin), Pyay, and Myaung Mya.

Beginning in 2006, two field demonstrations were implemented: alternate wetting and drying (AWD) and variety trials of aerobic rice. In Myaung Mya, during the 2006 dry season, farmers using AWD needed only 5 pumping sessions to irrigate their crop, compared with the usual farmer practices, which required 8 to 10 pumping sessions. On average, AWD saved about 40% in fuel compared with the usual farmer practices, with a slight yield penalty.

In Pyay, during the 2006 dry season, five farmers each had a slightly higher yield when adopting AWD, but, more importantly, they required less water. This is important because this area often faces a water shortage late in the cropping season because of canal spoilage. In the wet season, yield increased by 15 baskets per acre using 30% less water.

The field trials were repeated in 2007 with similar results. These trials clearly validated the potential of AWD in lowland rice cropping systems to significantly reduce water usage while maintaining yields.

Also in Pyay during 2006, participatory variety selection trials involving farmers were conducted at three sites: Pyay, Yezin Agricultural University, and Nyaung U. All aerobic varieties outyielded the check variety. Further trials were conducted in 2007 using different nitrogen fertilizer rates.

Lessons learned

The following issues emerged after the farmer participatory field trials:

1. The perched tube used by farmers to observe water level is a simple and effective tool for farmers.
2. Adoption of AWD is less likely in areas with plenty of water resources that can be accessed by low-pressure–high-volume pumps, especially in the Ayeyarwaddy Delta in the monsoon season. AWD is well suited for the summer season.
3. AWD has tremendous potential in cropping areas with limited water resources such as central and upper Myanmar.
4. Aerobic rice has promising potential for farmers in water-scarce areas.
5. Problems that were encountered were the logistics of being able to apply water on time in irrigation systems where water is distributed in a rotational manner; power failures limited the efficiency of timely water distribution in areas serviced by electrical pumps; land leveling was insufficient in some areas, which affected drainage; and poor maintenance of irrigation channels.

III. Activities of the Labor Productivity Work Group

Field activities began in 2006 and they included the following:

Characterization of losses due to weeds in farmers' fields

The community of major species of weeds and the associated losses were assessed at six sites—Yangon Division (1 site), Ayeyarwaddy Division (2 sites), West Bago Division (2 sites), and Sagaing Division (1 site). During the 2006 summer cropping season, yield from farmers' fields was, on average, 18% lower than that of fields managed by researchers (Table 2). In lower Myanmar, 5 sedges, 10 grasses, and 7 broadleaf weeds were common. In upper Myanmar, 4 sedges, 2 grasses, and 6 broadleaf weeds were identified.

Table 2. Yield losses in wet direct-seeded rice due to weeds in six townships in Myanmar during the summer rice crop in 2006.

Township	Grain yield (t ha^{-1})			% yield reduction	Range in % yield reduction
	No. of fields	Researcher-managed	Farmer-managed		
Hlegu	9	5.68	5.42	5	0–12
Myaung Mya	20	5.66	3.84	32	22–40
Kyaik Latt	20	5.02	3.88	23	1–40
Pyay	20	3.17	2.92	8	3–16
Lepadan	20	3.84	3.42	11	0–17
Shwe Bo	20	3.74	3.63	3	0–9
Mean		4.88	4.01	18	

Demonstration and evaluation of the drum seeder

The sites were the same as above, except that an additional site was added in Mandalay Division in 2007. The drum seeder has been a successful technology in the Indo-Gangetic Plains for direct seeding of rice paddies (see Singh et al 2008 and references therein) but is a new technology for Myanmar. The technology was compared with the broadcast application of rice seeds.

In lower Myanmar (four sites), crop establishment via a drum seeder followed by weeding at 14, 28, and 42 days after seeding increased yields over direct seeding (farmers' practice) by 23.8% (mean yield increase of 1.0 t ha^{-1}). In upper Myanmar (one site only), the same crop establishment and weeding protocol led to an increased yield of 7.8% (yield increase of 0.4 t ha^{-1}).

IV. Activities of Postharvest Work Group

The efficacy of Super Bags for seed storage

In Yangon Division, Mandalay Division, and Kayin State, the efficacy of storing seeds in specially developed plastic bags that have three layers, including a membrane impermeable to oxygen (the IRRI Super Bag), was tested for rice, maize, mungbean, cowpea, and groundnut. Seeds were stored in Super Bags and traditional bags.

The germination percentage of rice seed (Table 3) and groundnut seed stored in Super Bags was significantly higher than that in traditional bags after 6 months of storage.

The efficacy of hermetically sealed storage of paddy

We investigated whether hermetical storage of rice in 5-ton cubic tubes can be done without using insecticides. These large cubes are designed for use by millers and seed merchants. Moisture content and germination percentage were found to be stable and the milling process was good after 6 months of storage. Thereafter, milling quality of the stored rice decreased.

Table 3. Effect of the IRRI Super Bag on germination of rice after 6 months of storage.

Division	Township	Super Bag		Traditional bag	
		Moisture content (%)	Germination (%)	Moisture content (%)	Germination (%)
Yangon	Thonekwa	13.2	93	15.0	70
Yangon	Postproduction trials	13.8	88	15.9	–
Mandalay	Tatkone	13.0	88	14.2	46

Diffusion of flat-bed dryers

Strong links with the private sector through the MRPTA have led to the construction of more than 40 flat-bed dryers and the associated training of farmer groups. This has been a tremendous development that highlights the potential benefits of private-public partnerships.

Training through the IMOP

Three training courses aimed at training of trainers (ToT) were conducted between 2006 and 2008 across the four work groups. These workshops were conducted at the Central Agricultural Research and Training Centre (CARTC), with a total of 136 participants. The participants were regional officers, township managers, and extension workers from project sites.

Each of the other work groups conducted its own training during 2006-08 under the IMOP banner. An example is the ToT and training of farmer courses conducted by the Productivity and Sustainability Work Group (Table 4).

IRRC scientists and senior research assistants provided assistance during initial ToT courses for all work groups.

Strengths and potential of the IRRC Myanmar Outreach Program

The experimental testing of component IRRC technologies under field conditions in Myanmar validated their potential to provide positive and low-cost practices that are easily followed by farmers. The participation of farmers led to “learning by doing” and provided an opportunity to obtain direct feedback on how farmers adopt and adapt these new technologies. Establishing common demonstration sites for testing these technologies provided an opportunity for farming communities to become aware of a set of new technologies, and they can then decide which ones are most appropriate to their needs. Evidence was clear of farmer acceptance of these technologies, with neighboring farmers beginning to adopt then. Moreover, farmer participatory demonstration sites and high-profile field days led to positive feedback from key stakeholders, including high-level policy advisers.

Table 4. Number of training of trainers (ToT) and training of farmers (ToF) activities conducted by the Productivity and Sustainability Work Group, 2005-08.

Location	Training on SSNM and LCC[a]				Demonstration and SSNM/FFP	
	ToT		ToF			
	Times	No. of farmers	Times	No. of farmers	Times	No. of farmers
Ayeyarwaddy	10	104	11	493	11	493
West Bago	6	45	11	262	11	354
Sagaing	10	150	16	720	16	720

[a] SSNM = site-specific nutrient management, LCC = leaf color chart, FFP = farmers' practice.

Two key strengths of the IMOP have been the extended partnerships developed with other research and extension agencies, and regular briefings of high-level government officials. The partner agencies include Yezin Agricultural University, the Department of Agricultural Research, the Myanma Rice Research Centre at Hmawbi, the Irrigation Training Centre, and the MRPTA. Raised awareness of the IMOP at the policy level has occurred through regular meetings with the director general of the Department of Agricultural Planning, and with managers of the MAS divisions involved in the field activities. This scaling up of our activities has been supplemented by high-profile annual meetings between the IRRI IRRC work group coordinators and their Myanmar IRRC counterparts. The managing director of extension chaired these meetings, which were also attended by the general manager of the Project Planning, Management, and Evaluation Division.

Based on the experiences of the IMOP, the integrated implementation of activities of the four working groups led to greater farmer and multistakeholder participation and strengthened partnerships. The challenge now is to develop strategies to scale out these technologies to end-users in the main rice-growing areas of Myanmar. This is now the top priority of the IMOP.

References

Buresh RJ, Witt C, Ramanathan R, Mishra B, Chandrasekaran B, Rajendran R. 2005. Site-specific nutrient management: managing N, P, and K for rice. Fert. News 50:25-28, 31-37.

Department of Agricultural Planning. 2008. Myanmar agriculture at a glance. Department of Agricultural Planning, Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar. 132 p.

Department of Agricultural Research. 2007. Myanmar agriculture in brief, 2007. Department of Agricultural Research, Ministry of Agriculture and Irrigation, Yezin, Myanmar.

Dobermann A, Witt C, Dawe D, Abdulrachman S, Gines HC, Nagarajan R, Satawathananont S, Son TT, Tan PS, Wang GH, Chien NV, Thoa VTK, Phung CV, Stalin P, Muthukrishnan P, Ravi V, Babu M, Chatuporn S, Sookthongsa J, Sun Q, Fu R, Simbahan GC, Adviento MAA. 2002. Site-specific nutrient management for intensive rice cropping systems in Asia. Field Crops Res. 74:37-66.

Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. 2008. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. 272 p.

Notes

Authors' addresses: Maung Maung Yi, Myanma Agriculture Service, project planning, Management and Evaluation Division, Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar; Aye Tun and Aye Aye Mar, Myanma Agriculture Service, Plant Protection Division, PO 11011, Yangon, Myanmar; Kyaw Yee, Myanma Agriculture Service, Land Use Division, Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar; Than Aye, Department of Agricultural Planning, Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar; Grant R, Singleton, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines.

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Part II
From Science to Practice

Experiences from Research, Academe, and Extension Organizations

Tackling hunger through early rice harvests in northwest Bangladesh: making a difference with direct seeding and varietal choice

M.A. Mazid and D.E. Johnson

Rural people of northwest Bangladesh face regular food shortages during early October to mid-November because of a lack of employment opportunities for agricultural laborers and marginal farmers. This seasonal crisis/hunger, termed *monga*, is due in part to the widespread cultivation of long-duration rice varieties that are transplanted after the land has been puddled in the rainy season, and which are not harvested until November. The introduction of shorter-duration rice varieties, direct seeding and appropriate weed management, and crop diversification sought to increase opportunities in the system. The options aimed to advance the harvest of the rice crop to generate employment within the *monga* period for the landless and agricultural day laborers. Early harvest provides an early food supply to marginal farmers and the employment generated during *monga* enables those depending on agricultural wages to buy food. In addition, early rice harvests increase the opportunities for increasing cropping intensity by enabling the cultivation of postrice crops.

Technology options were introduced to farmers through partnerships with government and nongovernment organizations and research institutions through farmer participatory and group approaches with farmer field schools. Preliminary results show that early-maturing varieties combined with direct seeding (DSR) gave better yields than the traditional practices, but these varied by location. DSR options that performed well include dry DSR by line sowing using a *lithao* in upper fields with light-textured soils, and pregerminated (wet) DSR sown using a drum seeder was better suited to the medium-high land. DSR options save labor for crop establishment and dry DSR was preferred by farmers as it reduced costs and enabled farmers to establish a crop after little rainfall. A national program for *monga* mitigation in northwest Bangladesh, with an action plan of three years (2008-10), was launched by the Bangladesh government and this included the options of direct seeding and shorter-duration varieties for "early harvest."

Keywords: *monga*, weeds, establishment, field school, poverty, NGO, crop diversification

Monga describes a seasonal hunger crisis in early October to mid-November (Bengali: *ashwin-Kartik*) in northwestern Bangladesh. Rice is the predominant crop and at that time the crop is not ready for harvest and there are few opportunities for employment in the rural area. Many laborers have little or no cash to buy food in the market. *Monga* affects two main groups of people: (1) agricultural day laborers and the landless (<0.2 ha or <50 decimals of land) who do not have employment or cash, and (2) marginal farmers who have land size of 0.2–0.6 ha (50–149 decimals) and face a food shortage for 1 to 2 months during the *monga* period. The rice crop, which usually has a transplanted (T. aman) long-duration (140–145 days) variety (LDV) such as BR11/Swarna, is not mature at this time. Prior to harvest, little other work is available for agricultural laborers. Laborers are therefore compelled to borrow money, often at extortionate rates (approx. 40%), from landowners (small-large farmers) as an advance on future labor wages to be earned from mid-November to December. Sometimes, laborers migrate to cities or other districts for work. It is estimated that about 2.85 million agricultural laborers (equivalent to 0.55 million families/households, HH) are within category 1 in five districts of Greater Rangpur, northwestern Bangladesh. In HH category 2, about 0.85 million marginal farmers (0.17 million farm families) are affected by regular *monga*. During the *monga* period, marginal farmers may take high-interest loans from *Mohajon* (moneylenders) or sell their harvest early at a low price to buy food. Farmers may also sell assets such as poultry and livestock at low prices to overcome *monga*.

Rangpur, Kurigram, Lalmonirhat, Nilphamari, and Gaibandha districts in greater Rangpur are considered to be a region of food surplus. There are, however, no industries, and agriculture is the main occupation. The majority of the population are either landless agricultural day laborers or marginal farmers. *Monga* also occurs from mid-March to mid-May (Bengali*: Choitro-Boishakh*), as again there are few opportunities for employment until land preparation for the main-season crops gets under way. Hunger in this period tends to be less widespread than in October**.**

Given the regular periods of hunger and poverty, an imperative is to generate employment opportunities during these periods for those dependent on paid employment. The approach tried was to "advance the harvest" by growing shorter-duration rice varieties and by using direct seeding to allow the crop to be established sooner. The intention was not only to create *early-harvest* employment but also to increase the opportunities for growing postrice crops (rabi crops) to intensify cropping, generate employment, and improve livelihoods. Specific objectives of the activities were to (1) identify opportunities to generate employment for the agricultural day laborers during *monga* periods; (2) secure food for marginal farmers (0.2–0.6 ha) and reduce food shortages in the *monga* periods; (3) evaluate direct-seeding options and weed control options for the short- and long-duration rice varieties; and (4) identify opportunities for crop diversification to raise farmers' total productivity.

Developing technology options to raise productivity and mitigate *monga*

Short-duration and high-yielding rice varieties

A medium-duration rice variety (BRRI dhan33) was available for inclusion in these activities as an alternative to the longer-duration (140–145 days) aman varieties BR11 and Swarna. BRRI dhan33 is a photo-insensitive early-maturing rice variety (115–118 days), with bold grain, good eating quality, and yield potential of 4.0–4.5 t ha^{-1}. This variety was developed by BRRI and released by the National Seed Board in 1997. While recommended for transplanting (TPR), it can also be direct seeded**.** With dry direct seeding, BRRI dhan33 has been shown to have 10–13 days' shorter duration than with transplanting.

Direct seeding and weed management

Traditionally, rice is grown as a single rainfed monsoon crop (aman)**;** however, the widespread installation of shallow tubewells allows irrigated rice to be grown in the dry season (boro) in many areas of Rangpur. Further, increasing production costs in irrigated areas are encouraging farmers to seek cheaper production methods and, particularly, to reduce irrigation water and labor requirements. The potential for direct seeding combined with herbicides to reduce production costs was assessed in the wet season (aman) and in the irrigated season (rabi). The work began on-station in 2004 and continued until 2008, with parallel activities being conducted on-station and on-farm. The aims of these activities were to test different crop establishment methods, identify the most suitable weed control options for different DSR methods, to test the leaf color chart (LCC) to guide nitrogen use in dry and wet DSR, and to record farmers' views of the advantages and constraints of wet and dry DSR.

On-station experiments

The experiments were conducted at the BRRI Regional Station, Rangpur.

Direct seeding in aman 2004/boro 2005

Wet DSR (pregerminated seed) was sown using a hand-pulled "lightweight" drum seeder (DS) or by hand-broadcasting (BC) in the boro season only, onto plowed and puddled land, and compared with the usual farmer practice of transplanting. The experiment at the BRRI-Rangpur research station was conducted with three replications in aman 2004 and boro 2005 on an irrigated area. Pregerminated seed of rice cultivars BR11 (aman) and BRRI dhan28 (boro-irrigated) were sown using 56 and 75 kg ha^{-1} by DS and BC, respectively. TPR was spaced at 20 cm × 20 cm in rows. Hand weeding at 30, 45, and 65 DAS/DAT was compared with preemergence application of oxadiazon (Ronstar 25 EC; 375 g a.i. ha^{-1}) in DS/BC or pretilachlor (Rifit, 500 g a.i. ha^{-1}) in TPR, each followed by one hand weeding.

Direct seeding and weed control (aman 2006) and nitrogen application (boro 2007)

Dry direct seeding using a *lithao* (an iron hand-pulled plow) into dry soil was compared with wet DSR by a drum seeder. Weeds under each direct-seeding method were controlled with oxadiazon or ethoxysulfuron or pretilachlor in TPR, or hand weeding (3 times). In the boro season of 2007, in addition, two nitrogen management options were compared as either the BRRI recommended rate (124 kg N ha^{-1}) or "as needed" based on the LCC. The experimental design was a split-split plot with crop establishment method as main plots, N management as subplots, and weed control options in the sub-sub plots, with three complete replications. Rice cultivar BR11 was grown in the aman season. The cold-tolerant modern rice variety BRRI dhan36 was used in the boro study with seeds being soaked on 10 January and sown on 15 January for dry DSR and 18 January for wet DSR.

In preparation for dry DSR, 2–3 tillage passes were undertaken and final land preparation was "laddering" 2 days before sowing. Furrows were opened by a *lithao* and pregerminated seeds were sown by hand and seed covered thinly with soil. For wet DSR, an initial dry tillage was undertaken, followed by irrigation, and the land wet-cultivated to "puddle" the soil a week before sowing. Finally, sprouted rice seeds were sown in line by using a drum seeder.

Preemergence herbicide oxadiazon was applied at 2 days after sowing in dry DSR and 8 days after sowing in the drum seeder plots. The early postemergence herbicide ethoxysulfuron was applied at 17 DAS in wet DSR and at 30 DAS in dry DSR. In TPR, pretilachlor (500 g a.i. ha^{-1}) was applied at flooding. An additional hand weeding was done at 60 DAS in plots where herbicides were applied. Three hand weedings were done at 30, 45, and 60 DAS in each establishment method. Weeding time was recorded for costing. The BRRI recommended rate of N application is 124 kg ha^{-1}, equal to three splits at 30, 45, and 60 DAS, and it was compared with N topdressing based on LCC values (panel 3.5 for TPR and 3 for DSR) starting from 30 DAS at 10-day intervals up to panicle initiation (PI) stage.

Farmers' field trials

Crop establishment and weed control options were assessed on-farm with five farmer groups in irrigated rice. Plot size varied between farms but ranged from 800 to 3,200 m^2 (20–80 decimals). BRRI provided the rice seed (BRRI dhan33), loan of the drum seeder or *lithao,* herbicide, and guidance for the application of the options. Farmers supplied the land, labor, and fertilizer.

To initiate on-farm activities to evaluate direct seeding, farmers with access to suitable land types—highland, medium-high land, or irrigated areas for boro or early aman rice—were invited to join a "group discussion." Within this forum, the options for direct seeding and boro cropping were introduced, and interested farmers were invited to join the program. Training was given initially by BRRI-Rangpur staff on direct seeding of rice, weed management including herbicide use, and the use of the

Table 1. Rice yield (t ha^{-1}) in rainfed and irrigated rice in trials at BRRI Rangpur Station, 2004-05.

Establishment method	Weed control			
	Rainfed 2004 (aman season)		Irrigated 2005 (boro season)	
	Hand weeding	Herbicide	Hand weeding	Herbicide
Transplanted	3.55	4.03	5.02	5.10
Wet DSR by drum seeder	3.80	4.60	5.88	6.41
Wet DSR by broadcasting	Not tested		5.78	6.34
S.E.	0.16 (6 d.f.)		0.23 (10 d.f.)	

LCC. Training of 20–25 farmers in a "group" lasted one day and included sessions of theory and practice. Farmers were also provided with a technical handout on the direct-seeding options. "Clusters" consisting of 4–5 farmer groups from a community-based organization (CBO) were formed with each "cluster" having a "local service provider" (LSP) appointed, initially a volunteer, in order to provide technical support to farmers. Although the LSPs were initially voluntary, once established, it was expected that LSPs would charge farmers for their services and advice. Out-scaling of this model was undertaken by linking with an international NGO—Intercooperation (IC)—that had a project, LEAF (Livelihoods, Empowerment, and Agroforestry Project; IC-LEAF), based in Rangpur. IC-LEAF in turn worked with local partner NGOs in five districts (SOLIDARITY–Kurigram, UDDYOG–Gaibhandha, BRIF and SERP–Nilpharmari, GAUS/RIB in Laxmichap in Nilpharmari, and SEED in Gangachora, Rangpur).

Results

Rice yields

Aman and boro seasons 2004-05. On-station experiments showed that significantly higher yields could be obtained with direct seeding than with transplanting (Table 1). Further, herbicide use in most cases gave greater yields than hand weeding alone probably as a result of reduced weed competition and disturbance. Hand-weeding costs rather than herbicides were 43% greater, however, in DSR than in TPR (data not shown).

Aman season 2006. Wet-seeded rice sown with a drum seeder (6.12 t ha^{-1}) gave 8% greater mean grain yield than with transplanting (5.65 t ha^{-1}), though the difference was not significant (Table 2). Oxadiazon plus one HW in wet DSR resulted in a greater grain yield than HW alone, and substantially, though not significantly, more than ethoxysulfuron plus HW (Table 3). Wet, drum-seeded DSR combined with the preemergence herbicide oxadiazon gave the highest grain yield (6.87 t ha^{-1}). The postemergence herbicide ethoxysulfuron (5.88 t ha^{-1}) gave a similar weed control and grain yield as three hand weedings (5.60 t ha^{-1}). Pretilachlor gave the greatest mean yield in TPR though the differences in the yields between the weed control treatments

Table 2. Effect of crop establishment methods on grain yield in trials at BRRI Rangpur Station, aman 2006.

Crop establishment method	Grain yield ($t\ ha^{-1}$)
Wet DSR by drum seeder	6.12
TPR	5.65
5% LSD	0.63

Table 3. Effect of weed control options in different methods on grain yield in trials at BRRI Rangpur Station, aman 2006.

Crop establishment method	Weed control options	Grain yield ($t\ ha^{-1}$)
Wet DSR by drum seeder	3 hand weedings (HW)	5.60
	Oxadiazon + 1 HW	6.87
	Ethoxysulfuron + 1 HW	5.88
TPR	3 HW	5.21
	Pretilachlor + 1 HW	5.96
	Ethoxysulfuron + 1 HW	5.65
5% LSD		1.10

were not significant. Compared with three hand weedings, herbicide application reduced weed control cost by 53–57% in wet drum-seeded DSR and by 34–42% in TPR (Table 4).

Boro season 2007. N management guided with the LCC resulted in a slightly greater (<10%) grain yield than the recommended rate in wet and in dry DSR (Table 5). Across weed control methods, wet DSR sown using a drum seeder gave significantly greater grain yield (4.63 $t\ ha^{-1}$) than dry DSR sown with a *lithao* (3.73 $t\ ha^{-1}$) in the boro season (Table 6). Yield differences with the different weed control treatments within the establishment methods were not significantly different. In the wet DSR, the preemergence herbicide oxadiazon had the greatest grain yield, followed by early postemergence herbicide ethoxysulfuron. In dry DSR, oxadiazon again gave the greatest mean yield, but this was similar to hand weeding, and ethoxysulfuron gave the least.

Yield losses due to weeds occurring where no hand weeding was undertaken were greater in dry DSR than in wet DSR regardless of the weed control treatment (Table 7). Only in the treatment combination of wet DSR by a drum seeder combined with oxadiazon were the yield losses due to weeds constrained to less than 20% of the

Table 4. Costing of labor in different weed control options with crop establishment methods, trials at BRRI Rangpur Station, aman 2006.

Crop establishment method	Weed control options	Cost (US$ ha^{-1})
Wet DSR by drum seeder	3 hand weedings (HW)	110
	Oxadiazon + 1 HW	47
	Ethoxysulfuron + 1 HW	52
TPR	3 HW	66
	Pretilachlor + 1 HW	47
	Ethoxysulfuron + 1 HW	41

Table 5. Effect of N management in wet and dry DSR on grain yield, in trials at BRRI Rangpur Station, boro 2007.

Method	N management	Grain yield (t ha^{-1})
Wet DSR by drum seeder	N by LCC	4.85
	N by recommended rate	4.40
Dry DSR by *lithao*	N by LCC	3.84
	N by recommended rate	3.62
5% LSD		0.884

Table 6. Effect of weed control options in wet and dry DSR on grain yield in trials at BRRI Rangpur Station, boro 2007.

	Grain yield (t ha^{-1})			
Method	3 HW	Oxadiazon + 1 HW	Ethoxysulfuron + 1 HW	Mean
Wet DSR	4.04	5.09	4.75	4.63
Dry DSR	3.80	3.97	3.42	3.73
5% LSD		1.082		0.625

Table 7. Grain yield losses (t ha^{-1}) due to weeds in wet and dry DSR plots without hand weeding in trials at BRRI Rangpur Station, boro 2007.

Weed control	Wet DSR by drum seeder			Dry DSR by *lithao*		
	Weeding	No hand weeding	% of loss	Weeding	No hand weeding	% of loss
3 HW	4.04	1.72	57	3.80	0.71	81
Oxadiazon + 1 HW	5.08	4.23	17	3.97	1.60	60
Ethoxysulfuron + 1 HW	4.74	2.59	45	3.42	1.13	67

yields obtained from plots with supplementary hand weeding. These results highlight the importance of ensuring effective weed control where rice is direct seeded and the extent of potential losses when adequate control is not achieved.

Of the main weed species in hand-weeded plots with dry DSR, *Cynodon dactylon* produced the most biomass (8.7 g m^{-2}), followed by *Paspalum distichum* (6.8 g), *Cyperus polystachyus* (6.4 g), *Marsilea minuta* (4.0 g), *Echinochloa crus-galli* (3.2 g), and *Hedyotis diffusa* (2.0 g). *Cyperus difformis* was controlled by ethoxysulfuron effectively in dry DSR but not in wet DSR. With hand weeding alone, more broadleaves and sedges were found in wet DSR than in dry DSR. The preemergence herbicide oxadiazon gave more effective control of weeds than the early postemergence herbicide ethoxysulfuron in both wet and dry DSR methods. Oxadiazon effectively controlled most grasses, broadleaves, and sedges in either wet or dry DSR.

Economics

Crop establishment using dry DSR required more labor for hand weeding and greater costs than was required for the 3 HW in wet DSR (Table 8). The use of preemergence herbicide oxadiazon reduced weeding cost by about 53% compared with 3 HW in dry DSR and by 77% with wet DSR. The use of oxadiazon reduced weeding cost more than the early postemergence herbicide ethoxysulfuron. These results illustrate that the use of herbicides in DSR to reduce the need for hand weeding offers considerable advantages over manual weed control methods.

Use of irrigation water

Dry DSR required less frequent but longer irrigation events (12,209 hours) than wet DSR (27 and 295 hours), suggesting that the irrigation costs of dry DSR may be less than in wet DSR. Dry DSR does not require the land to be flooded and puddled as with TPR, and dry DSR can be established successfully on saturated soil. Where farmers are reliant on irrigation, this can lead to considerable savings on lower pumping costs.

Table 8. Labor required and costs of weed control options with different crop establishment methods, BRRI Rangpur Station, boro 2007.

Method	Weed control options	Labor days ha^{-1}	Weeding cost (Tk ha^{-1})
Dry DSR	3 hand weedings (HW)	269	350
	Oxadiazon + 1 HW	112	165
	Ethoxysulfuron + 1 HW	140	192
Wet DSR	3 HW	201	262
	Oxadiazon + 1 HW	30	59
	Ethoxysulfuron + 1 HW	50	76
5% LSD		4	–

Working with farmers

To validate DSR technology in different areas and learn more of possible constraints and opportunities with DSR, farmers' field trials commenced in 2004. The number of farmers' field trials conducted rose from 5 in 2004 to 38 in 2005, 96 in 2006, and 132 in 2008.

Aman season

In farmers' fields in 2005, irrigated DSR established using a drum seeder gave grain yields (5.42 t ha^{-1} ± 0.35) that were greater than those with hand broadcasting (4.95 t ha^{-1} ± 0.47) or transplanting (4.89 t ha^{-1} ± 0.40). Further, farmers reported lower labor requirement for sowing for DS, which required 3 person-days ha^{-1} for sowing compared with 77 days ha^{-1} for transplanting. In addition, savings occurred as no nursery bed was required for DSR.

In the 2005 aman season, BRRI dhan33, a short-duration variety (SDV, 118 d), was wet-sown on 20-25 June using a drum seeder (DS) on puddled soil and dry-sown with a *lithao* on dry soil. At the same time, seeds were sown in a nursery bed and later 20–25-day-old-seedlings were transplanted. The long-duration variety BR11 was sown with a drum seeder on 8-18 June. The short-duration variety BRRI dhan33 matured during 10-25 October and farmers harvested similar grain yield from wet DSR by a drum seeder and dry DSR by a *lithao*, but TPR crops gave 21% lower yield than DSR (Table 9). The direct-sown long-duration variety BR11 (135 d) also matured during the *monga* period on 2-12 November 2006 and produced a greater grain yield than short-duration variety BRRI dhan33 (105 d) that had been direct seeded (either dry or wet sown).

In the 2007 aman season, Intercooperation, along with three partner NGOs—SOLIDARITY in Kurigram District, ZIBIKA in Lalmonirhat, and UDDYOG in Gaibandha—outscaled the "*monga* mitigation" options with farmers' groups. These

Table 9. Grain yield in farmers' fields of BRRI dhan33 rice following different crop establishment methods for *monga* mitigation, BRRI Rangpur, aman 2006.

Crop establishment method	Name of variety	DS/DT	Date of harvesting	Grain yield (t ha^{-1})
Wet DSR by drum seeder	BRRI dhan33	25-30 June	10-15 October	4.81
Dry DSR by *lithao*	BRRI dhan33	25-30 June	10-15 October	4.82
TPR	BRRI dhan33	25-30 June	20-25 October	3.86
Wet DSR by drum seeder	BR11	7-18 June	2-12 November	5.01

Table 10. Grain yield in farmers' fields of BRRI dhan33 vs BR11 with different crop establishment methods, Rangpur, aman 2007.

Name of variety	Method	Harvesting period	Grain yield (t ha^{-1})		
			Farmers (no.)	Range	Average
BRRI dhan33	DSR	5-13 October	24	3.2–4.8	3.8
	TPR	13-22 October	23	2.4–4.2	3.3
BR11	DSR	30 Oct.-15 November	15	4.0–5.1	4.3
	TPR	20-30 November	6	2.9–3.6	3.2

demonstration fields used BRRI dhan33 in highland and medium highland areas, and comparing transplanting and direct seeding (dry seeding) in a total of 59 farmers' fields. Across these areas, the yields of TPR and DSR were broadly similar, though DSR gave about 10% more grain yield than TPR overall (Table 10). Grain yields in farmers' fields were greater on average with DSR than with TPR. The long-duration variety in particular suffered from terminal drought when the harvest was delayed in the TPR crop.

Boro season

The low temperatures that occur during December to January cause problems with crop establishment. To avoid seedling mortality due to these low temperatures, farmers found that boro rice must be direct seeded by mid-December, a month earlier than is usual for TPR. This suggests that the adoption of direct seeding by farmers will be an option only where irrigation is available earlier than for transplanting.

Table 11. Rice grain yield of BRRI dhan33 obtained from farmers' fields, BRRI-IRRI (LPWG-IRRC)-NGO collaboration, Rangpur, aman 2007.

Name of areas	Farmers (no.)		Grain yield (t ha^{-1})	
	DSR	TPR	DSR	TPR
Sobandaha, Sadar, Kurigram	4	6	3.45	3.54
Dud khaoa, Rajarhat, Kurigram	6	3	3.52	3.70
Bogarchara, Harano mosjid, Sadar, Lalmonirhat	2	8	4.84	4.19
Kanteshwar para, Aditmari, Lalmonirhat	4	6	3.18	2.40
Shapara, Gaibandha	4	16	3.44	2.82
Total/mean	20	39	3.69	3.33

Collaborative action

In 2006-07, about 1,000 farmers were trained (Table 12) through the collaborative alliance between the NGO Intercooperation–LEAF and the local partners, the Bangladesh Rice Research Institute and IRRI. Field days were held to extend the options for "early harvest" and gather farmers' feedback at crop-cut ceremonies. In the feedback from farmers, one of the major impacts of direct seeding was that where a variety was sown by direct seeding at the same time as the nursery beds were established, harvest was some 10 days earlier than with transplanted crops. Dry direct seeding, however, often allowed the crop to be sown before nursery beds were sown. For this option, it was not necessary to wait until sufficient rainfall had fallen or irrigation was provided to allow the land to be puddled.

It became apparent that a critical factor in the selection of sites and farmers' groups was the suitability of the land for direct seeding in the aman and boro season cropping. The gently undulating toposequence of northwest Bangladesh offers a wide range of environments that can determine the success of direct seeding. Experience has shown that the greatest chances of success for dry direct seeding were on the medium/highland land types. These areas were less susceptible to early monsoon flooding and the soils tended to be freer draining. Farmers are acutely aware of differences in the moisture regimes at the different positions on the toposequence and they take account of these in the timing of farming operations. It becomes difficult to direct-seed rice on heavy clay soils once they become wet, and flooding can suddenly occur with the onset of monsoon rainfall.

Experience of working in farmers' fields and across a range of sites was that drum seeding with wet DSR was a feasible option where farms had irrigation water available, or where the soil had good "water-holding capacity" and where rainwater could be retained and excess rainwater drained from the field. Dry seeding and the *lithao* were better options where farmers had no irrigation facilities, where rainfall

Table 12. Training sessions and participants organized by BRRI regional station, Rangpur, 2006 and 2007.

Organizations[a]		Training 2006		Training 2007	
		Training events (no.)	Participants (no.)	Training events (no.)	Participants (no.)
GO	DAE, Rangpur region	6	383	4	131
	BRDB, Rangpur	2	52	2	20
NGO	RDRS Bangladesh	1	8	2	75
	TMSS, Lalmonirhat	2	47	–	–
	USS, Nilphamari	3	140	1	4
	GAUS, Nilphamari	–	–	1	30
	SEED, Rangpur	–	–	2	18
	IC-LEAF with PNGOs (SOLIDARITY, UDDYOG, BRIF, SERP)	–	–	5	210
Total		14	630	17	488

[a] DAE = Directorate of Agriculture, BRDB = Bangladesh Rural Development Board, RDRS = Rangpur-Dinajpur Rural Service, TMSS = Tengamara Mohila Sabuj Songstha, USS = Udayunchur Seba Songsta, GAUS = Gramin Arto Unnion Sonstha, SEED = Social Equality Effective Development, IC = Intercooperation, BRIF = Bangladesh Rural Improvement Foundation, SERP = Service Emergency for Rural People.

was inadequate for land puddling, or where the soils were of light texture (e.g., sandy loam) with poor water-holding capacity such as are often found in high/medium-high land.

Farmers' opinions on DSR

Farmers' opinions on DSR were as follows:

- DSR was an option that reduced costs compared with TPR, as it avoided the need for nursery preparation, seedling uprooting, and transplanting and this reduced labor and saved production cost.
- Weed growth was greater in DSR than in TPR, but the use of herbicide with a supplementary hand weeding in DSR greatly reduced weeding control costs.
- DSR rice matured 10–12 days earlier than TPR and could be harvested during the *monga* period. Early harvests increased the chance to establish a second crop such as potato, wheat, mustard, and vegetables. The earlier second crops also gave more yields due to reduced water/temperature stress, and there was less need for pesticide/fungicide spraying of potato, which reduced production costs.

- Dry DSR by a *lithao* is a technology option that is suitable for light-textured soils and can effectively be undertaken after relatively little irrigation or rainfall compared with either wet seeding or transplanting. Harvests of dry DSR were earlier than with TPR and yields were as good as with wet DSR by a drum seeder.
- Soils that had been puddled for either TPR or wet seeding "cracked" due to low rainfall in 2006 while the soils that had not been puddled and were dry-sown did not crack. Further, rice growth was good in the dry DSR plots despite the drought though, in some cases, supplementary irrigation was required to escape drought**.**

Farmers' opinions of the short-duration rice cultivar BRRI dhan33 were that

- BRRI dhan33 (118 d) matured about 25–30 days earlier than BR11 and allowed harvest during the *monga* period.
- BRRI dhan33 with DSR matured at 103–105 days or some 40 days earlier than transplanted BR11, Swarna (145–150 d), and others, and BRRI dhan33 yielded 3.2–4.8 t ha^{-1}.
- Early harvesting of BRRI dhan33 resulted in a high market price for the grain and for the straw that was used for livestock during the *monga* period.
- Farmers were able to increase cropping intensity and total productivity by growing rabi (winter) crops such as potato, wheat, mustard, and vegetables after the earlier harvest of BRRI dhan33.
- Early establishment of potato reduced the risk of fungal blight of potato and reduced the costs of preventive spraying. To control disease in late-planted potato crops requires 10–12 sprayings compared with only 2–4 times for early-planted potato crops.
- Early maize crops, relay-sown with potato, gave higher grain yields than later crops due to the lower risk of the maize harvest being spoiled by early rains.
- Agricultural day laborers were able to buy food during *monga* months as they had employment for the rice harvest and for establishment of the succeeding crops.
- Marginal farmers growing BRRI dhan33 were able to harvest aman rice early, which improved income and household food security during the *monga* period.

Perceptions on BRRI dhan33 as a mitigation factor for *monga*

Farmers, NGOs, and media were convinced about the performance of the shorter-duration rice, BRRI dhan33, as it provided job opportunities and improved food availability during the *monga* period. The *monga* mitigation activities were promoted in a range of media, including Rangpur Radio, BTV, private cable TV such as Channel I, Bangla Vison, Boishakhi & ATN Bangla, and local and national newspapers. Some 22 newspaper articles were published in 2006 and 63 news items in 26 newspapers in 2007 (Table 13). Reports in local and national newspapers during 2006-07 drew

Table 13. Media coverage of *monga* mitigation activities in northwest Bangladesh during 2006 and 2007.[a]

Print media/newspaper	2006	2007
	Date	Date
Dainik Jugar Alo	9 June, 24 June, 15 November,22 December	6 June, 28 September, 3 October, 21 October, 15 December
News Age	10 June	–
The News Today	13 June	15 September, 22 October
Dainik Naya Diganta	13 June, 22 June	–
The Bangladesh Observer	14 June	16 September, 10 october, 11 October
Saptahic Autol	19 June	–
The Daily Star	22 June	–
Dainik Manab Jibon	24 June	–
Danik Ittefaq	28 June	29 August, 5 October, 7 October, 11 October, 21 October, 15 December
Dainik uttar Janopad	–	25 August
Dainik Nilsagar	–	28 August
Dainik Uttar Anchal	–	13 September, 21 October
Dainik Ajker Janagan	–	13 September, 11 October
The New Nation	–	15 September, 19 October, 20 October, 5 October (Editorial)
Dainik Karatoa	–	16 September, 11 October, 21 October
The Financial Express	–	16 September, 10 October
Bangladesh Sanbad Sanasta	–	3 October
Dainik Saradesh	–	11 October
Dainik Sangbad	–	18 October
Dainik Dinkal	–	18 October
Dainik Pratam Alo		21 October, 23 October, 24 October (2 news)
Dainik Ajker Janagan	–	21 October
Daink Destini	–	21 October
Dainik Ghaghot	–	21 October
Dainik Palash	–	21 October

Continued on next page

Table 13 continued.

Print media/newspaper	2006	2007
	Date	Date
Dainik Amardesh	–	21 October
Dainik Samakol	–	21 October
Dainik Chadni Bazar	–	22 October
Dainik Desh Bangla	–	22 October, 23 October
Dainik Jugantar	–	24 October
Dainik Sangram	–	28 October
Masik Samprasaran Barta	–	6 October, 7 October

[a]Electronic media: Bangla Vison (3 October 2007); Channel i (11 November), ATN Bangla, Baisaki, and BTV (6 January 2008).

attention to the potential for *monga* mitigation of shorter-duration rice variety BRRI dhan33 and direct seeding for early harvests. These highlighted the importance of extension to the *monga*-prone areas. BRRI dhan33 became known as an "*anti-monga missile*" or as the *monga variety*.

The scope of *monga* mitigation in Greater Rangpur

- Highland (HL) and medium highland (MHL) areas are best suited to direct seeding of aman rice, and these landforms account for 38% (HL) and 50% (MHL) of the total land area in Greater Rangpur. In the five *monga*-prone districts (Rangpur, Kurigram, Lalmonirhat, Nilphamari, and Gaibandha) in Greater Rangpur, a total of 0.45 million ha have HL and MHL, of which 0.11 million ha are owned by marginal, small, and medium-sized farm households.
- It is estimated that a total of 6.74 million person-days (63 person-days per ha) of work opportunity could be generated with early harvesting of aman rice and accompanying postharvest operations on the marginal, small, and medium farms. This would employ 0.19 million day laborers continuously for 30 days during the *monga* period, or one-third of the *monga*-affected people in the area.
- A total of 2.8 million person-days (53 person-days per ha) of employment could be generated if 50% of the area of 0.11 million ha of HL and MHL were used for potato after the BRRI dhan33 harvest. This could create work for 0.19 million day laborers for 15 days during the *monga* period, or provide employment for a third of the total of *monga*-affected people.
- A combination of early rice harvest and planting of potato has the potential to generate employment for a total of 0.38 million day laborers or two-thirds of the total of *monga*-affected people in Greater Rangpur. Further, potential

Table 14. Proposed schedule for sowing/transplanting of BRRI dhan33 rice for staggered harvesting to mitigate *monga* during Ashwin-Kartik (early October to mid-November), BRRI Rangpur, Bangladesh.[a]

Cultivating method	Date of seeding	Date of transplanting	Date of maturity
Direct-seeded rice (DSR) (growth duration 105 days)	25-30 June (11-16 Ashar)	–	10-15 October (25-30 Ashwin)
	1-7 July (17-23 Ashar)	–	16-22 October (1-7 Kartik)
Transplanted rice (TPR) (growth duration 118 days)	28 June-4 July (14-20 Ashar)	22-28 July (7-13 Shravon)	23-29 October (8-14 Kartik)
	5-11 July (21-27 Ashar)	29 July-4 August (14-20 Shravon)	30 October-5 November (15-21 Kartik)
	12-20 July (28 Ashar-5 Shravon)	5-13 August (21-29 Shravon)	6-14 November (22-23 Kartik)

[a] It is estimated that potential exists to produce 428,000 metric tons of paddy during the *monga* period that would contribute to improved food security for marginal farmers.

exists to create 45 days of continuous work for agricultural laborers during the *monga* months of October to mid-November by staggered seeding or transplanting of BRRI dhan33 in HL and MHL in Greater Rangpur districts. A possible schedule for staggered seeding and transplanting is shown in Table 14.

Conclusions

Approaches for “*monga* mitigation” comprised the following technology options:

1. An appropriate rice variety: short-duration (115–118 days) BRRI dhan33
2. Appropriate crop establishment methods and time of establishment
   - Dry and wet direct seeding of BRRI dhan33 from 25 to 30 June
   - TP of 25-day-old seedlings of BRRI dhan33 from 20-25 July to 4-13 August
   - Dry and wet direct seeding of BR11 from 1 to 15 June
3. Crop diversification: planting potato during 1-14 November after the early aman rice harvest

These options can be combined with “staggered” seeding (25 June to early July) by DSR or as TPR to enable crops to be harvested throughout the *monga* period to reduce labor bottlenecks and improve productivity. This could create employment and increase food security for landless agricultural day laborers and marginal farmers during harvest and for the establishment of rabi crops. There is, however, considerable scope for agronomic fine-tuning of *monga* mitigation technologies.

This work has clearly shown that substantial benefit may derive from bringing together organizations with complementary mandates and skills to focus on a particular aspect of rural development. BRRI-IRRI have a long-established partnership for technology development, adaptation, and validation while within the NGO alliance there are strong links within the community and to community-based organizations. Bringing these alliances together brought benefits to rice researchers, NGOs, and farmers. Rice researchers were able to benefit from better feedback from farmers' fields, the NGO alliance benefited as it had greater access to technical support and options, and the farm communities had greater access to options for higher productivity. The technical merits of the *monga* mitigation model have been recognized as the Bangladeshi government established an action plan as part of its national program to cover 107,000 ha in 2010-11. It is believed there is considerable scope for greater collaboration between different types of organizations, in which there are complementarities between those operating in the rural sector, to enable synergies to be realized.

Further reading

Mazid M, Jabber MA, Mortimer M, Wade L, Riches CR, Orr AW. 2003. Improving rice-based cropping systems in north-west Banglaldesh: diversification and weed management. Proceedings of the BCPC International Congress on Crop Science and Technology, SECC, Glasgow, UK. 3:1029-1034.

Mazid MA, Mortimer AM, Riches CR, Orr A, Karmarker B, Ali A, Jabbar MA, Wade LJ. 2005. Rice establishment in drought-prone areas of Bangladesh. In: Rice is life: scientific perspectives for the 21st century. Proceedings of the World Rice Research Conference held in Tokyo and Tsukuba, Japan, 4-7 November 2004. International Rice Research Institute, and Tsukuba, Japan: Japan International Research Center for Agricultural Sciences. CD. p 193-195.

Mazid MA, Riches CR, Mortimer AM, Wade LJ, Johnson DE. 2006. Improving rice based cropping systems in north-west Bangladesh. Proceedings of the 15th Australian Weeds Conference "Managing Weeds in a Changing Climate." Adelaide, Australia. p 331-334.

Mazid MA et al. 2006. Direct seeding and weed control for rainfed and irrigated rice in northwest Bangladesh: on-farm wet DSR by drum seeder and weed control options in monsoon (aman 2004 & dry season (boro) 2005). Ripple (IRRI): January 2006, Vol. 1, No. 1.

Mazid MA. 2006. 1) One of Bangladesh's local champions. 2) Northwest Bangladesh–direct-seeded rice, drum seeders, and misty morning. Ripple (IRRI): January 2006, Vol. 1, No. 2.

Mazid MA. 2006. The direct approach – moving away from transplanting in South Asia. Rice Today. 5 (2).

Mazid MA. 2006. Adaptive research helps fight famine in Bangladesh. In: Ripple. IRRI. April-June 2006, Vol. 5, No. 2.

Mazid MA, Khamarker B, Mortimer AM, Riches CR. 2008. Developments in direct seeding of rainfed rice in the High Barind Tract. In: Riches C, Harris D, Johnson DE, Hardy B, editors. Improving agricultural productivity in rice-based systems of the High Barind Tract of Bangladesh. Los Baños (Philippines): International Rice Research Institute. p 33-46.

Mortimer AM, Mazid MA, Riches CR. 2008. Long-term sustainability in weed management for direct seeding of rainfed rice. In: Riches C, Harris D, Johnson DE, Hardy B, editors. Improving agricultural productivity in rice-based systems of the High Barind Tract of Bangladesh. Los Baños (Philippines): International Rice Research Institute. p 67-78.

Orr A, Jabbar MA, Mazid MA, Karmakar B. 2008. Decision-making for rabi cropping in the High Barind Tract of Bangladesh: a farmer perspective. In: Riches C, Harris D, Johnson DE, Hardy B, editors. Improving agricultural productivity in rice-based systems of the High Barind Tract of Bangladesh. Los Baños (Philippines): International Rice Research Institute. p 157-174.

Notes

Authors' addresses: M.A. Mazid, Bangladesh Rice Research Institute Regional Station, Rangpur; D.E. Johnson, International Rice Research Institute, Los Baños, Philippines. Email: brrirang@bdonline.com.

Developing direct-seeding options for rice farmers in the Indo-Gangetic Plains

V.P. Singh, Pratibha Singh, Y. Singh, A.J. Malabayabas, and D.E. Johnson

The rice-wheat farming systems of the Indo-Gangetic Plains (IGP) are essential to India's food security. These systems face multiple threats, however, to the future of the natural resource base. These threats include increased costs for irrigation and fuel, seasonal labor shortages, and unsustainable use of groundwater. In addition, climate change means increasingly variable monsoons that are likely to pose further constraints. Direct-seeded rice, as an alternative to transplanted rice, provides a potential entry point to save labor, reduce reliance on irrigation water, and increase productivity of the wheat crop. Technology options for direct seeding and related weed management were developed and validated in India commencing with on-station experiments and small-scale on-farm trials in 2000 and increasing to a total of more than 100 farmers' field trials by 2005. These farmers' trials, which compared both wet and dry direct-seeded rice with transplanted rice, were conducted in the states of Uttarakhand, Uttar Pradesh, and Bihar by four agricultural universities. The trials involved a wide community of farming stakeholders in diverse agroecosystems, and spanned mechanized farms (>2 ha) in Uttarakhand to smallholder farms (≤0.5 ha) in Bihar reliant on manual labor.

Direct seeding is "knowledge-intensive" and farmers require access to considerable amounts of information in order to respond to the variability of the monsoon, soil conditions, and weed infestations. Making such information available within the farm communities, and providing them with tools to aid better decision making and the means to evaluate their crop own management, is critical to the successful adoption of such practices. Activities with farmers' groups have continued since 2005 to validate direct-seeding practices on-farm, and also to explore the constraints to adoption and the information requirements to support effective farmer decision making.

Keywords: direct-seeded rice, on-farm trials, information sources, technical options, adoption constraints

Rice-wheat cropping systems cover 13.5 million hectares in the Indo-Gangetic Plains (IGP) from Pakistan, India, Nepal, and Bangladesh (Hobbs et al 2001, Aggarwal et al 2004). These systems provide livelihoods for 42% of the population of South Asia, and the IGP is a major source of food and income for tens of millions of farmers (Singh et al 2006, Hobbs et al 2001). The rice-wheat system in the IGP is essential to food security not only in India but also in its neighboring countries; there are, however, increasing constraints to production. The area has been found to be among those prone to degradation of natural resources, a problem that may be further compounded by climate change such as having more variation in the timing and duration of monsoons (Aggarwal et al 2004). Water resources are declining because of the increasing dependence on groundwater for irrigation (Gautam 2008). The unsustainable use of groundwater threatens the future of the natural resource base, and waterlogging and soil salinity are problems as a result of the overuse of groundwater (Aggarwal et al 2004). Moreover, increasing costs for irrigation and fuel and seasonal labor shortages are significant constraints to production (Mortimer et al 2008).

Direct-seeded rice (DSR) as an alternative to transplanted rice (TPR) may provide an entry point to address most of these production constraints, save labor, reduce irrigation water use, and increase the productivity of the succeeding wheat crop. Technology options for wet and dry direct seeding were developed and validated in India starting with research-station experiments established in parallel with small-scale on-farm trials in 2000. Farmers' trials compared both wet and dry direct-seeded rice with transplanted rice, and were conducted in the states of Uttarakhand, Uttar Pradesh, and Bihar in India through partnerships with different agricultural universities. The program extended over a range of agroecosystems in the IGP, and involved a wide community of farming stakeholders, spanning mechanized farms in Uttarakhand to smallholder farms (≤0.5 ha) that rely on manual labor in Bihar (Johnson et al 2006).

The complexity of rice production systems requires that farmers be equipped with substantial knowledge in order to decide on and apply the best technology options in any particular situation (Johnson and Mortimer 2008). Since 2005, therefore, activities with farmer groups have focused on the validation of direct-seeding practices in farmers' fields and in exploring "information needs" of farmers to effectively support their decision making. The aim of the project was to provide farmers with alternative methods of rice crop establishment to help them address increasing labor costs, and to augment their income by lowering rice production costs in the wet season (kharif) and increasing wheat yield in the winter season (rabi). In complement to these, the project expects to gain an understanding of the benefits and constraints of direct seeding, and to identify technical options to overcome these constraints.

Partners involved in the project were Indian universities, the International Rice Research Institute, through the Labor Productivity Work Group of the Irrigated Rice Research Consortium (IRRC), and the Natural Resources Institute (NRI). Universities involved were G.B. Pant University of Agriculture and Technology (GBPUAT) in Uttarakhand, Rajendra Agricultural University (RAU) in Bihar, Narendra Deva University of Agriculture and Technology (NDUA&T) in Faizabad, Uttar Pradesh, and CSA University of Kanpur in Uttar Pradesh. The partnership also involved extension institutions such as Krishni Vigyan Kendras (KVKs), institutes of the Indian Council of Agricultural Research (ICAR), and nongovernment organizations (NGOs). KVKs are part of the government-funded extension service and these are the primary links to farmers in disseminating knowledge on agricultural technologies as well as conducting on-farm trials (OFTs), field days, and training activities, and distributing information materials. On-farm trials were conducted in Uttarakhand, Uttar Pradesh, and Bihar.

In this chapter, we present the process by which partner institutions developed and validated technologies for direct seeding with rice farmers in the IGP. Further, we will consider the innovations developed through the partnerships, how these were affected by the partnerships, and how these are reflected in the uptake of direct seeding by farmers. The chapter will also examine the contributions of direct seeding to reducing costs and augmenting farmers' income. Some lessons learned will be discussed as well as possible next steps to enable out-scaling of these options in the IGP.

Innovations in rice establishment and developing options for direct seeding in the IGP

In recent decades, the usual rice establishment method for rice in the IGP is to transplant seedlings into fields that have been flooded and wet cultivated or "puddled." To puddle the fields, farmers either wait for sufficient rainfall to have accumulated or use canal or tube-well irrigation to adequately flood the fields.

Options tested: tractor-mounted seed drill and hand-drawn drum seeder

Through demonstrations and farmers' fairs (see below), farmers in Uttarakhand, Uttar Pradesh, and Bihar were introduced to methods of direct seeding as an alternative to transplanting. Options included the use of a tractor-mounted seed drill and a hand-drawn drum seeder. Tractor-mounted seed drills had been introduced from Australia and modified by the GBPUAT as an alternative to the broadcast seeding of wheat in the IGP. These machines are also suited to sowing dry rice seed into dry or moist soil without prior wet tillage or "puddling." Spacing between seed rows can be adjusted and ten rows can be sown in a single pass. The hand-drawn drum seeder produced in Vietnam is able to sow pregerminated rice seed (wet seeding). Wet seeding requires that the soil be puddled as for transplanting. The spacing between rows is fixed and 12 rows are sown in a single pass.

On-station experiments

The development of direct seeding and related weed management practices in Uttarakhand, Uttar Pradesh, and Bihar was based on results of station experiments. Different establishment options were evaluated, including (1) conventional transplanting, (2) wet seeding after puddling (drum seeding), (3) dry seeding after conventional tillage, (4) dry seeding after conventional tillage but with the last tillage following a flush irrigation, and (5) dry-seeding zero-tillage after flush irrigation. These were tested with the different weed management options of (1) no weed control, (2) one hand weeding at 30 days after sowing (DAS) or days after transplanting (DAT), or

(3) weed-free (herbicide + 2 hand weedings at 30–60 DAS/DAT). After the rice harvest, wheat was sown following conventional soil tillage or zero-tillage. The results of these studies provided an understanding of some of the constraints and information on the effectiveness of the system, and demonstrated the different establishment methods to farmers and researchers (Johnson et al 2005).

Farmer field days, dissemination of leaflets, and other communication materials

Annual "farmers' fairs" were held at Pantnagar, attended by several hundred farmers, and direct seeding was one of the many technologies promoted. From 2003 to 2005, 13 farmer field days were held. Farmers were brought in to the fairs in Pantnagar from neighboring areas in order to widen the awareness of direct seeding. Farmer field days held in Uttarakhand, Uttar Pradesh, and Bihar were well attended by farmers and state officials. In 2004, for example, farmers' field days were attended by 53 farmers and 16 scientists in Pantnagar, 250 farmers in Faizabad, and 700 farmers and a government minister in Patna. Dissemination of information on direct seeding and weed management was achieved through the distribution of more than 2,000 leaflets and posters produced in English and Hindi by the universities and extension service (Johnson et al 2006). The communication theme adopted was "*Effective weed management is critical to the success of direct seeding and major yield losses could result from poor weed control.*"

Workshops

Workshops of researchers and farmer-leaders were held in 2003 and 2005 in order to present the findings of the research and review activities. These provided opportunities to gather opinions on the progress made and promising future directions.

In addition to communication aimed at farmers and researchers, promotion of direct seeding was also aimed at senior staff and policymakers. In March 2004, the vice chancellor of GBPUAT presented "direct seeding of rice as a technology ready for national promotion" to a meeting of university vice-chancellors and the minister. Activities were also shared with the Rice-Wheat Consortium (RWC) and, as an example, a traveling group of scientists from Pakistan and Nepal visited project sites in Uttarakhand and met with collaborating farmers to learn of the progress with direct seeding.

On-farm trials

Farmers were introduced to direct seeding through field days, having visited researcher-managed trials, or through personal contact with researchers and extension staff. Farmers interested in trying direct seeding were supported by research/extension staff with technical advice and the loan of machinery. Plot size usually ranged from 0.1 to 0.5 ha. Farmers were given options to try either dry or wet seeding. Commonly, a single field was split with half being direct seeded and the other transplanted. These areas were then monitored, in collaboration with the farmer, throughout the season; weed growth was recorded and crop data were recorded at harvest. The activities started with four on-farm trials in 2000 and expanded to 99 on-farm trials in 2005. In addition, in the project target areas in 2005, almost 1,000 ha of direct-seeded rice were grown on farms that had been previously transplanted.

Impacts of the activities associated with DSR research and development

Direct-seeded rice in farmers' fields

On-station experiments in Uttarakhand, Uttar Pradesh, and Bihar indicated that yields from DSR are comparable with those of transplanted rice provided weeds are effectively controlled. The timing of land preparation and sowing in relation to commencement of the monsoon was critical for the success of DSR. Land preparation for dry-seeded rice had to be completed before the soil became too wet, which makes it impossible to create a good seedbed. In fields with heavy clay soils, the "window of opportunity" is relatively narrow, whereas fields with lighter textured loam soils were less constrained. The operation of seed drills is equally constrained and sowing had to be completed before the soil became too wet for the drill to operate effectively. Further, rice seedlings have to emerge before the soil surface is flooded for longer than a few hours lest the germinating seeds perish in the anaerobic conditions. Farmers with full access to irrigation could start land preparation before the onset of the monsoon by "light" irrigation to moisten the soil sufficiently to allow the rice to germinate. For farmers without access to irrigation, a sudden onset of the monsoon could cause flooding and subsequently poor establishment. Timely application of herbicides could also be difficult to achieve when monsoons start "suddenly" and when there are few "breaks in the weather." On-farm trials have, however, demonstrated that DSR can be successful, giving broadly similar yields, but with reduced costs and improved timeliness, compared with transplanting. Some farmers adopted DSR technologies and, at sites where the project was active in the three states, the area under direct-seeded rice rose from less than 10 ha in 2000 to 250 ha in 2004 and to 975 ha in 2005.

Grain yields of rice

Grain yields of rice from the direct-seeded areas on-farm were commonly slightly lower than the transplanted areas and only infrequently the other way around (Fig. 1). On occasions, the yield of direct-seeded rice was substantially lower than transplanted rice due either to failure to achieve good crop establishment or inadequate control of weeds. These on-farm studies provided valuable insights into the sort of problems that farmers would encounter when adopting direct seeding and their likely needs in terms of technical support.

In on-farm trials in Uttarakhand, yields of transplanted and direct-seeded rice were similar in 2003 and 2004 when weeds were controlled, whereas yield losses in nonweeded plots were slightly higher in DSR than in TPR (Singh VP et al 2008a). Analyses of costs and returns have shown that production costs were least for the combination of dry direct-seeded rice and zero-till wheat and net returns were highest in dry direct-seeded rice and zero-till wheat (Singh VP et al 2008a).

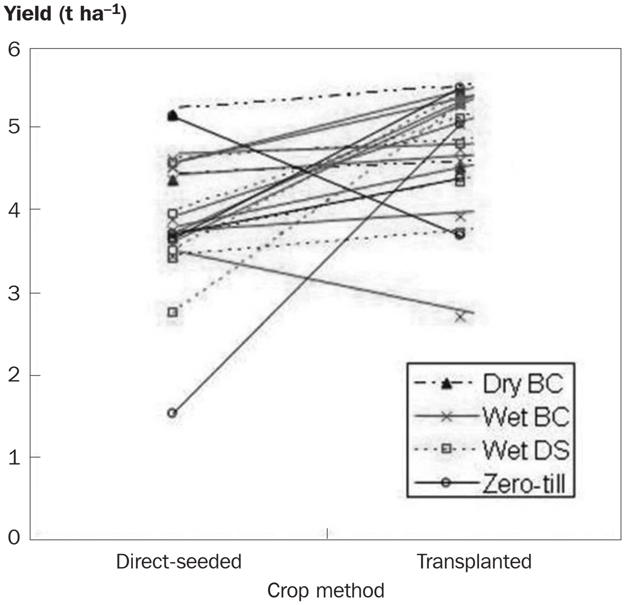

Fig. 1. Grain yield of rice in on-farm trials (n = 22) comparing four direct-seeding methods with transplanting in eastern Uttar Pradesh, kharif 2004. (Dry BC = dry seed, broadcast after dry tillage, Wet BC = pregerminated seed broadcast on puddled soil, Wet DSR = pregerminated seed sown with a drum seeder, Zero-till = dry seed sown with a zero-tillage drill.)

In on-farm experiments conducted at Modipuram, Uttar Pradesh, in 2002-03, direct seeding adopted in the previous rice crop resulted in significantly higher wheat yield (5.61 t ha^{-1}) (Sharma and Singh 2008). In these studies, labor costs declined with direct seeding of rice but other inputs, and particularly herbicides, are essential to achieve acceptable yields.

Results of on-station experiments in Bihar in 2003-04 show that, where weeds were controlled, yields of DSR and TPR were similar (Sinha et al 2008). Further, the choice of rice establishment method did affect yields of the subsequent wheat crop; dry direct-seeded rice resulted in greater wheat yields (in wheat sown either by conventional or zero-tillage) relative to TPR (Sinha et al 2008). On-farm trials in Bihar showed that rice yields from TPR were slightly higher than from DSR in 2003 but the converse was true in 2004 (Sinha et al 2008). Furthermore, farmers claimed that direct-seeded fields were less susceptible to drought stress, and required less irrigation than transplanted fields.

Weeds

The change from transplanting to direct seeding of rice resulted in not only an increase in weed growth but also a shift in the relative importance of particular species (Singh VP et al 2008b). A weed species "shift" with DSR was anticipated in the project planning and experiments were designed to record these changes. The information gathered would serve to develop control measures in response to the changes. Changes in weed species composition depended on the establishment method—with wet direct seeding, *Fimbristylis miliacea* and *Ischaemum rugosum* increased in importance. With zero-tillage, *Echinochloa colona* and *Cyperus rotundus* increased, and, with dry drill-seeded rice, *Echinochloa crus-galli, Cyperus iria,* and *Cyanotis axillaris* increased (Singh VP et al 2008b).

Uptake of approaches by scientists

The project activities influenced the approach of scientists and in particular their recognition of the value of working with farmers and in farmers' fields. Prior to this study, this was an approach not widely practiced for agronomic work at GBPUAT, NDUA&T, or RAU and yet it was incorporated in activities from the project inception. The value of this approach was recognized, particularly for aiding in the identification of potential constraints that smallholder farmers might face with the adoption of direct seeding. The management problems relating to timing of operations at the beginning of the rainy season are a particular example in which participatory approaches provide valuable insights. At the onset of the monsoon, there is considerable uncertainty with regard to likely rainfall, and good drainage infrastructure and ready access to machinery are critical to successful crop establishment with direct seeding. Although such facilities are common on research stations, for smallholder farmers with limited infrastructure, being able to respond rapidly to the situation can be problematic.

A second area of major influence was incorporating aspects of weed ecology at the beginning of the agronomic experimentation, particularly the focus on shifts in the dominant weed species. Most weed management work extant at the beginning of the project was focused on the effects of agronomic practices on weed growth rather than in trying to understand the causal factors of weed shifts. This new approach was widely accepted among project partners.

Extensive data sets established on weeds and crop performance

Experimentation on rice establishment methods across a range of sites, combined with weed management options, provided extensive data on weeds and crop performance. These enabled weed scientists to anticipate weed problems in response to changes in management practices and identify suitable interventions.

Release of DSR as a technology for farmers/uptake by RWC for promotion

DSR technologies were developed at GBPUAT in collaboration with the International Rice Research Institute (IRRI) and NRI, and these now have an impact over a wide area. As the technologies became available to research organization/institutes/NGOs/private organizations, they were adopted for on-farm testing and promotion. In the Pantnagar area, many farmers took up the new technologies without direct support and in some instances the technologies were passed among farmers. In Uttarakhand, DSR was widely tested through the activities of GBPUAT in the districts

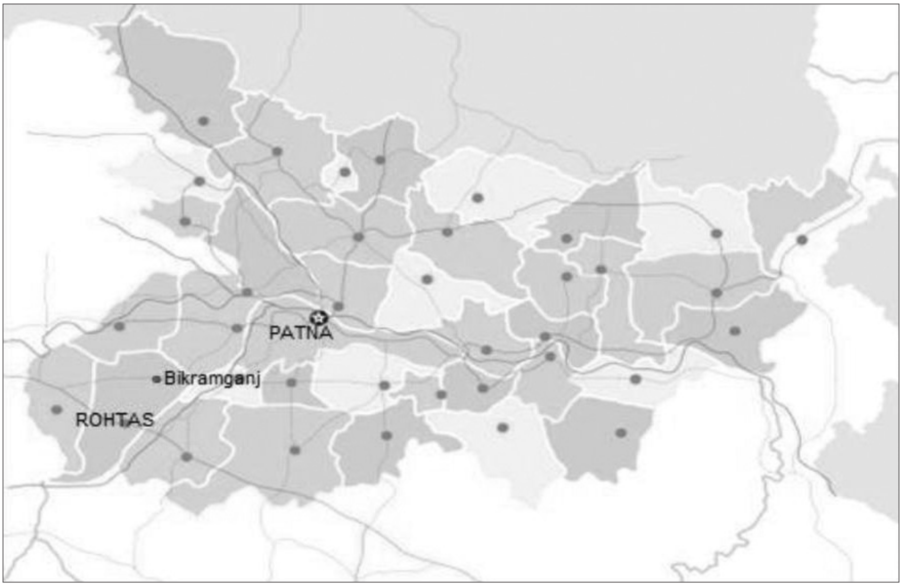

Fig. 2. Map of Bihar, India. Source: Wikipedia (2010).

of Udham Singh Nagar, Hardwar, Nainital, and Dehradun. In the neighboring state of Uttar Pradesh, which has the largest area under rice (5.5 million ha) of all states in India, state universities and the ICAR institutes are promoting DSR. In western Uttar Pradesh, the Project Directorate for Cropping Systems Research (CSR) and ICAR institutions conducted several demonstrations during 2005 and many farmers adopted DSR. Promotional work was undertaken by GBPUAT and by the directorate of extension through its KVK networks. In central Uttar Pradesh, CASUA&T at Kanpur conducted on-farm trials in the districts of Kanpur, Unnao, and Raibareilly. In eastern Uttar Pradesh, the university at Faizabad, NDUA&T, Kumarganj, conducted on-farm trials and demonstrations in nearly all 25 districts in its jurisdiction. DSR was also promoted with support of NGOs in Pratapgarh District, in eastern Uttar Pradesh, by the Benares Hindu University (BHU) at Varanasi. Further east, in Bihar, promotional activities have been undertaken in districts of Bikramganj, the rice bowl of Bihar, and in Patna (Fig. 2). The RWC has also been promoting DSR at a number of sites across the IGP and in southern India. An initial constraint to scaling out of DSR was the lack of suitable machinery but this has been overcome; machines, drills, and drum seeders are being manufactured at several locations and are now locally available.

Good dissemination through the press

Information on DSR and weed management options was disseminated through the press in articles on field days or on the technical options available to farmers. More than 40 newspaper articles were published between 2003 and 2005, and print coverage continued subsequently and is considered significant in the promotion of DSR. A study on the impact of DSR in the Indo-Gangetic Plains is in progress and will assess the economic contribution of DSR as an alternative form of crop establishment for farmers in Uttarakhand, Uttar Pradesh, and Bihar.

Costs and benefits of DSR

Costs and returns analysis of on-farm studies and experiments conducted in Uttarakhand compared the net incomes derived using different crop establishment methods. Total costs incurred in dry-seeded rice were Rs.2,470 (US$62) per ha less than in wet-seeded rice and Rs.2,682 ($67) less per ha than in TPR (Singh SP et al 2008). Major items accounting for cost savings in DSR over TPR were land preparation, crop establishment, and irrigation. Expenditures on seeds and weed management, however, were greater for DSR.

In 2007, household surveys in Uttarakhand, Uttar Pradesh, and Bihar indicated that returns (or incomes) of TPR farmers were significantly greater than for DSR farmers by $28 per ha in Uttarakhand, $33 in Uttar Pradesh, and $53 in Bihar. Although DSR fields generally produced lower yields than transplanted rice, on average, farmer production costs for DSR were significantly ($135 per ha) less than for transplanted rice in Uttarakhand, $139 less in Uttar Pradesh, and $127 less in Bihar. As a result, net returns per ha for DSR were greater than for transplanted rice in all three states.

Potential impact pathways for the development of direct-seeding practices for rice farmers in the IGP

The progression of the research and extension activities associated with the development of DSR, described above, led to the development of an impact pathway analysis for the development of direct-seeding options (Fig. 3).

The dissemination activities (e.g., on-farm trials, training, field days, press coverage) help boost the confidence of farmers in direct seeding and result in expansion of area cultivated to DSR, encourage farmers' organizations to promote the technology, and encourage other farmers to adopt the practice.

Farmers benefit from DSR through higher net incomes due to lower production costs. In addition, higher net incomes may be achieved because of higher yields of wheat grown after DSR. The time taken for rice to reach maturity in DSR is shorter than for TPR, which allows the wheat crop to be sown earlier, resulting in greater wheat yields. In addition to financial returns, direct seeding may also assist with the conservation of resources by reducing irrigation water use, by removing the need to puddle the soil at the end of the dry season in preparation for rice, and by improving soil structure. DSR can also increase the flexibility of production systems as it requires less time than nursery bed establishment and puddling of fields. DSR can also raise the level of autonomy of farmers because they are not as reliant on migrant labor for transplanting. The adoption of DSR by smallholder farmers can therefore generate environmental, social, and economic benefits.

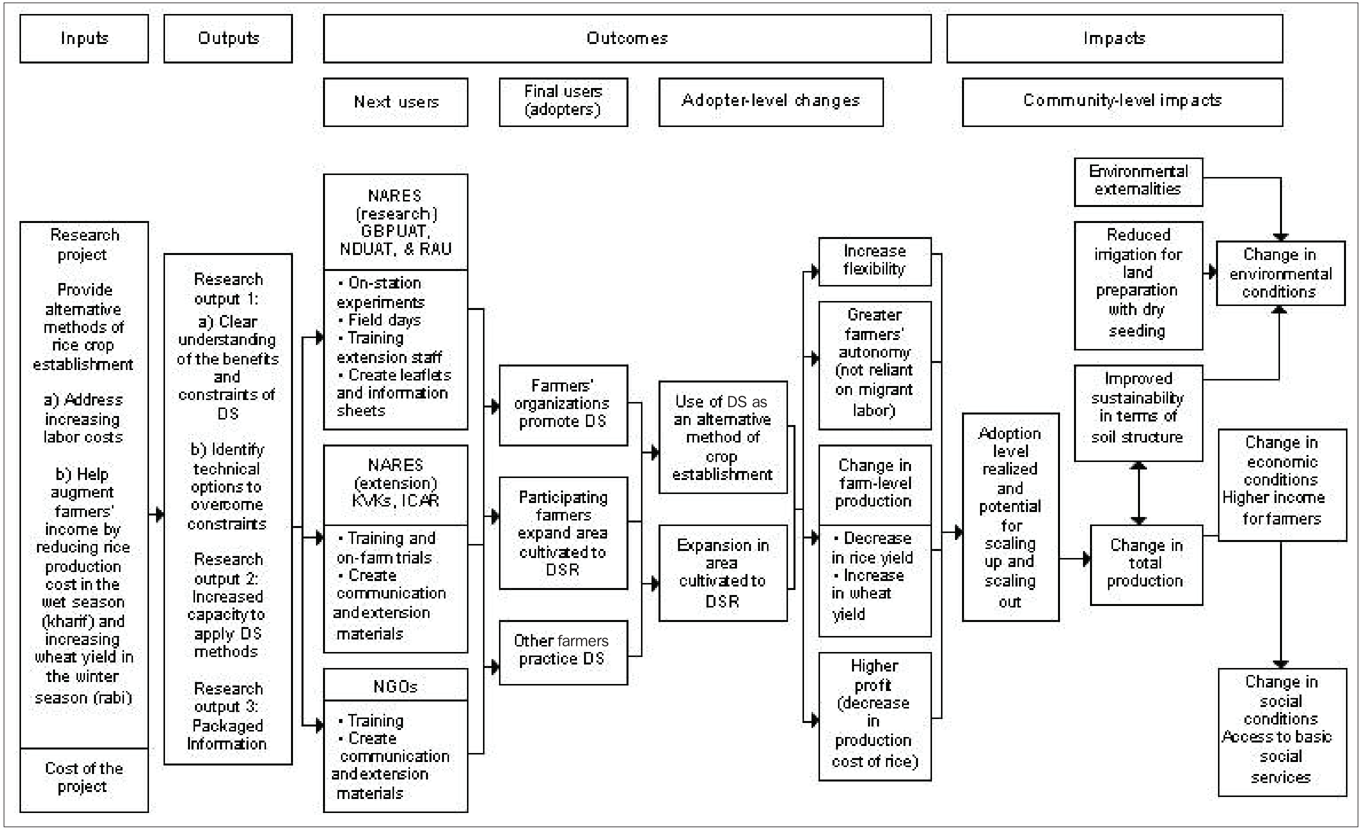

Fig. 3. Potential "impact pathways" from developing direct-seeding practices for rice production in the Indo-Gangetic Plains.

Lessons learned

Important lessons came from the research activities that began in 2000 with field experiments and farmers' field trials, and the subsequent promotion of DSR options until 2005. These are as follows:

1. Although there has been impressive adoption by farmers of DSR options, adoption has tended to be greater by larger farmers. Contributing factors include their better access to machinery, superior infrastructure on their farms, their willingness to take risk, and their ability to spread their risk through partial adoption of DSR.
2. Decision making with regard to the monsoon season is critical, particularly in relation to the timing of establishment of the rice crop and weed control. The unpredictability of the monsoon brings uncertainty to farmers with regard to crop establishment. Sudden onset of the monsoon can cause problems in land preparation for DSR and, once the land is sown, heavy rainfall can disrupt crop establishment and weed control operations.
3. Greater emphasis is needed on the flow of information within communities. DSR and weed management for these systems are relatively knowledge-intensive. To make DSR viable in a range of different weather conditions requires that farmers acquire, or be provided with, improved sources of information and the means to support their decision making.
4. In the development of DSR activities, two factors were underestimated in their importance:
   (i) Risk aversion: despite the advantages of DSR, some farmers saw it as a riskier option than transplanting. The provision of adequate technical support could help reduce this risk and misconception.
   (ii) Flexibility: a great advantage of DSR in some systems is that it enabled farmers to establish a crop earlier and have an earlier harvest than with transplanting. This can result in substantial livelihood benefits as it may allow the growing of additional crops such as maize, legumes, or potatoes after the rice harvest.

Future focus

In the IGP of India, the next phase of activities will include the development of links between the universities involved in the project and NGOs to enable greater promotion of DSR technologies.

There have been similar exciting developments with DSR in Bangladesh (Mazid and Johnson, this volume). Visits by Indian researchers and NGO staff to Bangladesh sites, and vice-versa, have provided an excellent opportunity for cross-country learning, and the potential for expanded promotion of DSR through coordinating the expertise and networks of NGOs in eastern India and western Bangladesh.

One gap in the studies conducted thus far is our lack of quantitative data on the role of direct seeding in household livelihoods, gender benefits, and the degree of flexibility DSR provides to the farming system options for smallholder farmers, and the associated reductions in risks and increases in productivity.

Finally, the exciting benefits of DSR in the IGP developed through IRRC co-investment with our Indian partners are currently being promoted through the RWC and a new large project, CSISA (Cereal Systems Initiative for South Asia), which has research and development hubs at key sites of the IGP in India and Bangladesh.

References

Aggarwal PK, Joshi PK, Ingram JSI, Gupta RK. 2004. Adapting food systems of the Indo-Gangetic plains to global environmental change: key information needs to improve policy formulation. Environ. Sci. Policy 7:487-498.

Gautam PL. 2008. Emerging issues and strategies in the rice-wheat cropping system in the Indo-Gangetic Plains. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 3-22.

Hobbs PR, Gupta R, Malik RK, Dhillon SS. 2001. Conservation agriculture for the rice-wheat systems of the Indo-Gangetic Plains of South Asia: a case study from India. Paper presented at the 1st World Congress on Conservation Agriculture, Madrid, 1-5 October 2001.

Johnson DE, Mortimer AM. 2008. Issues for weed management in direct-seeded rice and the development of decision-support frameworks. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 223-228.

Johnson DE, Mortimer AM, Orr AW. 2006. Promotion of integrated weed management for direct seeded rice in the Gangetic Plains of India. Crop Protection Programme. Final Technical Report, 1 April 2005-31 January 2006. Natural Resources Institute.

Johnson DE, Mortimer AM, Orr AW. 2005. Promotion of integrated weed management for direct seeded rice in the Gangetic Plains of India. Crop Protection Programme. Final Technical Report, 1 January 2003-31 March 2005. Natural Resources Institute.

Mortimer AM, Riches CR, Mazid M, Pandey S, Johnson DE. 2008. Issues related to direct seeding of rice in rainfed cropping systems in northwest Bangladesh. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 23-30.

Sharma SK, Singh KK. 2008. Production potential of the direct-seeded rice-wheat cropping system. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 61-73.

Singh SS, Khan AR, Gupta RK, Sikka AK. 2006. Air and soil pollution reduction through conservation agriculture in Indo Gangetic Plains. 8th World Congress of Soil Science, 9-15 July 2006, Philadelphia, Pennsylvania, USA.

Singh SP, Orr A, Singh S, Singh G. 2008. The economics of direct-seeded rice in eastern India. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 229-250.

Singh VP, Singh G, Singh SP, Kumar A, Singh Y, Johnson DE, Mortimer AM. 2008a. Direct-seeding and weed management in the irrigated rice production system. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 131-138.

Singh VP, Singh G, Singh SP, Kumar A, Singh Y, Johnson DE, Mortimer AM. 2008b. Weed species shifts in response to direct seeding in rice. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 213-220.

Sinha RKP, Singh BK, Singh M, Kumar M, Mortimer AM, Johnson DE. 2008. Effect of seed rate, weed management, and establishment methods on irrigated rice in Bihar. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B, editors. Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic Plains. Los Baños (Philippines): International Rice Research Institute, and Pantnagar (India): Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology. p 151-158.

Notes

Authors' addresses: V.P. Singh, Pratibha Singh, and Y. Singh (retired), G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, India; A.J. Malabayabas and D.E. Johnson, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines. Email: vpratapsingh@rediffmail.com.

Community management of rodents in irrigated rice in Indonesia

Sudarmaji, R.J. Flor, N.A. Herawati, P.R. Brown, and G.R. Singleton

Rodent depredations of agricultural produce, stored food, and the spread of several important human diseases do not generate enough attention in Indonesia despite promising progress in the development of effective management strategies. The lack of investment in rodent management adds to the plight of rural smallholders and the urban poor. In Indonesia, rodents are the number-one preharvest pest of rice. The emergence of the rice crisis in the first half of 2008, with global rice stocks at their lowest for a generation, emphasizes that we can no longer tolerate the level of pre- and postharvest losses caused by rodents to the staple food of Indonesians. A paradigm of ecologically based rodent management has been the major platform for developing community-based management for rice-growing communities in Indonesia. This paradigm was accepted in 2001 at a national level through a presidential decree. However, until 2005, the emphasis had been on developing a strong understanding of the ecology of the major rodent pest species and on developing farmer participatory adaptive research at a village scale. Since 2005, the emphasis has been on increasing our understanding of how farmer communities organize themselves to conduct rodent management, how they embrace ecologically based rodent management, and how to develop effective pathways for widespread scaling out of community-based rodent management. Underpinning these developments is our understanding of the many beliefs and practices that exist through the close association of rodents with the daily lives of humans, and how these influence the adoption and adaptation of management actions. In 2006, ecologically based rodent management was implemented at three villages in West Java. The five subsequent cropping seasons saw a 5% increase in rice yields at these villages compared with seven untreated villages. Progress has also been strong with the extension of rodent management technologies. We review this progress and highlight the most effective pathways, and the challenges, for scaling out ecologically based management at a community level.

Table 1. Ranking of major preharvest pests and diseases of the rice crop in Indonesia.

Pest/disease of lowland irrigated rice	Rank at national level
Rice-field rat	1
Brown planthopper	2
Stem borer	3
Blast	4
Tungro virus disease	5

Source: Forecasting Center for Plant Pest and Disease (Jatisari 2006 in Sudarmaji and Herawati 2008).

Rodents continue to be an important agricultural problem that has a significant impact on both the economic well-being and health of humans (Meerburg et al 2009). The impacts of rodents are not restricted to devastating agricultural products and food stocks; they also include human health, since rats and mice are found to be vectors of critically important diseases to humans, and the misuse of poisons has negative effects on biodiversity through nontarget effects (Singleton et al 1999, 2007). These impacts are felt more in Asia, where rodents are one of the most important constraints to agricultural production (Singleton 2003), but they also apply to other regions of the globe (Stenseth et al 2003). Preharvest losses in rice yield in Asia could reach 37.5 million tons, an amount that could feed more than 220 million people (Singleton 2003). At a global scale, some 280 million malnourished people could benefit if pre- and postharvest losses caused by rodents were reduced (Meerburg et al 2009). Rodents are also important reservoirs for more than 60 human diseases that include potentially debilitating diseases such as leptospirosis, scrub typhus, murine typhus, hantaviruses, and plague (*Yersinia pestis*) (Gratz 1994). In Indonesia and elsewhere in Southeast Asia, the impact continues to be felt because there is insufficient attention and investment for managing or addressing rodent problems for both rural and urban areas.

In Asia, where rice is the staple food and main livelihood source for many, fluctuations in rice supply and price affect hundreds of millions of people, especially members of poor households. It is smallholders and poor people that were hit hardest by the global rice crisis experienced in 2008 (Kellerhals 2008). In order to improve the plight of poor households in the face of a rice crisis, losses such as those caused by rodents need to be reduced. In Indonesia alone, rodents, the number-one preharvest pest of rice (Table 1), cause losses of around 17% annually (Geddes 1992, Leung et al 1999). This figure does not include postharvest losses. The damage continues to occur every year, with intensity as high as 20%. In 1961 and 1963, 1,822,000 ha experienced high rodent damage (intensity of 28–35%) in Java and Madura (Jatisari 2006 in Sudarmaji and Herawati 2008).

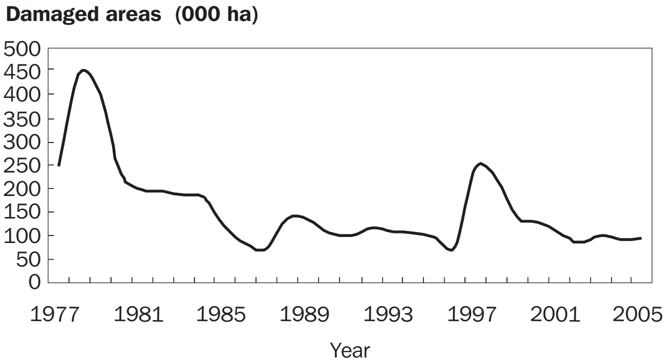

Fig. 1. Agricultural areas damaged by rodents in Indonesia from 1977 to 2005. Source: Forecasting Center for Plant Pest and Disease (Jatisari 2006 in Sudarmaji and Herawati 2008).

From 1977 to 2005, the national annual figures on the area of rice crop land where high rodent damage was experienced varied from 60,000 to 450,000 ha (Fig. 1). A promising trend is that the mean annual area experiencing high losses from 2000 to 2005 was substantially lower than in previous decades, coincident with the issuing of a presidential decree in 2001 that adopted ecologically based rodent management as a national benchmark. It is important to note that these figures reflect only areas of high damage; many rice-growing areas, particularly in Java and South Sumatra, experience chronic losses of 5–10% that are not reflected in the data in Figure 1.

In 2007, the government of Indonesia began a concerted effort to increase rice production. They set annual targets to increase rice production by 5% per year with the aim to increase production from 57 million t in 2007 to 67 million t in 2010. During this period in Java, some 35,000 ha of prime rice lands are being lost to urban development each year. Therefore, to help reach these production targets, despite the reduction in rice lands, it has become an imperative to reduce pre- and postharvest losses caused by rodents.

In this chapter, we briefly summarize the history of rodent management in Indonesia and then review progress toward validating and scaling out rodent management in Indonesia from 2006 onward. First, we explain what specific technologies are being promoted since a major shift in the early 2000s toward community management of rodents. Then, we examine the approach that was used to adapt and promote ecologically based rodent management (EBRM). For this, we highlight as case studies some innovative actions on dissemination at the national and provincial levels. We also explore the outcomes of these activities and show evidences of adoption and impact, as well as the lessons learned from this project. The chapter concludes with prospects of future activities to bring about sustainable and effective management of rodents through EBRM.

Brief history of rodent management in Indonesia

Prior to the 1990s, there was little progress in research on ways to successfully manage rodent pests. In the late 1980s, the integrated rodent management (IRM) program of the Food and Agriculture Organization (FAO) introduced community-wide management; however, it was not equally successful at all sites (Palis et al 2008, Van Elsen and van de Fliert 1990). The limited involvement of communities and the limited understanding of pest species may have brought about the limited reach of the program (Palis et al 2008). There was a considerable gap in the knowledge on rodent biology and behavior, which limited the understanding of factors that influence rodent population growth and the effectiveness of sustainable management of these pest populations (Singleton and Petch 1994). Recognition of these important gaps in knowledge on rodent ecology and behavior led to the Australian Centre for International Agricultural Research (ACIAR) funding a long-term program of research on the biology and management of rodents in lowland rice irrigated agroecosystems. This led to the establishment of a national rodent laboratory ("Laboratorium tikus") at the Indonesian Center for Rice Research (ICRR) in Sukamandi in West Java, and strong collaboration with scientists from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Canberra, Australia.

During the late 1990s, a paradigm of ecologically based rodent management (EBRM) was developed (Singleton 1997, Singleton et al 1999). This paradigm is now the basis for rodent management in many countries, including Bangladesh (Belmain et al 2006), Indonesia (Singleton et al 2005), Lao PDR (Douang Boupha et al 2003), Myanmar (Brown et al 2008), the Philippines (Palis et al 2008), Vietnam (Brown et al 2006), and in southern Africa (see www.nri.org/ecorat/).

Research done in West Java, Indonesia, from 1995 to 2002 initially aimed to understand the basic ecology of rodents and develop an ecologically based paradigm in managing rats in fields (Leung et al 1999, Singleton et al 2005, Jacob et al 2006, Jacob et al n.d., Sudarmaji et al 2006). The paradigm of ecologically based rodent management was accepted at a national level in 2001 through a presidential decree. Studies continued through 2005, when research was focused on developing a strong understanding of the ecology of the major rodent pest species and on developing farmer participatory adaptive research at a village scale (Singleton et al 2007). The collaboration between ICRR and CSIRO on rodent research in Indonesia evolved through the years from basic research into more applied studies. For 2006-09, community-level rodent management became the emphasis and included significant contributions from the Indonesian Center for Agricultural Technology Assessment and Development (ICATAD) and the International Rice Research Institute (IRRI). Studies shifted toward understanding how farmer communities organize themselves to conduct rodent management and how they are adapting ecologically based rodent management. Underpinning these developments is an understanding of the many beliefs and practices that exist through the close association of rodents with the daily lives of humans, and how these influence the adaptation and adoption of management actions. A majority of the current research activities integrate the provision of field assistance to farmers in provinces all over Indonesia where there is rat damage and a need for better management methods. These efforts have complemented other ways of dissemination of EBRM in Indonesia. Hence, research has evolved to focus on how to develop effective pathways for the widespread scaling out of community-based rodent management.

A basket of technologies: options for effective rodent management

By building a strong platform of understanding the ecology and behavior of the principal rodent pest, *Rattus argentiventer*, we developed a package of integrated management actions that has been verified as suitable for management. Some of these management actions are not necessary in all circumstances (see Box 1). The challenge has to been to develop sustainable community implementation of these farm management actions. One important management action is synchronous cropping, in which farmers in a community or over a large area are encouraged to plant their rice crop within a 1-month period to have synchronous maturation and reduce the rat breeding season (Leung et al 1999, Leung and Sudarmaji et al 2007). Rat campaigns before the planting season in which source habitats are thoroughly cleaned are also promoted. Another management action is to ensure that banks in rice fields are less than 30 cm wide to prevent rats from building burrow systems (Leung et al 1999). Fumigation and mass hunting may also be done, particularly at early to mid-tillering stage, as well as

Box 1. Integrated actions to manage the rice-field rat in lowland irrigated rice

Ecological studies provide the following **must do** activities at a community level for effective management of the rice-field rat in lowland irrigated rice in Indonesia:

- Synchronize planting so that crops are planted within 2 weeks of each other.
- Conduct community campaigns before the rice-field rat breeding season using local methods such as trapping and fumigation to control rats within 20 days of planting a transplanted crop or 35 days if the crop is direct seeded; these community actions usually focus on village gardens, main irrigation channels, and roadsides.
- Keep irrigation banks less than 30 cm wide to make it difficult for rats to build nests.
- Clean up any grain spills at harvest and practice good hygiene around houses and gardens.

Additional technology if chronic losses are greater than 10%

One simple technology added to the armory of rice farmers is a trap-and-fence system known as the community trap barrier system. It comprises a plastic fence surrounding a small rice crop (20 × 20 m) planted 2–3 weeks earlier than the surrounding crop, with traps set into the plastic. At night, rats follow the line of the plastic until they reach a hole, which they enter to reach the rice but instead are caught in a trap. They are subsequently removed the next morning (see Singleton et al 2001 for details).

sanitation, especially around rat habitats such as irrigation canal banks. The trap barrier system (TBS) is another management action that can be promoted for adaptation and adoption of farmers. TBS was developed through research that focused on the exploration of biological and ecological characteristics of the rice-field rat (Singleton et al 1999, Sudarmaji et al 2007, Leung and Sudarmaji 1999). The TBS is a system in which a trap crop, planted earlier than the rest of the area, is fenced, and covered with traps that are then monitored daily by farmers. As the development of TBS progressed, this technology was modified to be a more applicable tool for farmers, the linear trap barrier system (LTBS). Principally, both the TBS and LTBS have been developed based on the EBRM approach. However, the LTBS is more movable and cheaper than the TBS. The LTBS is also promoted as a management option. In the EBRM paradigm, not only are these technologies and their combination important but the correct timing of the rodent control action should also be considered.

In 2001, ICRR staff trained AIAT staff to construct CTBS demonstration plots in more than 10 districts in Central Java in both rice fields and rice nurseries. A household survey was conducted in 2002 in two of these districts to assess knowledge, beliefs, and practices on rat management and the adoption and adaptation of CTBS. The CTBS was considered an effective management technology, with an adoption rate of 51%. Interestingly, 98% of the farmers not involved in the demonstration plots had heard of CTBS. Of those who adopted the technology, 72% of the farmers made some modifications (Sudarmaji et al 2007).

Multistakeholder partnerships for EBRM in the research-extension interface

The way that EBRM is brought out to a larger number of users is through an effective research and extension interface in which adaptive research and extension are implemented simultaneously. In this interface, a partnership of various stakeholders is what moves the knowledge from research to end-users. Research conversely integrates feedback from end-users, which is then used to increase the effectiveness and efficiency for other users. This is consistent with recent developments in research and extension in which there is growing recognition of the range of other actors that play important roles in the adoption and adaptation of innovations, unlike traditional research and extension, in which mostly public institutions develop innovations and then other public institutions deliver the innovations to farmers (Plüss et al 2008).

The adaptive research in Indonesia on community-based rodent management involved many partners, led by ICRR and ICATAD and involving provincial staff through the Assessment Institutes for Agricultural Technology (AIATs) in West Java and South Sulawesi. International agencies such as CSIRO and IRRI were also involved. These are the main partners or the actors who jointly plan and implement activities relating to adapting and disseminating EBRM (Critchley et al 2008). ICRR, CSIRO, and IRRI collaborated with AIAT on demonstrating several plots for rodent control technologies. Effective communication and strong relationships were built among the partners. Through this partnership, ICRR, as the main institute that has the mandate to do research on rat control technologies in Indonesia, was able to effectively transfer the technologies to farmers after AIATs had verified them. The next step after piloting was to develop adaptive research through community participation at the village level. This step required other stakeholders: actors who have direct interest in production and consumption of rice at the study site, such as extension workers, government officials, private individuals (who may be local champions), and farmers. The project was implemented by ICRR and AIAT, although the day-to-day activities on EBRM were implemented by the community partners. The research was done in Citarik Village in Karawang District, West Java, with farmers and communities doing the management of rodents in their own fields. A parallel study was conducted in South Sulawesi but will not be reported here.

The success of the initial activities in Citarik intensified extension activities in the village. The project attracted the attention of high officials of the local government, who subsequently provided active support for rodent management activities. Since the local government has the authority to promote and provide some funds for rodent control programs, its strong involvement and support resulted in the participation of more farmers. Extension specialists funded by the local government also were able to provide assistance to farming communities during rodent management activities. Networks for collaboration among local government staff and extensionists working in different subvillages were strengthened because the local government organized regular meetings and informal training at the subvillage level. The strengthened partnerships and involvement of more partners show how partnerships evolve as there are outcomes of the joint action of different members (Waters-Bayer et al 2003).

The research and extension interface also involved activities to document and understand the knowledge and practices on rodent management of the farmers in the village. The need to establish data of initial socioeconomic conditions was recognized. Hence, while the initial activities were ongoing, we conducted a household survey of knowledge, attitudes, and practices (KAP) and economic inputs-outputs. The survey gathered information at the household level, and included key informants in the area (i.e., local government officials, water managers, community leaders, active farmers, farmer group leaders). This was jointly undertaken by the partners.

Avenues of EBRM dissemination in Indonesia

Linking with national initiatives

EBRM in Indonesia was disseminated at two levels and using different avenues. The first was at the national level, at which EBRM is linked with the national initiatives of P2BN, ICM, and Prima Tani. *Program Peningkatan Beras Nasional* (P2BN) or the National Rice Production Increase Program aimed to increase rice production in Indonesia up to 5% annually, equivalent to 2 million tons from 2007 to 2009. The P2BN program was implemented in 16 rice production provinces. The main approach to bringing out EBRM through the P2BN was by incorporating it in modules of integrated crop management (ICM). ICM consists of a package of technologies developed to increase rice productivity (Samaullah et al 2008). Modules of the technology package are extended at a national level through farmer field schools. The goal of a farmer field school is to transfer technology through ToT (training of trainers). The trainers/key persons are researchers who transfer knowledge to extensionists, seed producers, or plant protection staff at the provincial level. Then, these are expected to share their knowledge with other extensionists at lower levels (i.e., the district level), in collaboration with local government staff (see www.litbang.deptan.go.id). In 2008, some 60,000 farmer field schools were targeted for communicating ICM modules. For each farmer field school, 25 ha of rice was required to plant inbred rice. In 2008, ICM through farmer field schools was implemented over an estimated 1.58 million ha as a platform for achieving the goals of the P2BN program.

EBRM is also disseminated through Prima Tani, which is an initiative that aims to accelerate the dissemination of innovations in agricultural technology. This was launched by the Indonesian Agency for Agricultural Research and Development (IAARD) in 2005. Prima Tani is implemented through agroecosystem, agribusiness, regional, organizational, and welfare approaches with the goal of developing an industrial agribusiness unit at the village level. Prima Tani started in 14 provinces in 2005, where 21 agribusiness “laboratories” or demonstration sites were established at a village level. After one year, the number of sites multiplied as 25 provinces started implementing the Prima Tani program. By the end of 2007, over 200 districts in all provinces in Indonesia had a Prima Tani village, and demonstrations of EBRM were part of the agribusiness models. These demonstrations are targeted to be replicated at other sites.

Communication strategies

The ICRR played a leading role in introducing EBRM to a large number of people nationwide. The ICRR rodent laboratory is open to visitors interested in rice. In 2007-08, more than 10,000 people visited the laboratory and had intensive discussions about EBRM. In addition, staff of ICRR gave lectures and conducted training of personnel from AIATs, agricultural universities, and local government units, and provided material and assistance for LTBS/TBS construction in many provinces. Aside from West Java, demonstration sites on EBRM were established by ICRR staff in the provinces of Bengkulu, South Sumatera, West Sumatera, South Kalimantan, and Southeast Sulawesi. In areas including Bengkulu and South Sumatera, the high urgency of rodent problems, particularly where rats prevent the planting of a second rice crop, led to stronger linkages between ICRR and the Directorate of Food Crops. ICRR rodent staff were invited to be part of a technical team advising the “National Disaster Program.” This program addresses problems in areas that have experienced a natural disaster. The program supports potential agricultural sectors that need reconstruction programs. Therefore, through this program, the government links with several national research institutes, including ICRR, in order to advise, assist, and supervise farmers until the situation has returned to normal (www.deptan.go.id).

The Third National Rice Week was organized by and held at the ICRR in July 2008. This is also an important media occasion to raise the public profile of rice research because of the attendance of high-ranking officials. Indeed, the event was

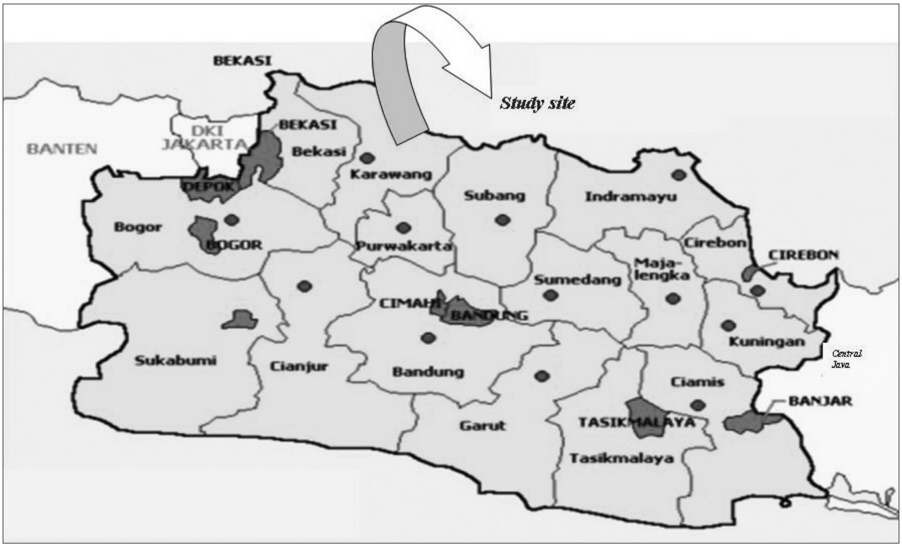

Fig. 2. Location of the study site, Karawang, West Java.

attended by the president of Indonesia, who emphasized new developments and the need to increase rice production. About 20,000 people visited ICRR and viewed the displays on EBRM. The visitors included officials involved in policy-making that affects agricultural programs. Moreover, during the National Rice Week, leaflets on EBRM were developed and distributed to farmers and government extension officers. More than 5,000 leaflets, booklets, posters, and CDs were distributed.

Two Web sites, the IAARD site (www.litbang.deptan.go.id) and the Indonesia Rice Knowledge Bank (www.puslitan.bogor.net), have information on EBRM.

Another innovative way of disseminating EBRM at the national level is to influence the knowledge and skills of future agricultural scientists and extensionists of Indonesia. An initiative involved strengthening the knowledge of university colleagues on EBRM, and to include technical knowledge in the curricula of universities. The most concrete development was the inclusion of EBRM principles in a new curriculum at the Faculty on Biology of Gadjah Mada University.

The second level of dissemination of EBRM involves adaptive research that has been started in West Java at the district level (Fig. 2). The dissemination of EBRM technologies at the province/district level required innovative approaches, combined with traditional approaches. Adaptive research was implemented at Karawang District, West Java.

In West Java, three villages (Citarik, Bojongsari, and Kertawaluya in Karawang District) were originally involved in the dissemination of community rodent management. In two of the villages, EBRM was introduced and the farmers were encouraged to use the different technology options to manage rodent pests. The third village (Kertawaluya) was a control or comparison village, where no interventions were introduced. Based on what farmers have seen of EBRM activities implemented in Bojongsari and Citarik, those from other villages asked to be advised on how to implement the same activities in their own villages. This led to the inclusion of seven additional neighboring villages within Tirtamulya Subdistrict in Karawang. The community activities had the support of the local government with the Bupati (district mayor) allocating funds for the construction of community trap barrier systems.

The message of EBRM was also communicated through television, radio, and print. The local radio in Cikampek and Bogor had special programs on better agricultural practices. In these programs, rat control technologies and EBRM were introduced. Each program had a talk-back session in which the audience could ask questions regarding what was taught on the program. Although EBRM activities are primarily promoted at the provincial level, the ICRR/ICATAD staff initiated coverage of EBRM by national television stations. TPI and Metro TV stations televised programs that brought out the EBRM messages to viewers nationally. These programs included an interactive dialogue segment, when resource speakers discussed technical and social aspects of EBRM. Concurrently, news on EBRM activities was published in the local newspaper to inform people of community activities.

Training in extension

More conventional methods of dissemination of EBRM were conducted to strengthen the understanding of extension staff and other end-users. Extensionists at the local level and farmer leaders were trained on the management options and approach of EBRM. In 2007, two training activities were implemented for extensionists, one for AIAT staff and two more for farmer group leaders. More training was done in 2008: 1 event for farmer group leaders and 10 for extensionists in other subdistricts. Thereafter, the trained extensionists conducted their own training of farmers in the villages (Fig. 3).

Dissemination of EBRM was successful in that it broadened the link among researchers, extensionists, and the local government to encourage farmers to adopt the technologies. The common issue that the group wanted to address was how to build farmers' awareness in doing rat control together at a community level since only a few farmers have strong motivation to adopt EBRM. Feedback from the extensionists is that they now have more confidence to help the farmers manage rodents since they have sufficient knowledge after the training. Some extensionists were sufficiently competent to be assigned as resource persons for the radio programs that discussed rodent management.

Adoption and evidence of impacts

Adoption of EBRM practices occurred among communities and individual farmers at the project sites and in neighboring areas. In 2007, as an outcome of dissemination efforts, farmers who had been trained on rodent management methods led the community actions before the planting season in Citarik and Bojongsari (Table 2). Then, throughout the season, farmer groups, coordinated by community leaders in subvil-

Table 2. Rat control activities by farmers in Citarik and Bojongsari during the 2007 dry season.

Site	Date (2007)	Control methods	Location	Number of rats captured
Bojongsari	12 March	Community action (flooding, digging rat burrows, sanitation)	Mango farm close to village	720
	23 March	Community action (fumigation, digging rat burrows, sanitation)	Along the irrigation channel bank	254
	30 March	Community action (fumigation, digging rat burrows, sanitation)	Along large bank by road bank	75
	24 April-10 July	TBS	Close to residential area	3
	24 April-28 June	TBS	Close to road	8
	27 April	LTBS	Along large bank by road bank	14
	27 April	LTBS	Irrigation channel bank	21
Citarik	27 April-28 June	TBS	Paddy field	8
	27 April-11 July	TBS	Close to residential area	9
	28 April-28 June	LTBS	Big dike in the middle of paddy field	

lages, implemented fumigation and sanitation in the main rat habitats such as road banks, borders between paddy fields and residential areas, irrigation channel banks, and dikes. With the encouragement of local government staff and extensionists, farmers volunteered their land to be part of the coverage area of the trap barrier system. The farmers involved recorded the number of rats captured daily from the TBS and LTBS within the entire crop season.

One season after the trials in Citarik and Bojongsari, other villages realized the need for timely rodent management and started doing coordinated rat control actions with active community participation within their villages. In the wet season of 2007, a total of six villages had rodent management activities at the community level (Table 3). Between October and December 2007, an average of nine community actions to control rodents were done in each village. For each activity, 40–235 villagers participated.

The number of villages conducting community activities to control rodents increased in 2008 from the original two treatment villages where the EBRM demonstrations were done to six villages doing rodent control actions on their own in 2007.

Fig. 3. Training on rat bio-ecology and its control technology by trained extensionists in Karawang, West Java.

In 2008, 10 villages were involved (Table 4); these villages covered a total of 12,670 households and 43,085 people.

In West Java, of the villages that implemented rodent management activities in the wet season of 2008, four villages (Karang Jaya, Karang Sinom, Kamurang, and Tamansari) implemented EBRM activities with minimal assistance and supervision from trained extension staff.

For these intensive rat control activities, monitoring systems and communication between neighboring villages have been put in place to avoid severe losses. Since they have monthly meetings (i.e., farmer group level, subvillage level, village level, and subdistrict level), there is an opportunity for them to discuss the rodent situation with each other. Extensionists and local government officials participate in these meetings to support the community actions. Farmers became aware that rodents could move between villages, so they appreciated the importance of effective communication on rodent management at a subdistrict and not just village level.

In West Java, three years have seen an impressive increase in the adoption of EBRM at both the village and district level, and in participation in community-based actions to control rodents. At a broader scale, the complementing district- and national-level dissemination initiatives have facilitated a sustainable adoption of EBRM in

Table 3. Rodent control activities in villages in West Java, wet season of 2007. The range in the number of participants in the different community actions is shown in parentheses.

Village	Field area (ha)	Frequency of activity (Oct.-Dec.)	No. of rats captured	Total number of farmers involved per village
Citarik	120	10**	4,147	803 (45–155)
Bojongsari	212	8	3,073	1,374 (121–235)
Kertawaluya	406	8	3,594	[a]
Parakan	232	9	3,012	[b]
Cipondoh	255	7	3,415	946 (65–200)
Parakan Mulya	171	9	2,362	581 (40–102)
Total	1,396		19,603	3,704

[a] Other activities not monitored. [b] Number of participants not monitored.

Table 4. Rodent control activities (8 took place in each village during March-April 2008) in West Java villages, dry season of 2008.

Village	Field area (ha)	Total rats captured	Number and estimation of farmers involved per activity
Citarik	120	3,284	774 (55–200)
Bojongsari	212	2,638	559 (55–105)
Kertwaluya	406	1,940	438 (45–68)
Parakan	232	2,493	510 (51–83)
Cipondoh	255	2,860	574 (59–81)
Parakan Mulya	172	2,621	538 (60–78)
Karang Jaya	199	3,012	601 (60–89)
Karang Sinom	261	2,412	441 (42-82)
Kamurang	200	2,849	550 (59-90)
Tirtasari	264	3,612	734 (30-79)
Total	2,321	27,721	5,719

Indonesia. The main initiatives include the integration of EBRM into demonstrations of agricultural business models at Prima Tani sites in South Sulawesi, South Sumatra, and West Java, the training of AIAT staff, inclusion of EBRM in integrated crop management (ICM) modules for farmer field schools (FFS) (Samaullah et al 2008), as well as through the continued scaling out of EBRM at the district level. From 2005 to 2008, more than 800 extension staff underwent formal training on EBRM. These people are now working in new areas (new villages and districts) outside the original core project sites to assist farmers in implementing rodent management strategies. These training courses were co-funded by ICRR (from the ACIAR project, IRRI, and government of Indonesia) and provincial AIATs.

On the farmer level, participation in community activities is as much an outcome of the change in knowledge on effective rodent control as the contribution of extensionists, local officials, and farmer leaders in organizing and bringing together farmers for community action. There has been a strong focus on the use of community action for rodent management and the use of a linear trap barrier system (LTBS) early in the cropping season, which prevents the use of other less environmentally sustainable control practices, including rodenticides, fumigation, and the mixing of used vehicle oil with toxic chemicals (see Singleton et al 2003a) later in crop growth, after damage is already high. More and more farmers are becoming involved in early community action to control rodents. The farmers themselves tried out the different rodent management options and have adapted these to their situation. For example, farmers were constrained from adopting TBS because of the complexity of TBS construction and the unavailability of tractors and sufficient water at land preparation, resulting in asynchronous schedules in farm activities. However, since they have seen that the TBS could work for them, farmers decided to adapt it into an LTBS. They found the LTBS to be easy to construct and it can be readily transferred to another place when needed. Through this adaptation process, farmers found that while the LTBS is simpler to set up than the original TBS, the effectiveness in catching rats was similar. The farmers are willing to share the cost of LTBS materials with each other, although extension staff proposed that funding for these materials could be through the annual local government budget.

Environmental and economic impacts

In West Java, an important environmental impact of the implementation of EBRM has been a 50% reduction in the use of chemical rodenticides. At the start of the project, 98% of farmers used chemicals to control rats. After 2 years, the use of chemical rodenticides was 46% in treatment villages (Bojongsari and Citarik) compared with 88% in the control village (Kertawaluya). There also was an overall reduction of 45% in the number of farmers using the ecologically disastrous cocktail of chemicals (including endosulfan) along with used motor oil that is spread on the flooded rice crop.

Farmers who conduct ecologically based rodent control have increases in yield and reductions in their expenses in growing their crop. Rat damage in Citarik and Bojongsari (West Java) was less than 10% as opposed to 15% damage in a typical year. Farmers got an average yield of 5.5 t ha^{-1} in the second planting season of 2007,

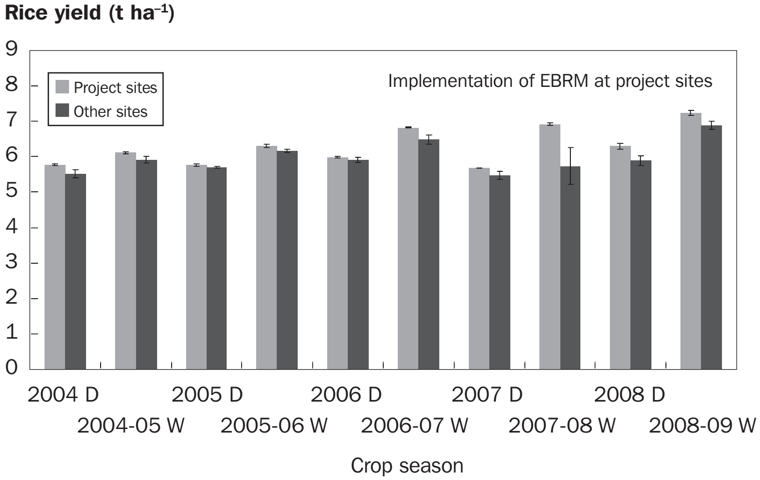

Fig. 4. Mean yields of rice (t ha^{-1}) from core project sites (n = 3) and other sites (n = 7) from before the project on ecologically based rodent management (EBRM) and after implementation of EBRM in 2006 at Karawang District, West Java. D = dry-season rice crop; W = wet-season rice crop.

whereas the average yield is usually around 5 t ha^{-1} (Fig. 4). At these sites, over five cropping seasons from 2006 to 2009, there was a 5% increase in rice yield in three villages where EBRM had been implemented compared with yields in seven villages where EBRM had not been adopted (Fig. 4). This increase takes into account differences in yield prior to implementation.

Scaling out and scaling up EBRM in Indonesia: lessons learned

From 2005 to 2008, the development of effective partnerships with the various stakeholders has greatly facilitated both scaling out to a wider number of farmers and scaling up to promote the inclusion of EBRM in agricultural policies and programs. The partnership brought together researchers and extension specialists to facilitate taking the knowledge to farmers as well as encouraging farmers through participatory action research to adapt the knowledge to suit their needs. In this partnership, the ICRR has played a major role, a role that is beyond its mandate for research. However, the linkages facilitated through the leadership of ICRR in the multistakeholder platform have developed an impressive model for sustainable diffusion of EBRM.

Another lesson learned is the importance of local "champions." These are the people at the site who have the capacity and interest to try out the new knowledge and technologies. These people encourage other farmers to adopt new technologies or they find ways to organize community actions and facilitate other important linkages. These champions may be local opinion leaders who are better connected to those working in research. These champions acquired resources that shaped their understanding and actions on rodent control. Once farmers have seen that it was effective in the fields of the champion farmers, the diffusion of knowledge and practice is facilitated.

From the technical side, a main limitation for those implementing the project and providing training is the lack of people who have expertise on rodents. Indonesia currently has only four rodent experts. These experts need to find effective ways to transfer the skills and knowledge that they have to others who can then teach more people in the different provinces throughout the country. This requires investment in both research and extension because, although site visits are essential, they consume much time of the experts, particularly when research is their main mandate. When the demands on experts to train others become too high, this leaves them little other time. One initiative ICRR staff identified that may help release the pressure on their time in the future was to link with universities by including EBRM in biological curricula. The aim in the medium term is to equip the next generation of agricultural scientists and extensionists with the requisite knowledge on the biology and management of rodents.

Another identified need for scaling out is the availability of materials (such as TBS materials) that effectively demonstrate EBRM to those who are not experts on rodents and rodent management. These materials should complement communication materials, specifically, leaflets, which are relatively easier and cheaper to produce. The challenge is to involve communities in investing in those materials and making arrangements on their maintenance.

Bringing out knowledge on the population response of rodents to communities often requires demonstrations of the impact of the crop management actions of farmers. For example, the rice-rice-rice cropping system in Citarik resulted in no yield for the third crop. There also were some problems in the neighboring rice-rice villages such that, during their community actions, farmers were able to trap 400 rats in 1 week in an LTBS. The continuous interaction of experts and extensionists with the community allowed the farmers to see that the rate of increase in the rodent population was directly related to their particular rice cropping systems.

Rodent impacts on the ICRR research farm have historically also been associated with asynchronous cropping in the area adjacent to the ICRR crops at Sukamandi (e.g., Singleton et al. 2003b). Recently, following advice from ICRR rodent experts, the farmers realized the cause of the recent high losses—rats—and they organized very quickly to conduct community action and they collected around 6,050 rats within a 3-day campaign.

However, despite the knowledge that farmers may already have acquired, some challenges may still hinder EBRM. One is that irrigation schedules may dictate asynchrony of cropping and the other is that share farming/absentee ownership of rice crops may result in a lack of motivation to participate in rodent control activities in the community.

Future prospects for EBRM in Indonesia

The Karawang region of West Java has seen impressive progress with implementing community-based ecological management of rats in lowland irrigated rice crops. This provides a good model for reducing losses due to rodents in similar agroecosystems elsewhere in Indonesia, where *R. argentiventer* is the predominant pest species. The groundwork has been laid both at finding an approach that brings research and extension together in disseminating EBRM and in scaling it out to more end-users. However, there is more to be done. In 2006, ecologically based rodent management was implemented at three villages in West Java. The sustained increase in rice yields at the EBRM villages compared with seven untreated villages is impressive; however, more detailed analyses are required to quantify the economic impact of EBRM adoption on lowland rice farming. Moreover, while there are positive indicators of impact, a post-KAP study that measures the changes in knowledge, attitudes, and practices of farmers on rodent control has to be done to quantify the level and extent of adoption of EBRM.

To scale out EBRM in Indonesia, decision support models that are aimed at key end-users need to be developed to increase the efficiency of diffusion and adoption. The innovations developed over the past decade and the stakeholder partnerships that have proven effective have to be strengthened further. Having mechanisms to effectively coordinate the different actors working toward the same goal has been previously identified as a key to strengthening this (Lizares-Bodegon et al 2002). The linkages with universities toward influencing the curricula for next-generation scientists and extensionists also need greater commitment of personnel and resources. To build on the impressive progress, more investment is required in national technical teams, more effort is required to develop policy briefs, and professional advice is required on the development of effective communication campaigns that promote sustainable EBRM at a national level.

As for the continuous adaptive research on rodent management, it would be beneficial to map out the impact of rodents nationally in terms of whether where damage occurs it is chronic or sporadically acute, in order to identify future geographic priorities and the potential number of farmers that can benefit from concerted training and associated communication campaigns on EBRM. Linked with this is the need to be aware that different agroecosystems are most likely to require different management strategies, especially if other species are involved. Such an audit of hot spots of rodent damage in Indonesia would be most beneficial in assessing what new expertise or resources are required to address the identified barriers/weaknesses and opportunities.

Lastly, building on lessons learned, the government at national and local levels giving support to EBRM dissemination could be strengthened further. The initiatives of local governments through their involvement in the current project highlight an awareness of the importance of rodent control activities at the village level. Furthermore, this also indicates their concern to protect local areas from rodent infestations. The national government, through allocating increased funding to the Agriculture Department for training on EBRM in all provinces, could generate a good return on investment (i.e., increased national production of rice). The training should cover both classroom activities and field work. At the level of communities, the continued support of local governments is crucial. Their involvement in EBRM dissemination could facilitate the sustainable and effective management of rodents through the widespread out-scaling of EBRM in Indonesia.

References

Belmain S, Meyer A, Kamal NQ, Shafali RB, Singleton G, Aplin K, Mian Y. 2006. Ecologically based rodent management for rice-based cropping systems in Bangladesh. In: Sweetmore A, Kimmins F, Silverside P, editors. Perspectives on pests. II. Achievements of research under the UK Department for International Development Crop Protection Programme, 2000-05. Aylesford (UK): Natural Resources International. p 179-181.

Brown PR, Yee N, Singleton GR, Kenney AJ, Htwe NM, Myint M, Aye T. 2008. Farmers' knowledge, attitudes, and practices for rodent management in Myanmar. Int. J. Pest Manage. 54:69-76.

Brown PR, Tuan NP, Singleton GR, Ha PTT, Hao, PT, Tan TQ, Tuat NV, Jacob J, Müller WJ. 2006. Ecologically based management of rodents in the real world: applied to a mixed agro-ecosystem in Vietnam. Ecol. Appl. 16:2000-2010.

Critchley W, Verburg M, van Velhuizen L. 2008. Facilitating multi-stakeholder partnerships: lessons from PROLINNOVA. www.cgiar-ilac.org/content/facilitating-multi-stakeholder-partnerships-lessons-prolinnova. Accessed January 2009.

Douang Boupha B, Aplin KA, Singleton GR. 2003. Rodent outbreaks in the uplands of Laos: analysis of historical patterns and the identity of *nuu khii.* In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM, editors. Rats, mice and people: rodent biology and management. Canberra (Australia): ACIAR. p 103-111.

Geddes AWM. 1992. The relative importance of pre-harvest crop pests in Indonesia. Bulletin 47. Kent (UK): Natural Resources Institute. 70 p.

Gratz NG. 1994. Rodents as carriers of disease. In: Buckle AP, Smith RH, editors. Rodent pests and their control. Wallingford (UK): Centre for Agriculture and Biosciences International. p 85-108.

Jacob J, Rahmini, Sudarmaji. 2006. The impact of imposed female sterility on field populations of ricefield rats (*Rattus argentiventer*). Agric. Ecosyst. Environ. 115:281-284.

Jacob J, Sudarmaji, Singleton GR, Rahmini, Herawati NA, Brown PR. n.d. Ecologically-based management of rodents in the real world: application to a rice-based agro-ecosystem in Indonesia. Crop Prot. (Submitted.)

Kellerhals MD. 2008. Food crisis has long-term global challenges. www.america.gov/st/peacesec-english/2008/April/20080417110732dmslahrellek0.8059656.html. Accessed 27 January 2009.

Leung LP, Singleton GR, Sudarmaji, Rahmini. 1999. Ecologically-based population management of the rice-field rat in Indonesia. In: Singleton GR, Hinds LA, Leirs H, Zhang Z, editors. Ecologically-based management of rodent pests. ACIAR Monograph 59. Canberra (Australia): Australian Centre for International Agricultural Research. p 305-318.

Leung LP, Sudarmaji. 1999. Techniques for trapping the rice-field rat, *Rattus argentiventer*. Malay Nat. J. 53:323-333.

Lizares-Bodegon S, Gonsalves J, Killough S, Water-Bayers A, van Veldhuizen L, Espineli M, editors. 2002. Participatory technology development for agricultural improvement: challenges for institutional integration. Philippines: International Institute for Rural Reconstruction. 37 p.

Meerburg BG, Singleton GR, Leirs H. 2009. The year of the rat ends: time to fight hunger. Pest Manage. Sci. 65:351-352.

Palis FG, Singleton GR, Flor RJ. 2008. Humans outsmarting rodents: adoption and impact of ecologically based rodent management in Asia. In: Singleton GR, Joshi RC, Sebastian LS, editors. Philippine rats: ecology and management. Science City of Muñoz (Philippines): Philippine Rice Research Institute.

Plüss L, Scheidegger U, Katz E, Thönnissen C. 2008. Understanding the research-extension interface: capitalizing experiences of nine agricultural projects in East Asia. Rural Dev. News 2/2008. p 40-46.

Samaullah MY, Sasmita P, Toha HM, Guswara A, Suharna, editors 2008. Pelatian TOT SL-PTT padi nasional. Balia besar penelitian tanaman padi, Sukamandi, West Java, Indonesia. (In Bahasa Indonesia.)

Singleton GR. 1997. Integrated management of rodents: a Southeast Asian and Australian perspective. Belgian J. Zool. 127:157-169.

Singleton GR. 2003. Impacts of rodents on rice production in Asia. IRRI Discussion Paper Series No. 45. Los Baños (Philippines): International Rice Research Institute.

Singleton GR, Hinds LA, Leirs H, Zhang Z. 1999. Ecologically-based management of rodent pests: re-evaluating our approach to an old problem. In: Singleton GR, Hinds LA, Leirs H, Zhang Z, editors. Ecologically-based management of rodent pests. ACIAR Monograph No. 59. Canberra (Australia): Australian Centre for International Agricultural Research. p 17-29.

Singleton GR, Petch DA. 1994. A review of the biology and management of rodent pests in Southeast Asia. ACIAR Technical Reports No. 30. Canberra (Australia): Australian Centre for International Agricultural Research.

Singleton GR, Sudarmaji, Nguyen VT, Douang Boupha B. 2001. Non-chemical control of rodents in lowland irrigated rice crops. ACIAR Research Note 26 (9/01). Canberra (Australia): Australian Centre for International Agricultural Research. 8 p.

Singleton GR, Kenney A, Tann CR, Sudarmaji, Hung NQ. 2003a. Myth, dogma and rodent management: good stories ruined by data? In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM, editors. Rats, mice and people: rodent biology and management. Canberra (Australia): Australian Centre for International Agricultural Research. p 554-560.

Singleton GR, Sudarmaji, Tuan NP, Sang PM, Huan NH, Brown PR, Jacob J, Heong KL, Escalada MM. 2003b. Reduction in chemical use following integrated ecologically-based rodent management. Int. Rice Res. Notes 28:33-35.

Singleton GR, Sudarmaji, Jacob J, Krebs, CJ. 2005. Integrated management to reduce rodent damage to lowland rice crops in Indonesia. Agric. Ecosyst. Environ. 107:75-82.

Singleton GR, Brown PR, Jacob J, Aplin KP, Sudarmaji. 2007. Unwanted and unintended effects of culling: a case for ecologically-based rodent management. Integrative Zool. 2:247-259.

Stenseth NC, Leirs H, Skonhoft A, Davis SA, Pech RP, Andreassen HP, Singleton GR, Lima M, Machangu RM, Makundi RH, Zhang Z, Brown PR, Shi D, Wan, X. 2003. Mice, rats, and people: the bio-economics of agricultural rodent pests. Frontiers Ecol. Environ. 1:367-375.

Sudarmaji, Rahmini, Singleton GR. 2006. Habitats utilization and movement of the rice-field rat to village habitats at various rice stages: implications for rodent management. In: Sumarno, Suparyono, Fagi AM, Adnyana MO, editors. Rice industry, culture and environment. Proceedings of the International Rice Conference 2005. Subang (Indonesia): Balai Besar Penelitian Tanaman Padi. p 307-312.

Sudarmaji, Anggara AW, Rahmini. 2007. The effectiveness of trap barrier system to control rats in lowland irrigated rice ecosystem. In: Kasim F, Widjono A, Sumarno, Suparyono, editors. Rice industry, culture and environment. Book 2. Sukamandi (Indonesia): Indonesian Center for Rice Research. p 529-531.

Sudarmaji, Herawati NA. 2008. Ekologi tikus sawah dan teknologi pengendaliannya. In: Daradjat AA, et al. editor. Padi: innovasi teknologi produksi – Book 2. Jakarta: LIPPI Press. p 295-322. (In Bahasa Indonesia.).

Sudarmaji, Herawati NA, Rahmini. 2007. Farmers' beliefs and practices on rat management and their adoption of trap barrier system in Central Java. In: Kasim F, Widjono A, Sumarno, Suparyono, editors. Rice industry, culture and environment. Book 2. Sukamandi (Indonesia): Indonesian Center for Rice Research. p 533-538.

Van Elsen K, van de Fliert E. 1990. Development of a community-based program on integrated rodent management in rice in Indonesia. In: Quick GR, editor. Rodents and rice. Report and proceedings of an expert panel meeting on rice rodent control, Los Baños, Philippines, 10-14 September 1990. Manila (Philippines): International Rice Research Institute.

Waters-Bayer A, Wettasinha C, van Veldhuizen L. 2003. Looking ahead. In: Wettasinha C, Waters-Bayer A, van Veldhuizen L, editors. Advancing participatory technology development: case studies on integration into agricultural research and development. Silang, Cavite (Philippines): International Institute of Rural Reconstruction. p 255-257.

www.deptan.go.id. Accessed November 2008.

www.litbang.deptan.go.id. Accessed November 2008.

www.puslitan.bogor.net. Accessed November 2008.

www.nri.org/ecorat/. Accessed April 2009.

Notes

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Authors' addresses: Sudarmaji and N.A. Herawati, Indonesian Center for Rice Research, Jl Raya No. 9 Sukamandi, Subang 41256, West Java, Indonesia; R.J. Flor and G.R. Singleton, International Rice Research Institute, DAPO Box 7777, Manila, Philippines; P.R. Brown, CSIRO Ecosystem Sciences, GPO Box 284, Canberra, Australia. Email: balitpa@vision.net.id.

Outscaling AWD in a public-managed reservoir-type irrigation system: a case study in the Philippines

E.B. Sibayan, J.L. de Dios, and R.M. Lampayan

Access to irrigation by farmers is anchored on the principle that each has the same right regardless of farm size and proximity to the water source. But, in reservoir-type irrigation, most farms at the downstream end do not get enough water. This is because of the upstream farmers' wasteful practice of continuously flooding their fields with 5 to 7 cm of water throughout the crop's growth duration. This is based on their belief that more water applied to the rice crop will mean more yield. This practice may have also been exacerbated by the National Irrigation Administration's (NIA) existing policy of imposing an irrigation service fee (ISF) per unit area and not by volume. This prompted the NIA in 2006 to enhance irrigation water availability by infrastructure rehabilitation and maintenance, and by the promotion of water-saving technologies (WST). Compared with the heavy investments needed to develop new irrigation infrastructure, the adoption of WST by farmers is inexpensive and has great potential to save water. During the 2007 dry-season technology demonstration of alternate wetting and drying (AWD) in Lateral F, District I, of the Upper Pampanga River Integrated Irrigation System (UPRIIS), located in Central Luzon, Philippines, water users in the turnout service area (TSA) were able to attain the same yield as in 2006. This was despite having less water savings (15% to 35%) due to the adoption of AWD and veering away from their normal continuously flooded water management. The initial success of AWD adoption in UPRIIS and the lessons learned through the farmer participatory research, development, and extension activities have been translated into a kind of blueprint to guide similar adoption and dissemination activities of AWD in other national irrigation systems in the Philippines. However, the speed and extent of adoption will depend very much on the long-term commitments of the implementing agencies and local partners.

Keywords: upstream, downstream, lateral, turnout, service area, rice irrigation, water saving

In most irrigation systems in the Philippines, farms within the service or command area of the system do not get the same volume of water, that is, farms at the upstream end irrigate more frequently and get more water than those at the downstream end. They maintain 5 to 7 cm of ponded water in their rice paddies continuously throughout the crops' growth duration. On the contrary, farms at the tail-end or downstream experience an insufficient supply of irrigation water, resulting in delayed planting and crop stress (Taylan 2005). This illustrates the inequitable distribution of irrigation water, which is contrary to the principle of having equal access to this important farm resource regardless of a farm's area and distance from the source.

Later in this 21st century, agriculture must meet the requirements of farm produce from an increasing population. However, with increased population, urbanization, and economic development, water requirements for urban development and industry must be satisfied first. In such a situation, it would be difficult to increase the water supply to agriculture. The only option is to save water used in rice production and use it more effectively to produce more rice with the same amount of or less water (Bouman and Tuong 2000**,** Dong et al 2004).

On-farm research and studies had been conducted for the last 20 years regarding on-farm water use with the objective of using less water to produce rice in order to increase water productivity and, where possible, save water. For the same period, the cropping intensity of the country had been pegged at 1.3 despite rehabilitation and repair of irrigation systems, for which the cost had increased tremendously (NIA 1996).

The studies conducted on water-saving technologies (WST) varied from (1) modification of farming operations and techniques such as dry plowing instead of puddling, (2) direct dry or wet seeding instead of transplanting, (3) maintaining saturated soil condition instead of continuously flooding during the crop growth period, and (4) modifying irrigation water application through the alternate wetting and drying (AWD) irrigation technique (Bouman et al 2007, Tabbal et al 2002). Of these, the latter proved to be more successful than the others simply because researchers were able to come up with simple tools and acceptable schemes on how the technology could be implemented using the existing strong linkages between the stakeholders, namely, the officials of the National Irrigation Administration (NIA) and the organized water users, the Irrigators' Association (IA).

The AWD water-saving technology entails an irrigation scheduling in which the field is allowed to dry for a number of days before re-irrigation, without stressing the rice plants. The number of days of nonflooded soil in AWD before irrigation is applied can vary from 1 day to more than 10 days. Based on field studies, water level in the field can be allowed to drop below the ground surface by as much as 15 cm (Bouman et al 2007), and will not cause any yield decline since the roots of the rice plants will still be able to take up water from the saturated soil and the perched water in the root zone. A simple perforated field water tube installed at 15-cm deep from the soil surface helps farmers decide when to irrigate, and see the hidden source of water available for crop use. The technology promotes efficient water use, and generates 15% to 35% water savings compared with the continuously flooded practice of the farmers (Lampayan et al 2005). This savings can pave the way to possibly increasing the area that can be irrigated in a cropping season within an irrigation system. It can also provide the basis for the preparation of an effective schedule of irrigation water delivery, ensuring equitable water distribution among farms regardless of location within the service area of an irrigation system. The establishment of observation wells in strategic locations within the irrigation system's service area for monitoring and observing the perched groundwater is a required component of the technology.

In deep-well-pump irrigated farms in Central Luzon, AWD was successfully adopted by farmers in past years through the Technology Transfer for Water Savings (TTWS) project collaboratively implemented by IRRI, PhilRice, and NIA (Lampayan et al 2005). Farmers' adoption of AWD was remarkable, mainly because farmers had to shoulder the cost of pumping. About 20–35% savings on water translated into decreased fuel cost and increased benefit.

However, in large public-managed gravity irrigation systems such as the Upper Pampanga River Integrated Irrigation System (UPRIIS), the concept of water savings may be less enticing to farmers. UPRIIS is the largest typical public reservoir-backed gravity national irrigation system in the Philippines supplying water to Central Luzon, the rice granary of the country. Divided into four districts, UPRIIS gets water from the Pantabangan Dam in the foothills of northern Nueva Ecija Province and, recently, from the Casenan River of Nueva Viscaya Province, irrigating around 130,000 ha of rice fields in Nueva Ecija, Pampanga, Bulacan, and Tarlac provinces. The Pantabangan Dam also stores water for hydroelectric power generation. Besides UPRIIS, deep-well pumps (DWP) and shallow tubewells (STW) owned and operated by farmers' groups (DWP) and individual farmers (STW) are commonly found in this area to augment water, especially for irrigating downstream farms in the system.

In UPRIIS, farmers pay only a nominal water fee on an area basis; thus, most of them do not see any incentive to use irrigation water judiciously. Although these farmers are organized into Irrigators' Associations (IAs), distribution of water among them is commonly not equitable. At the upstream and midstream sections of the canals where water appears to be abundant, farmers access water excessively. This leaves downstream farmers with late access to water (30 days later than the upstream farmers), which is oftentimes less sufficient for their crops. The challenge that confronts us is therefore how to promote AWD in such environments so that water can be evenly allocated, especially to downstream farmers, and to prepare farmers for the increasingly water-scarce situations in the future. Another challenge is how to change the attitude and perception of rice farmers toward the value of irrigation water. Good functioning and cooperation among members of IAs seem to be important requirements to facilitate successful AWD implementation in large gravity irrigation systems.

In the 2007 dry season, we introduced AWD in one of the service areas of the UPRIIS through a farmer participatory research approach to serve as a "lighthouse" for widespread outscaling of the technology in the farming community of UPRIIS and other gravity irrigation systems in the country. The study also aimed to (1) obtain insights into current water management practices by farmers and identify their behavior in coping with water scarcity at the system level, (2) document the process in the outscaling and adoption of AWD, (3) identify the factors affecting AWD adoption, and (4) identify impacts of AWD adoption. The lessons learned from the study will be translated into a kind of blueprint to guide similar adoption, dissemination activities, and policy guideline formulation for nationwide adoption of AWD in irrigated rice areas in the Philippines. This chapter discusses the preliminary results of the first two-season (2007 dry season and 2007 wet season) implementation and adoption of AWD at the study sites, including feedback by farmer-cooperators of AWD as an effective water-saving technology in rice production.

Methodology

Project partners and sites

The study is truly a collaborative one involving a national rice research institution mandate to undertake rice research and development (PhilRice); the National Irrigation Administration (NIA), which administers various water resource systems; and the International Rice Research Institute (IRRI). IRRI, PhilRice, and NIA-UPRIIS have had successful collaboration dating back to the early 1990s. Also considered as part of the study team are farmer-cooperators who are themselves members of IAs.

UPRIIS was selected as the project site. Within UPRIIS, we piloted AWD during the 2007 dry season among the farmers' group (IA) in Lateral F in Tondod, San Jose City (Fig. 1). In the 2007 wet season, the study site was relocated in one of the sublaterals in Main Canal B, Lateral B6 (Fig. 2), one of the laterals with Pook Malaya IA. This new site is currently in the irrigation management transfer (IMT) stage. Both sites belong to District I of UPRIIS.

Selection of partners from the NIA-UPRIIS

In November 2006, we convened a preliminary meeting at PhilRice with the key personnel from NIA, PhilRice, and IRRI to discuss possible solutions to the water-scarcity problems of UPRIIS. The meeting established the strong commitment of partners to introduce AWD at the farmers' level because of the benefits that can be derived from it, at both the field and system level. The outcome of the meeting was a vision for 100% adoption of the technology in the whole system, and to become a model system in outscaling AWD in the whole country.

Implementation of AWD beyond farmers' fields requires a number of institutional arrangements. Selection of the partners from NIA-UPRIIS was basically based on whose jurisdiction the identified lateral belonged to. The manager and the district engineer designated the operations supervisor, the head of the Institutional Development Office (IDO), and the senior water resources facilities technician (SWRFT) assigned to the IA as the main contact partners that help implement the activities on the ground.

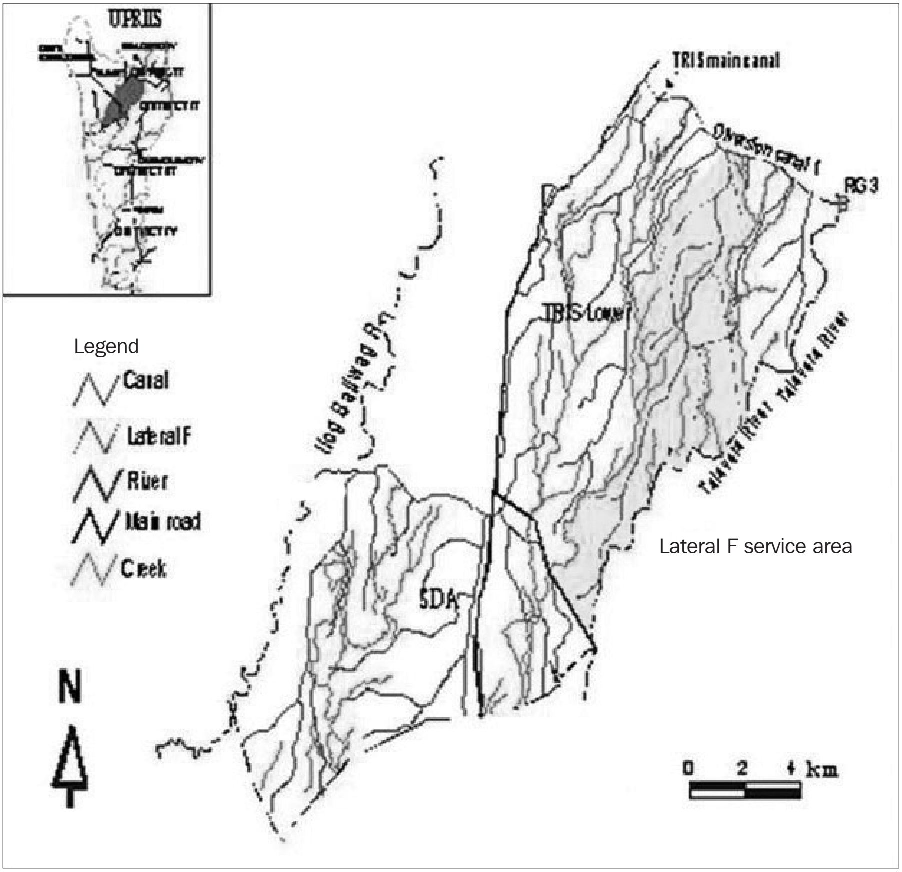

Fig. 1. Lateral F service area, District 1, UPRIIS, Nueva Ecija, Philippines.

Instrumentation and monitoring activities

Two measurement programs were carried out to monitor the proper implementation of AWD in farmers' fields and to produce data for evaluation. The first set concerns biophysical measurements. Perforated field water tubes with dimensions of 10 cm diameter × 25 cm length were installed to monitor ponded water depths and the perched water depths within the root zone. The tubes were buried up to 15 and 20 cm below the soil surface and readings were made every other day and during irrigation. Groundwater tubes were also strategically installed within the study sites using PVC pipes with a diameter of 3.8 cm with perforations in the lower 50 cm. They were buried at about 2 meters and were used as observation wells to monitor the level of the groundwater table throughout the year. D-Diver dataloggers (Van Essen Instruments) were installed in the canal to monitor the amount of irrigation water that entered into the clustered farms (in this case, the turnout service area, TSA) throughout the cropping season.

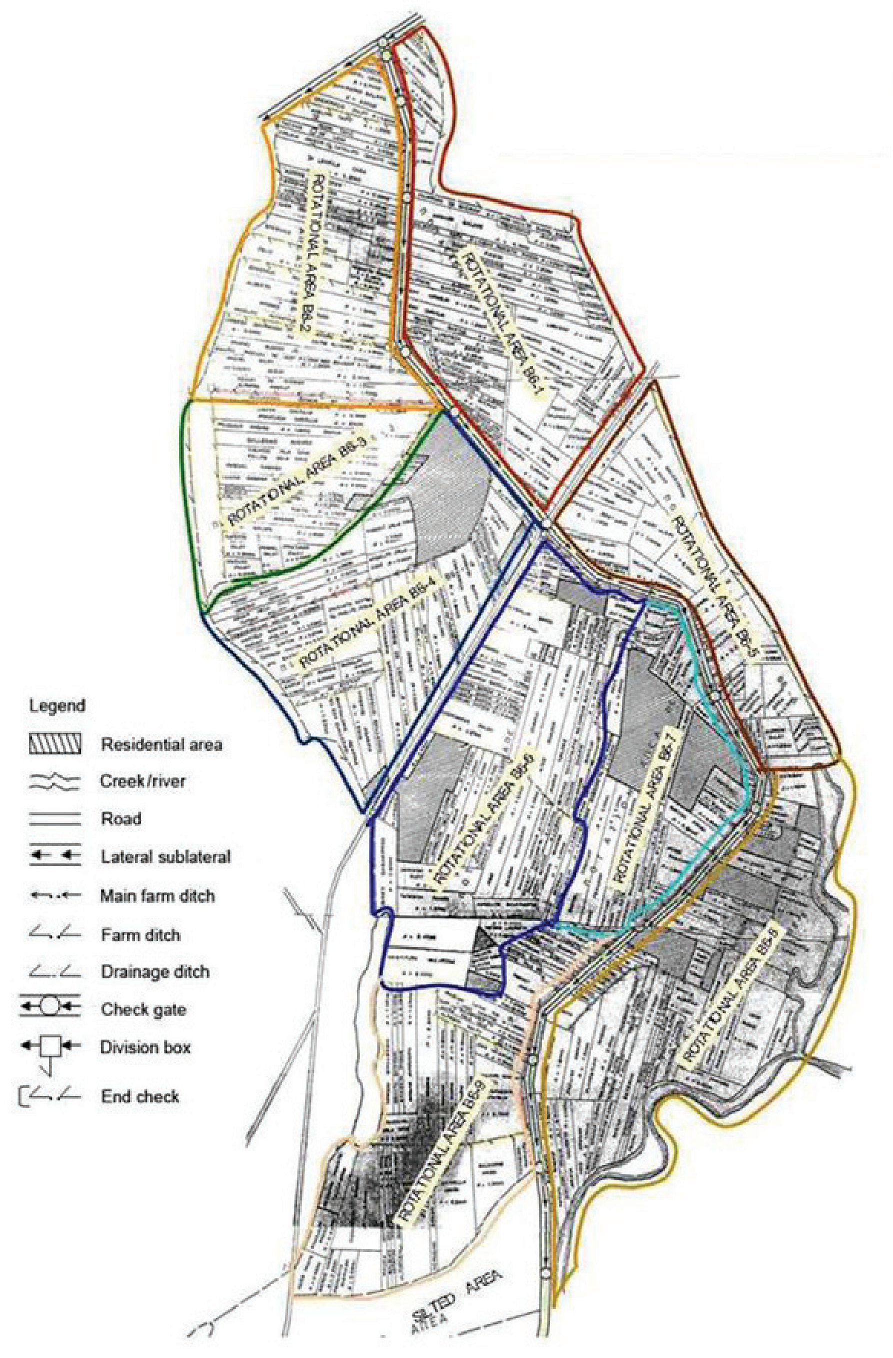

Fig. 2. Lateral B6 service area, District I, UPRIIS, Nueva Ecija, Philippines.

The second set concerns bookkeeping for all inputs, activities performed by farmers in their fields, and final yields. Examples of activities are land preparation, sowing, weeding, and harvesting. At all sites, local assistants were appointed by the project to help with the biophysical measurements and to assist farmers with the bookkeeping. Project-team partners regularly visit the sites, meet and discuss progress with farmers, and evaluate the collected data.

Results and discussion

Introduction of AWD in Lateral F

The first project site in Lateral F in Tondod, San Jose City, stretching down to San Fabian, Sto. Domingo, Nueva Ecija, has a perennial problem of water inadequacy at the downstream, especially during the dry season since the UPRIIS started its operation. The canal has a total length of about 18 km. Farmers have no option but to plant nonrice crops such as vegetables in order to have a source of livelihood and be productive in the remaining half of the year. In 2000 and 2001, Lateral F was used as a case site by Moya et al (2002) to establish a baseline situation and understand farmers' perceptions on water problems and their current water management practices. In this lateral, the downstream portion of the canal suffered from water scarcity during the dry season, and farmers resorted to using shallow pumps to help support their rice crops during the season. Moya et al (2002) reported that on average and regardless of water source, farmers in this lateral irrigated their fields 17–20 times to maintain flooded conditions, and applied about 1,300 mm of water during the dry cropping season.

During the 2007 DS (December 2006 to May 2007), two turnout service areas, one each at the upstream and midstream sections of Lateral F, were identified for AWD implementation. The upstream TSA has a service area of 57 ha and part of Atom IA. This TSA has a problem of water inadequacy at its tail-end portion. The second TSA, which is at the midstream portion of the lateral, has a service area of 23 ha and part of Villamapa IA. The elevation of the service area of this TSA is almost the same as the bottom of the lateral canal; hence, high seepage was observed. A meeting was conducted by PhilRice with the farmers in both IAs concerned, together with the officials of NIA-UPRIIS District I to introduce the AWD technology to the farmers and convince them to become partners and use their farms as a technology demonstration area.

Convincing farmers to adopt AWD was a big challenge for the project team members. Farmers in Lateral F, especially from the upstream or those close to the main water source, were initially hesitant to participate in the activity for two main reasons. First, the technology is very new and they have never seen how it was implemented and how it performed. They would not like to take a chance because they all believe that rice should be cultivated and grown with standing water almost all of the time as what they learned from their predecessors. Second, it is during the dry season that they usually get better yields as commonly experienced in the past. It is the time for them to recover from whatever losses they had during the wet season due to unfavorable weather and occurrence of pests and diseases. To encourage farmers to try the

Table 1. Average yield and depth of irrigation applied on farms that adopted AWD in two turnout service areas (TSA), Lateral F, District I, UPRIIS, Nueva Ecija, Philippines, 2007 dry season.

Location	Total service area (ha)	Average depth of water applied (m) 2007 DS	Average yield ($t\ ha^{-1}$)	
			2006	2007
Upstream (Atom IA)	51.4	1.88	7.32	8.48
Midstream (Villamapa IA)	24.3	0.87	6.56	7.14
Average	–	1.38	6.94	7.81

technology, an arrangement was agreed upon between farmers and the project, such that whatever yield reduction that they would incur in adopting AWD based on their 2006 DS yield would be compensated by the project. With these terms, all the farmers in the two TSAs participated and became cooperators of the project. With upstream farmers adopting AWD, it was hoped that more irrigation water would be made available for the midstream and downstream farmers in the lateral.

To prepare the farmers with the technology, a two-day technology update/seminar on rice farming with emphasis on AWD was conducted at PhilRice. The principles of AWD and the objectives of the project were explained in detail. Moreover, recent advances in rice production techniques that address some of the other common problems that farmers face were presented and discussed (e.g., seed quality, SSNM for nutrient management, drum seeder for increased labor efficiency, postharvest technologies, etc.). The success story of farmers' adoption of AWD in pump systems in Tarlac and Nueva Ecija during the TTWS implementation as reported by Lampayan et al (2005) was also presented.

However, low attendance of farmers was seen when the briefing was held at PhilRice. Only about 20% of the target farmers were able to come for the seminar. In order to cover all the participating farmers, the briefing/seminar was conducted on-site. All these were attended and facilitated by the concerned NIA partners. Extension materials such as leaflets and posters were distributed to the farmers. We used flipcharts during the lectures, and actually installed field water tubes with the farmers. The flipcharts became a handy training tool for trainers for the farmers to learn more about the technology. Farmers' knowledge on current rice farming technologies was enhanced and they became familiar with new technologies. The farmers used newly released rice varieties, and some even planted hybrid rice, and used harvest and postharvest technologies such as the rice threshers and flat-bed dryers.

On average, farmers' yields were higher in the 2007 dry season than in the 2006 dry season in both locations of the lateral (Table 1). Average yield in the 2007 dry season was about 7.8 $t\ ha^{-1}$ as against 6.9 $t\ ha^{-1}$ in the 2006 dry season. In Table 2, 10 of the 16 farmer-cooperators from TSA 1 of Atom IA had higher yield in 2007 than in 2006, with 0.3–3.3 $t\ ha^{-1}$ yield difference. Likewise, yields in the TSA under

Table 2. Yield comparison of 2006 and 2007 dry-season cropping, Atom IA, TSA 1, upstream, Lateral F, District I, UPRIIS, Nueva Ecija, Philippines.

Cooperator no.	Area of farm (ha)	Variety planted (2007)	2006 DS yield (t ha^{-1})	2007 DS yield (t ha^{-1})	Date of harvest
1	2.03	SL 8	8.74	9.58	20 April
2	2.8	PJ 25	7.55	7.88	11 April
3	2.0	NSIC 134	No data	6.25	15 April
4	0.97	NSIC 134	5.93	7.73	12 April
5	1.11	SL 8	9.50	9.14	12 April
6	1.11	SL 8	9.10	9.01	16 April
7	1.11	PSB Rc 82	5.14	5.86	7 April
8	1.0	PJ 25	7.50	10.00	11 April
9	1.0	PJ 25	8.50	8.25	11 April
10	1.0	1163	8.75	8.15	5 April
11	0.5	PSBRc 82	8.20	10.00	21 April
12	0.58	SL 8	7.07	8.88	13 April
13	1.06	SL 8	11.08	10.42	17 April
14	1.0	PJ 25	6.60	8.35	17 April
15	1.81	PJ 27	5.52	5.52	7 April
16	1.75	SL 8	7.86	10.63	18 April

Villamapa IA are shown in Table 3. Of the 18 cooperators, 13 had yields higher than what they had in the 2006 dry season. The increase in yields in the 2007 dry season may be attributed to the improved variety (hybrid) that farmers were planting that year. The average depth of water applied by the upstream farmers (Atom IA) was still higher than that of the midstream farmers (Villamapa IA) (1,800 mm vs 870 mm) (data not shown). However, midstream farmers claimed that they were able to get sufficient water now with upstream farmers adopting AWD. These data, however, do not claim that the same or even an increase in yield during the imposition of AWD was due to the capacity building provided or AWD adoption but rather showed that the partial or full adoption of AWD will not have a negative effect on rice yield.

Implementation of AWD in the IMT scheme service area in Lateral B6

In the 2007 wet season, the study site was relocated to one of the sublaterals in Main Canal B of UPRIIS-District I to assess the impact of AWD in service areas with irrigation management under the full responsibility of farmers' IA. Lateral B6 (Fig. 1) is one of the laterals under Pook Malaya IA (Fig. 3) piloted for NIA's Irrigation Management Transfer (IMT) scheme. With a service area of 257 ha and nine TSAs along its stretch, Lateral B6 is within Barangay Cabugao and Malaya, both of Sto. Domingo,

Table 3. Yield comparison of 2006 and 2007 dry-season crops, TSA 1, Villamapa IA, Lateral F, District 1, UPRIIS, Nueva Ecija, Philippines.

Cooperator no.	Farm size (ha)	Variety planted 2007	2006 DS average yield (t ha^{-1})	2007 DS average yield (t ha^{-1})
1	3.0	SL 8	No data	5.90
2	0.5	SL 8	2.50	6.00
3	0.8	PJ 25	5.13	7.00
4	1.0	PSB Rc 14	5.35	5.60
5	1.3	Bigante	7.31	7.58
6	1.3	SL 8	8.46	8.46
7	1.3	SL 8	8.35	8.58
8	1.6	SL 8	8.44	8.44
9	2.0	PSB Rc 82	4.75	5.10
10	1.8	SL 8	8.06	9.28
11	0.8	PSB Rc 82	5.63	7.50
12	1.8	Bigante	6.19	6.94
13	2.0	IR 64	6.90	6.48
14	1.0	PSB Rc 82	6.40	7.85
15	0.7	PSB Rc 82	6.57	5.43
16	1.6	PSB Rc 82	5.69	5.88
17	1.3	SL 8	8.81	9.27
18	0.5	PSB Rc 82	7.00	7.20

Nueva Ecija, and has been under the IMT scheme since 2006. In service areas under IMT, the IAs are mandated to manage the water allocation to their members, while NIA responsibility is to manage the water at the main canal and make sure that water will be available in the service areas under the IMT scheme. In this case, the IA's role is crucial in attaining equitable distribution of water, and maintaining a harmonious relationship among farmers in the service area. When farmers need irrigation in the service area, IA officials will communicate this to NIA water masters, who will request a water release from the dam.

In the 2007 WS, we monitored the first four of the nine turnouts that cover a total area of 121 ha for AWD implementation (Fig. 4). Following the AWD recommendation (irrigating only after water in the observation well is 20 cm below ground surface), the TSA leader (Mr. Gamurot) mentioned that farmers claimed that they made only three to four irrigations during the season (Gamurot, personal communication). This was due to the high rainfall that occurred (853 mm) from May to October 2007. This rainfall was distributed evenly during the growing season, and thus frequent irrigation from the canal was not necessary. Groundwater table depths in the field (Table

Fig. 3. The Pook Malaya Irrigators' Association president with co-farmers, Nueva Ecija, Philippines.

Fig. 4. Implementation of AWD in Pook Malaya IA by checking the water level in a rice field using a field water tube.

Table 4. Depth of groundwater table, 2007 WS, in four turnout service areas (TSA) within Lateral B6, Sto. Domingo, Nueva Ecija, Philippines.

Month	Water table depth (cm below ground surface)				
	TSA 1	TSA 2	TSA 3	TSA 4	Mean
September	30	10	8	18	16.5
October	20	35	15	20	22.5
November	15	36	18	23	23.0

Table 5. Total monthly rainfall and number of rainy days in District 1, UPRIIS, Nueva Ecija, Philippines, for 2007.

Month	Total rainfall (mm)	No. of rainy days
January	0.0	0
February	0.0	0
March	24.6	1
April	4.5	2
May	244.6	14
June	256.3	16
July	170.9	23
August	350.6	26
September	298.0	18
October	128.6	9
November	303.8	14
December	11.5	3
Total	1,793.4	126

Source: PhilRice Central Experiment Station.

4) were also shallower at the start of AWD imposition in September (average of 16.5 cm) and deeper toward November (average of 23 cm). Rainfall data for 2007 (Table 5) gathered from the nearest agro-meteorological station in the locality showed that the rains came quite early during the wet season, providing enough water for land preparation although crop establishment was accomplished later. Personal accounts during conversations with TSA leaders revealed that the rains were enough to support crop growth and development, and to perform necessary farming activities such as fertilization.

Changes in perceptions by stakeholders on water management

Farmers who adopted AWD were ones who had been cultivating rice for a long time. They never thought that rice could grow without being continuously flooded. The farmers, specifically those in the upstream and midstream, reduced the water they used by almost half as measured by the divers even during the dry season.

During the 2007 WS implementation of AWD in the four upstream turnouts of the lateral, farmers at the downstream end said that it was the first time that the water reached their farms early in the cropping season and they transplanted almost at the same time as the rest of the farmers in the lateral. They did not have to resort to using shallow tubewells to pump irrigation water at the land soaking and nursery establishment stage. The upstream farmers also felt gratified because they contributed to the timely farming activity by their fellow farmers downstream by improved access to irrigation water. There was no more conflict among the water users and this eliminated the need for downstream farmers to go upstream and reposition the water toward their farms. In the same manner, NIA field staff assigned to assist the farmers in the area claimed that they had fewer calls from this group of farmers compared with other groups that were not familiar with AWD. Downstream farmers also claimed that with AWD adoption in the IA service area, they were able to easily secure loans from informal lenders compared with previous years (Gamurot, personal communication). With their farms now getting sufficient and timely irrigation water, this provided an assurance to lenders that farmers could repay their loans timely. However, sustaining the new water management scheme in the area was seen as a big challenge for the IA. Although more farmers became eager to participate in the institutional activities of the IA to sustain the adoption of AWD, providing an incentive mechanism for upstream farmers to adopt the technology remains an issue that needs to be addressed by both the NIA and IA.

From the NIA's perspective, the success of AWD at the study sites has empowered them to alleviate water scarcity through improved distribution and access to irrigation water through upstream farmers' full adoption of AWD and allowing more water to flow toward the downstream, to increase irrigated area and cropping intensity in the whole system, and to improve the relationship among water users since irrigation water reaches the downstream on time. With satisfied water users, the NIA believed that farmers would also be more willing to pay an irrigation service fee (ISF). As a way forward, policy support also needs to be sought as a major step to get millions of farmers in the Philippines to adopt the technology.

Lessons learned

In the process of technology demonstration and adaptation in the UPRIIS, the following valuable lessons were learned:

1. The farmers' attitude of "to see is to believe" is strongly reflected in this study. Farmers are not willing to change any of their "practices" unless they are assured that whatever losses they have can be properly compensated. However, once they are convinced about what they see, they can be very good agents for transferring a technology that they adopted. The support

and cooperation of the farmers and the linkage between NIA officials and farmers through the IA were also instrumental and vital for the success of farmers' adoption and transfer of a technology; a change in the leadership of the organization may also be necessary to get more support and participation as what was done in this IA.

2. Farmers are willing to adopt this technology provided they are assured that there will be no negative effect on the crop and that enough water will be available when they need it. This is important because the control of the resource, in this case irrigation water, is out of the farmers' hand. Thus, the engagement of both parties with the researchers is important in order to bring the technology to the individual farmers' level and later scale it out with needed support from NIA management.
3. The adoption and practice of AWD paved the way for an improved relationship among water users at the lateral level.
4. For farmers at the tail-end, this would mean (a) reduced farming cost since they no longer pump water for seed bedding, seedling maintenance, and land soaking; (b) ease in securing loans from private individuals to finance farming when these informal lenders learn that sufficient irrigation water reaches them; and (c) peace of mind knowing that water will be available when they need it.

Concluding remarks

Scaling out of AWD can be done in the following manner: (1) Establishment of demonstration farms at the turnout level where all the farms covered by the turnout will be participating. This is to ensure that all the farmers in the TSA will collectively agree on how water at the turnout can be divided and shared equitably. (2) AWD implementation at the upstream turnouts. With half of the farms adopting AWD, a considerable amount of water can flow toward the remaining half of the lateral, thus benefiting the downstream farms that are initially deprived of the right quantity and timely delivery of irrigation water. (3) Implementation at the IA level so that everyone practices AWD and water entering the head gate of the lateral can be reduced, allowing more water to flow toward downstream laterals. (4) At the main canal and finally at the system level. The idea begins by convincing farmers with some degree of influence such as the officers but with full support from the O & M group of NIA to assure farmers that they will get the water they need on time.

However, to achieve this modality of scaling out, some interventions had to be instituted such as (1) capability enhancement for both farmers and NIA field staff, (2) support from NIA management, and (3) a review of the memorandum of agreement (MOA) between NIA and the IA conducted by both parties. Capability enhancement for both farmers and NIA field staff is necessary. Based on the interactions made with the farmer-cooperators, we found out that most of them just rely on what fellow farmers say. Some information such as the importance of basal fertilizer application, advantages of the use of certified and hybrid seeds, burning of rice straw, etc., was based on the information handed down to them by their fathers. They also claim that they seldom see extension workers in the field. On the part of the NIA, management admitted that its field staff, if they ever had agriculture-related training, it was already outdated. Some NIA field staff assigned as water tenders do not have basic agricultural knowledge or know about the science of rice farming. They are more knowledgeable on farmer organizing and the bulk of their responsibility lies with ISF collection. Support from the management of NIA is also necessary. The establishment and proper monitoring of the demonstration and trial farms need additional funds for mobilization and some incentive for additional tasks to be accomplished, which initially is not in their terms of reference. To establish a mutual and shared responsibility on the scaling out of AWD, a review of the MOA that is periodically signed by the NIA and the water users represented by the IA officials should be done. It is suggested that the adoption of AWD be indicated and corresponding incentive mechanisms be identified. This is to recognize the commitment offered by the farmers that will be tantamount to achieving the goals set by the NIA management, for example, better water availability in all sections of any service area within an indicated time frame and a secondary target of saving water in the reservoir for future use. Duplication of the scaling-out strategy can be done in other similar systems such as the Magat River Integrated Irrigation System (MaRIIS) in Isabela, Northern Luzon, the second-largest reservoir/gravity-type irrigation system and also a major rice-producing region in the Philippines.

References

Bouman BAM, Lampayan RM, Toung TP. 2007. Water management in irrigated rice: coping with water scarcity. Los Baños (Philippines): International Rice Research Institute, 54 p.

Bouman BAM, Tuong TP. 2000. Field water management to save water and increase its productivity in irrigated lowland rice. Agric. Water Manage. 49:11-30.

Dong B, Molden D , Loeve R, Li YH, Chen CD, Wang JZ. 2004. Farm level practices and water productivity in Zhanghe Irrigation System. Paddy Water Environ. 2:217-226.

Lampayan RM, Bouman BAM, de Dios JL, Lactaoen AT, Espiritu AJ, Norte TM, Quilang EJP, Tabbal DF, Llorca LP, Soriano JB, Corpuz AA, Malasa RB, Vicmudo VR. 2005. Transfer of water saving technologies in rice production in the Philippines. In: Thiyagarajan TM, Hengsdijk H, Bindradan P, editors. Transitions in agriculture for enhancing water productivity. Proceedings of the International Symposium on Transitions in Agriculture for Enhancing Water Productivity, 23-25 September 2003, Kilikulam, Tamil Nadu Agricultural University, Tamil Nadu, India. p 111-132.

Moya PF, Dawe D, Valencia S. 2002. The effects of dumping on water use and profitability in dry-season rice: a case study in UPRIIS, Philippines. In: Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Tuong TP, Ladha JK, editors. Water-wise rice production. Proceedings of the International Workshop on Water-wise Rice Production, 8-11 April 2002, Los Baños, Philippines. Los Baños (Philippines): International Rice Research Institute. p 333-345.

NIA (National Irrigation Administration). 1996. Annual report 1996. NIA, Manila, Philippines. 46 p.

Tabbal DF, Bouman BAM, Bhuiyan SI, Sibayan EB, Sattar MA. 2002. On-farm strategies for reducing water input in irrigated rice: case studies in the Philippines. Agric. Water Manage. 56:93-112.

Taylan VT. 2005. Irrigation water utilization at the Upper Pampanga River Integrated Irrigation System. Unpublished. PhD dissertation. Institute of Graduate Studies. Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines.

Notes

Authors' addresses: E.B. Sibayan and J.L. de Dios, Philippine Rice Research Institute, Science City of Muñoz, Philippines; R.M. Lampayan, International Rice Research Institute, Los Baños, Philippines. Email: ebsibayan@philrice.gov.ph.

Improving crop establishment and reducing losses from weeds in direct-seeded rice in Sri Lanka

A.S.K. Abeysekera, H.M.S. Herath, U.B. Wickrame, and D.E. Johnson

Farmers who have adopted direct seeding face serious problems to achieving good crop stands to manage weeds. To better understand weed management problems that farmers face and to develop management options for increased rice productivity, field surveys and field trials were conducted in different agroecological zones in Sri Lanka.

More than 90% of the farmers direct-seed their rice crops by sowing pregerminated seeds manually into moisture-saturated and puddled soil. Weeds account for a 30–40% yield loss (about 160–200 kg ha^{-1}) despite farmers investing US$40–60 ha^{-1} for herbicides. Losses to weeds are aggravated by poor cultural practices and fertilizer management. To achieve a good crop stand and suppress weeds, some farmers use high seed rates (200–400 kg ha^{-1}) and apply high herbicide doses.

Different crop establishment combined with weed management options was tested in farmers' fields at 12 locations to evaluate its effects on weed growth in and yield of rice. A drum seeder required a lower seeding rate (70 kg ha^{-1}) and saved at least 30% of seed compared with manual broadcasting (>100 kg ha^{-1}). Row seeding also enabled mechanical interrow weeding, thus providing easier removal of weeds. It is more effective for controlling weedy rice in infested areas. Row seeding followed by the application of bispyribac-sodium and rotary weeding was an effective alternative to broadcast seeding. Water seeding is an effective crop establishment method under waterlogged conditions.

The RRDI-Sri Lanka and the DOA extension service conducted awareness programs on direct-seeding technology options tested in farming communities. Farmers were interviewed to gather their views on the options demonstrated. Farmers highly favored drum seeding because of advantages such as (1) reduced seed rate, (2) lower herbicide costs, and (3) higher crop yield than manual broadcasting. Training of trainers and farmers on options for direct seeding and integrated weed management was conducted as part of "scaling-out" activities with the DOA. Training manuals, videos, and leaflets were developed to expand outreach to other communities.

Keywords: Broadcasting, seeding, rice, water, weeds

Table 1. Annual rice production area (ha) and average yield (t ha^{-1}) of rice in Sri Lanka.

Land category	Season	Average area cultivated (ha)	Average grain yield (t ha^{-1})
Major irrigation			
	Maha	256,000	4.66
	Yala	177,000	3.90
Minor Irrigation			
	Maha	136,000	3.27
	Yala	56,000	3.03
Rainfed	Maha	168,000	2.99
	Yala	77,000	2.55

Rice is the staple food of Sri Lankans. It provides livelihood to more than 1.3 million farmers. More than 34% of Sri Lanka's total labor force is directly or indirectly involved in the rice sector. Rice is cultivated twice a year as either an irrigated or rainfed crop (Table 1), with 560,000 ha grown in the main season (Maha) and 310,000 ha in the minor season (Yala). Although rice yields have tripled since the 1950s (Department of Census and Statistics, Sri Lanka 2007), it is projected that the national average rice yield of 4.5 t ha^{-1} needs to rise to 5.1 t ha^{-1} for the country to be self-sufficient soon (Fig. 1).

Rice is grown across a wide range of environments in Sri Lanka, including different altitudes, soils, and hydrological conditions. Annual total rainfall ranges from 600 mm in semiarid areas to 6,000 mm in wet areas. Average temperature ranges from 15 °C in the highlands to 30 °C at sea level. Rice is grown in almost all agroecological environments below 1,200 m. The greatest potential for increasing rice productivity is in the Low Country Dry Zone (LCDZ) and intermediate zone (IMZ), where solar radiation and other climatic parameters as well as edaphic conditions are relatively favorable for growing rice.

Yield gaps between the agronomic potential of cultivars and the productivity realized in farmers' fields are evident in all rice ecosystems in Sri Lanka. Although research has been successful in improving the genetic potential of new rice cultivars, farmers have failed to achieve the potential yield gains. Reasons cited for this "yield gap" in farmers' fields are considered mainly the shortcomings in crop management resulting from socioeconomic and/or institutional constraints. It is envisaged that improving crop management practices in land preparation, water and weed management, and soil fertility will help achieve and sustain greater productivity on rice farms.

In recent years, rice cultivation has become less attractive because of rising production costs, reduced returns to farmers, and risks from unfavorable conditions such as flood or drought. To improve the profitability of rice, a priority is to reduce production costs, particularly those incurred for labor.

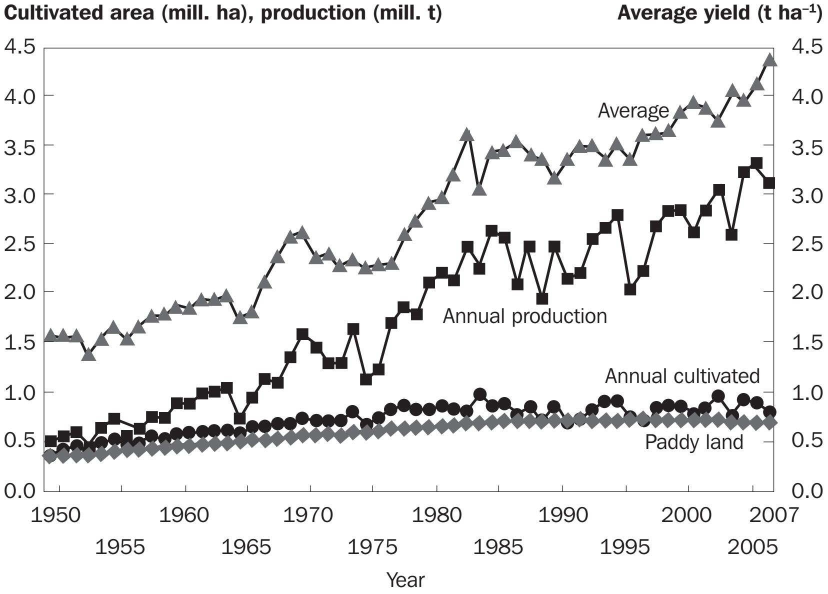

Fig. 1. Annual rice area planted (ha), production (million t), and average yield (t ha^{-1}) of rice in Sri Lanka (1950-2007). Department of Census and Statistics (2007). Paddy statistics of Sri Lanka.

Previous studies have shown that weeds are the major biotic constraint in direct-seeded rice (DSR). Rice yield losses from weeds in DSR have been estimated from studies in farmers' fields to be about 20% in the Low Country Wet Zone (Ranasinghe 2003) but others report that these are in the range of 20–40% (Herath Banda et al 1998). It is evident, however, that these yield loss estimates depend on climatic and crop management practices. Studies conducted at the Rice Research and Development Institute (RRDI) found that row seeding together with one herbicide application is effective and sufficient to achieve a good harvest from a direct-seeded rice crop. This practice reduces seeding rate and herbicide costs, and results in higher grain yield. Water seeding was also found as the best establishment practice in a waterlogged situation (Abeysekara et al 2008). Such options, however, were not adopted by a majority of farmers because of socioeconomic and technical constraints.

In order to better understand farmers' situation, a survey and field demonstrations were conducted to identify farmers' practices and perceptions on establishment and weed management options in DSR. These results will contribute to the development of more effective weed management practices under differing farmers' circumstances, environments, and cropping patterns.

Table 2. Number of farmers surveyed in the different agroecological zones and irrigation schemes.

Agroecological zone	Major irrigation	Minor irrigation	Rainfed
Dry zone	89	12	0
Intermediate zone	50	44	0
Wet zone	12	30	46
Total	151	86	46

Developing weed management options with farmers for direct-seeded rice

A field survey and demonstrations in farmers' fields were conducted in three different agroecological zones in 2005-07 by RRDI-Sri Lanka, in collaboration with the International Rice Research Institute (IRRI). A pretested questionnaire was used in interviewing 283 randomly selected farmers in three agroecological zones covering the different rice-growing ecosystems (Table 2). Farmers were interviewed about their practices and perceptions on rice management, problem weeds, and possible control measures. In addition, to support the survey data, quadrat sampling of weeds was done in farmers' fields to determine species plant numbers and biomass.

Farmer demonstration plots were established in farmers' fields in three different agroecological zones in Sri Lanka: the dry, wet, and intermediate zone. In each zone, four experimental fields were established as replicates at different sites. Two DSR establishment methods were compared as treatments in plots (8 m × 3 m): (1) pregerminated seeds (24 h soaking followed by 24 h incubation) were sown using a drum seeder on drained puddled soil, and (2) pregerminated seeds (48 h soaking followed by 24 h incubation) were broadcast-seeded in puddled soil with 3–5 cm of water depth. These were compared with dry-seeded, hand-broadcast rice (DSR), which is the most widespread method used by farmers. Pregerminated seeds (24 h soaking followed by 48 h incubation) were also used in this method. To control weeds at the experimental sites, bispyribac-sodium (300 mL ha^{-1}) was applied at 12 days after sowing. In addition, a rotary weeder was used in row-seeded plots. Weed dry weight, rice yield, and yield component data were collected in collaboration with extension officers and farmer-leaders at each experimental site.

Rice establishment practices

Farmers reported that transplanting was not practiced at all until the early 1950s to fill gaps in the DSR crop. In the 1950s, farmers used traditional rice varieties, tall plants with droopy leaves, which may help the crop compete with weeds. Farmers used few external inputs and gave little attention to weed management and other cultural measures. In the early 1960s, transplanting of rice was introduced and direct-seeding area declined to approximately 60–70% of the total area. A reversal in the trend of

Table 3. Different rice establishment methods used by farmers in the survey area (sample size 283).

Method of establishment	Number of farmers						
	Dry zone		Intermediate zone		Wet zone		
	Major	Minor	Major	Minor	Major	Minor	Rainfed
Manually broadcast wet-seeded	83	6	40	44	12	15	37
Manually broadcast dry-seeded	4	6	5	0	0	2	0
Row-seeded wet-seeded	0	0	3	0	0	0	0
Water-seeded	0	0	0	0	0	0	0
Transplanting	2	0	2	0	0	13	9

crop establishment happened in the 1970s, when the area planted with direct-seeded rice surpassed 90%. Until today, more than 90% of farmers sow rice by manually broadcasting pregerminated seed on puddled soil (Table 3), as this requires less labor and time than transplanting. Very few farmers practice dry seeding or *Manavari* in survey areas although, in the eastern province, some use dry DSR to save water and also to establish the rice crop early to avoid difficulty in establishment caused by subsequent heavy rains. Water seeding is not used by farmers although research findings have indicated that this method may be suitable for low-lying/waterlogged areas. Transplanting (TPR) is used by less than 7% of farmers.

Studies have shown that grain yields with direct seeding do not differ from those of transplanted rice if farmers can achieve good rice crop stands and control weeds effectively in DSR. Weeds pose a particular problem in DSR as the rice and weeds are usually at similar growth stages and, unlike with TPR, a delay usually occurs before the fields can be flooded, which allows weeds to flourish. Saturated soil, rather than flooded conditions, at the time of seeding allows growth of semiaquatic grass weeds, which emerge at the same time as rice, and these dominate the weed flora in DSR.

Production constraints

Herath Banda et al (1998) did a farm survey in the rice-growing areas of Sri Lanka and reported that weeds were the major biotic constraint in DSR in all agroecological zones, though other rice yield gaps were due to several factors and farmers' practices. Other researchers have reported that weeds, insect pests, and poor management practices were the predominant factors constraining rice production (Dhanapala and Claridge 1990). Our results concur with the above results and indicate that weeds were major constraints to production across the agroecological zones, followed by either a water shortage or flooding (Table 4).

Table 4. Production constraints faced by farmers in the different agroecological zones (sample size = 283 farmers). The farmers reported more than one major constraint.

Constraints	Percent of farmers reporting		
	Dry zone	Intermediate zone	Wet zone
Pests and diseases	32	39	47
Weeds	80	78	82
Water shortage	52	65	12
Floods	–	5	25
Soil problems	17	15	16
Cost of inputs	25	18	23
Shortage of labor	18	22	6
Low profitability	8	14	12
Others	51	27	60

Many technology options for raising productivity in DSR have not been adopted by farmers because of socioeconomic and technical constraints, including poverty, a perceived low return to investment, labor shortage, and inadequate access to information and technical support. Climatic factors also contribute to the yield gaps in farmers' fields. Farmers reported that, in the past, they used to cultivate the rice crop at the onset of the monsoon. Because of the above factors and the busy life of farmers, they now start their cultivation late. Timely cultivation and collective participation were primary considerations in DSR to reduce the risks of terminal drought, pest problems, and disease incidences.

Weed flora in DSR

A weed survey of farmers' fields indicated that 28 weed species in DSR were problem weeds causing serious yield losses. Grasses were the principal weeds in the dry and intermediate zones, whereas broadleaf weeds and sedges dominated in the wet zone. Table 5 shows the common weed species observed in rice fields and ranked by farmers as their problem weeds. *Echinochloa crus-galli* and *E. colona* were ranked as the first and second problem weed in the three agroecological zones. Yield losses from weeds are higher in the dry zone than in the wet and intermediate zone.

The mean dry weights (g m^{-2}) of dominant weeds in farmers' fields are shown in Table 6. In the dry zone, grass weeds were the most dominant, followed by the sedges and broadleaf weeds. Weedy rice (*Oryza sativa*), *Salvinia molesta*, and *Digitaria ciliaris* were considered serious problems in some, but not all, areas.

Table 5. Weed species in rice fields ranked according to the summed dominance view of farmers in different agroecological zones.

Weed species	Rank[a]		
	Dry zone	Intermediate zone	Wet zone
Echinochloa crus-galli	1	1	1
E. colona	8	2	2
Leptochloa chinensis	2	3	13
Ischaemum rugosum	3	4	26
Isachne globosa	4	7	16
Panicum repens	5	26	17
Cynadon dactylon	6	5	14
Paspalum conjugatum	7	6	7
Eragrostis japonica	16	8	15
Coix lachrymal	28	15	25
Monocharia vaginalis	9	27	8
Eichhornia crassipes	24	14	24
Sphaeranthus africanus	27	22	10
Limnocharis flava	19	20	9
Sphenoclea zeylanica	26	28	18
Murdannia nudiflora	15	9	12
Ludwigia octovalvis	21	21	11
Commelina diffusa	14	13	22
Aeschynomene indica	20	25	19
Marsilea quadrifolia	23	16	6
Eclipta alba	25	23	21
Fimbristylis miliacea	10	19	3
Cyperus difformis	13	10	20
C. rotundus	12	11	23
C. iria	11	18	4
C. pulcherimus	17	24	27
Scripus supinus	22	12	5
Fimbristylis dichotama	18	17	28

[a] The lower the rank number, the higher the summed dominance view of farmers.

Table 6. Mean dry weight of weeds sampled in the dry zone.

Weed	Dry weight (g m^{-2})
Grasses	
Echinochloa crus-galli	38.4
Leptochloa chinensis	36.2
Ischaemum rugosum	30.2
Isachne globosa	30.0
Panicum repens	28.3
Paspalum distichum	20.4
Cynodon dactylon	18.5
Fimbristylis miliacea	16.2
Sedges	
Cyperus iria	12.5
Scirpus supinus	11.8
Cyperus difformis	11.4
C. rotundus	9.3
C. pulcherimus	6.3
Broadleaf weeds	
Monochoria vaginalis	22.4
Ludwigia perennis	18.4
L. octovalvis	14.3
Aeschynomene indica	12.5
Lindernia sp.	12.4
Sphenoclea zeylanica	8.3
Eclipta alba	7.5
Ammania baccifera	6.4

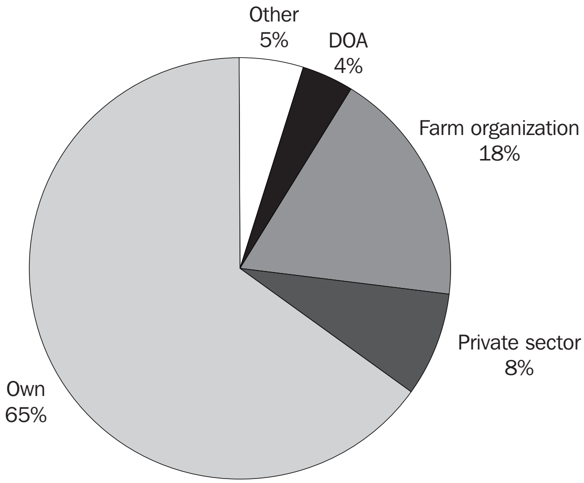

Fig. 2. Source of seed paddy used by farmers in the survey area.

Cultural management practices

1. Seed quality

Contamination of rice seed with weed seeds was considered to be a major cause of weed infestations. About 30% of the farmers use certified rice seed from the DOA, private companies, and farmer organizations, while the rest of the farmers save their own seed or exchange seed with neighbors (Fig. 2). Very few farmers produce their own "clean seed" and, recently, the government of Sri Lanka initiated the "self seed paddy production program" with the help of farmer organizations in order to improve the quality of seeds farmers are using.

2. High seeding rate

Achieving the planned rice plant density in the field is dependent on farmers' practices and in particular on seedbed "leveling," control of drainage and flooding, seed germination rate, seeding rate, and pest incidence. Rice seeding density in farmers' fields varied between 200 and 400 plants m^{-2}. This density can be achieved with a recommended seed rate of 100 kg ha^{-1} provided there is 85% seed germination with a seed weight of 25 g $1{,}000^{-1}$ grains. The survey data indicated that the majority of farmers used seed rates of 100 to 200 kg ha^{-1} to overcome poor land preparation and poor seed germination, and to help reduce weed infestations.

3. Land preparation

Good land preparation is seen as an important requirement for effective weed management in DSR. Land preparation methods varied according to soil type, location, season, and economic resources. Land preparation is undertaken under dry, moist, or wet conditions. Most farmers prepare their fields under flooded conditions but, in other areas, where water is a problem, dry land preparation is practiced. In the areas surveyed, 95% of the farmers interviewed used wet land preparation. The recommended tillage practice for DSR involves cleaning bunds and irrigation canals, followed by two plowings with a disc plow, one harrowing, and one land leveling. Recommended operations would require an estimated 40% of the total crop water requirement, and 20% of the cost of cultivation, and take 20–25% of cropping time. In order to reduce this cost and time, farmers tend to "hurry" land preparation using a rotavator and plank for leveling.

Table 7 shows the different land preparation practices used by farmers in the survey area. Many of the farmers did not follow the recommended tillage practices with recommended tillage implements. This may be one of the reasons leading to an increased perennial weed population such as *Paspalum distichum, Digitaria* spp., *Isachne globosa, Murdannia nudiflora,* and *Cynodon dactylon*, which dominate the weed flora in some areas. These weeds are difficult to control by herbicides.

Sixty percent of the farmers used preplant herbicides such as paraquat and glyphosate to achieve an immediate kill of weeds and shorten land preparation; 70% of these farmers used paraquat. Studies at RRDI over six consecutive seasons indicate that the use of preplant herbicide combined with reduced tillage was equally as ef-

Table 7. Different land preparation practices used by farmers in the survey area.

Type of practice	% of farmers using	Purpose	Implement use
Cleaning bunds and irrigation canals	48	Water management Weed management	Mammoty[a]
Application of preplant herbicides	60	Easy to prepare land Weed management	Sprayer
One plowing	100	Loosening the soil	Rotavetor
Two plowings	80	Weed and water management	Rotavator
Plastering bunds	92	Water and weed management	Mammoty
Puddling and leveling	90	Obtain good crop stand and management practices	Leveling plank

[a] The mammoty is a type of hoe with a large blade.

fective in managing weeds as the standard land preparation package of plowing and harrowing (Abeysekara et al 2001).

Bund cleaning and initial soil tillage aim to control existing weed growth and incorporate plant residues into the soil. Farmers use a rotavator for the initial soil tillage and this creates a plow pan at shallow depth. Survey data indicated that rotary tillage increased the germination and growth of weeds, especially perennial weeds, and reduced rice grain yield. Almost all the farmers in the survey practiced second plowing in order to reduce the weed problem. Twelve percent of the farmers in the dry zone, 7% in the intermediate zone, and 14% in the wet zone incorporated rice straw after the first plowing to increase soil fertility. Some farmers (4%) in the wet zone used green manure in rice fields as a source of organic fertilizer. In the dry zone, 13% of the farmers used half-burned paddy husk as a source of organic matter. The use of green manure in rice at land preparation is a common practice to supply plant nutrients. Past research at RRDI shows that the application of green manure as *Tithonia diversifolia*, *Croton lassifer*, or *Gliricidia* species at 10 t ha^{-1} significantly reduced weed biomass (Abeysekara and Sirisena 2001). As a consequence, the DOA has encouraged farmers to use green manure to reduce weed incidence and increase soil fertility.

4. Water management

Water management is well recognized as an effective method for weed control in DSR. Once the rice is established, emergence of many grasses can be suppressed with a depth of water of 5 cm or more. Shallow standing water, however, promotes the growth of some broadleaf weeds and sedges, such as *Monochoria* sp. and *Scirpus* sp., though these species may be readily controlled with herbicide. Irrigation water is in limited supply for some farmers, especially during the minor season. Because of the limited supply of irrigation water and poor management of irrigation canals, 23% of the farmers in the intermediate and dry zones have experienced water shortages in the dry season. This shortage also resulted in more weed problems. No water shortages

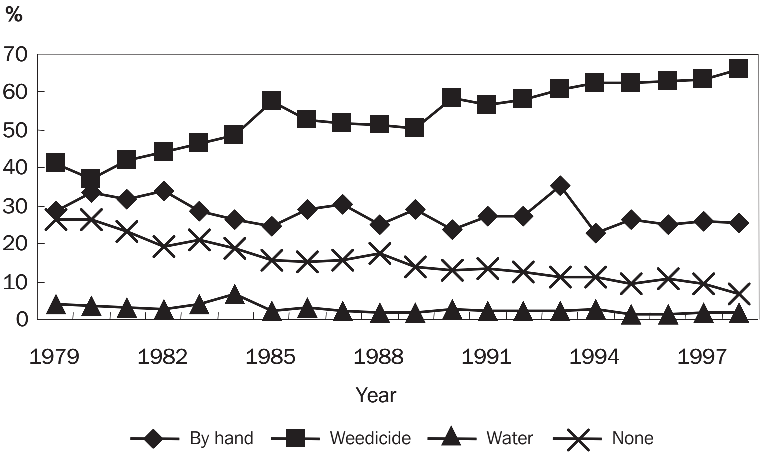

Fig. 3. Percentage distribution of weed control methods used by farmers in Sri Lanka.

were experienced by these farmers during the major season as both rainwater and irrigation were water-sufficient for weed management in DSR in the wet zone.

5. Chemical weed control

Herbicide use has increased greatly over the past four decades. This has replaced hand weeding because of labor shortages, and because it is tedious and time-consuming. Chemical weed control is practiced by nearly 90% of the farmers (Fig. 3). Although farmers spend around \$40–60 ha^{-1} for herbicide application, weeds account for yield losses of around 160–200 kg ha^{-1}. Farmers regard chemical weed control (Fig. 4) as the most reliable and economical weed control method in direct-seeded rice (Perera 1993). In Sri Lanka, herbicide use has been increasing as indicated by the increase in the volume of imports and sales of pesticides in the past 10 years (Figs. 5 and 6) (Registrar of Pesticide 2006). More than 20 herbicide products are now recommended for rice cultivation (Table 8). However, farmers commonly use 8 to 10 herbicides (Fig. 7).

Although the survey indicates that 90% of the farmers use herbicides, only 30% of users achieve effective weed control. This poor control is thought to be due to incorrect herbicide selection and application methods, and poor cultural and water management practices. Recently, *Isachne globosa, Leptochloa chinensis, Murdania nudiflora,* and some perennial weed species have become problematic weeds in rice cultivation because of the continuous application of some popular herbicides combined with inadequate cultural management practices.

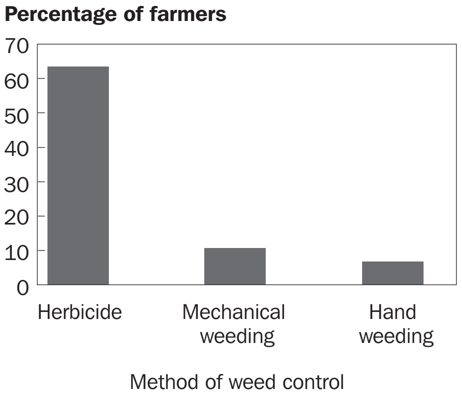

Fig. 4. Percentage distribution of weed control methods used by farmers in the survey area.

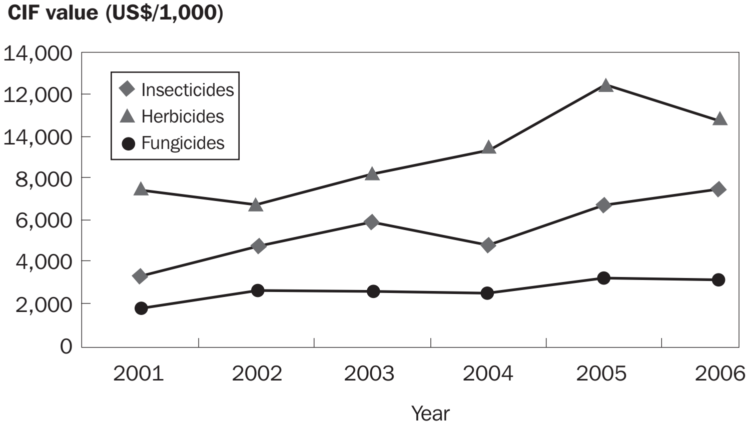

Fig. 5. Annual CIF (cost, insurance, and freight) value (US$/1,000) used for the imports of pesticides in Sri Lanka.

Improving direct seeding and weed management practices of farmers: farmer demonstrations

Row seeding was recently introduced to farmers through demonstration trials at 12 sites to address the difficulties mentioned. Results showed that, irrespective of the rice ecosystem, row-seeded plots gave 10–20% greater grain yields than the farmers' practice of broadcast seeding (Table 9). Row seeding of rice can reduce the seeding rate to about 60–80 kg ha^{-1} compared with the recommended rate of 100 kg ha^{-1} for manual broadcasting. Row seeding also allows mechanical weeding, which helps reduce reliance on herbicide and facilitates the control of weedy rice.

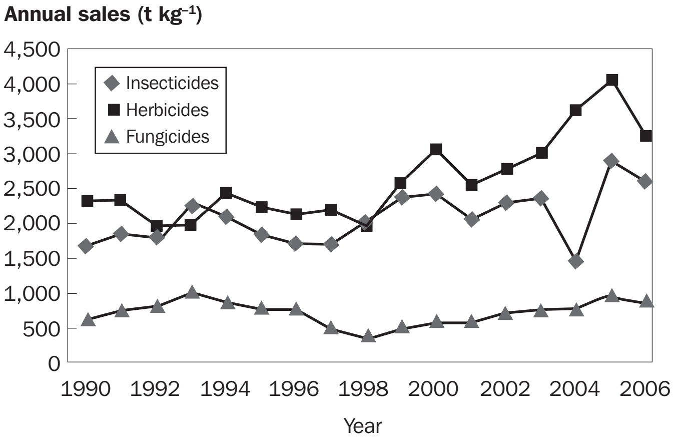

Fig. 6. Annual local sales of pesticides (tons) during 1990-2006 in Sri Lanka. Annual Report 2007, Registrar of Pesticides, Department of Agriculture.

Table 8. Recommended herbicides for rice weed control in Sri Lanka.

Common name	Chemical name	Rate of application (g or L ha^{-1})
3.4 DPA	Propanil 360 g L^{-1} EC	7.5 L
Ronsta PL	Oxadiazon + propanil	3.5 L
Nominee	Bispyribac-sodium 100SC	0.30 L
Sofit	Pretilachlor 300 g L^{-1} EC	1.6 L
Goal	Oxyfluorfen 240 g L^{-1} EC	0.25 L
Facet	Quinclorac 50% WP	0.6 L
Compro	Clomazone + propanil	1.0 L
Clincher	Cyhalofop butyl EC	1.0 L
Chese	Pendimethalin + propanil	5.7 L
Satunil	Thiobencarb 400 g L^{-1} + propanil 200 g L^{-1} EC	5.0 L
Whip Super	Fenoxyprop-ethyl 75 g L^{-1} EW	0.3 L
Lecspro	Fentrazamide + propanil	2.4 L
MCPA	MCPA 600 g L^{-1} SL	1.0 L
MCPA	MCPA 400 g L^{-1} SL	2.0 L
Hedanol	2.4 D 550 g L^{-1} SL	0.9 L
Sunrice	Ethoxysulfuron 15% WG	65 g
Invest	Cyclosulfamuron 10WP	200 g
Tillergold	Fenoxyprop-ethyl + ethoxysulfuron	0.5 L
Solito	Pretilachlor + pyribenzoxim	1.5 L

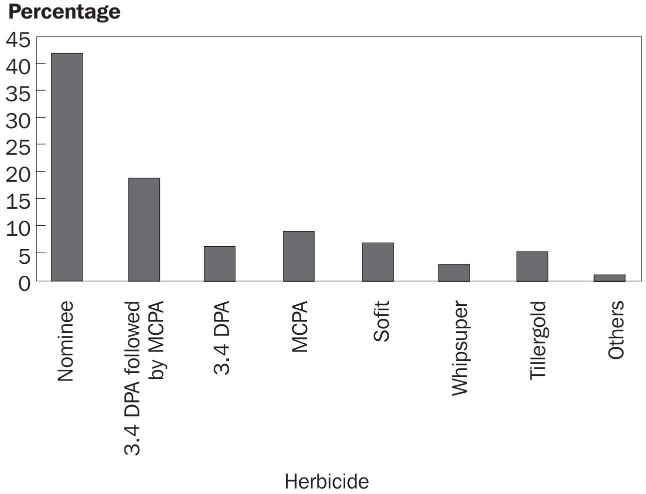

Fig. 7. Herbicides commonly used by farmers in the survey area.

Table 9. Average yield (t ha^{-1}) obtained from the demonstration plots using different rice seed establishment methods in the different rice agroecological zones.

Establishment method	Dry zone		Wet zone		Intermediate zone		
	Major	Minor	Minor	Rainfed	Major	Minor	Rainfed
Row-seeded + weeder + herbicide	6.4	5.9	3.9	4.1	5.8	4.6	3.8
Row-seeded + herbicide	6.0	4.8	4.2	3.6	6.1	5.3	4.1
Water seeding + herbicide	4.6	4.0	3.6	3.0	4.8	5.0	3.0
Manually broadcast-seeded + herbicide	4.0	3.8	3.4	2.8	4.2	5.0	3.2

Grain yield was significantly greater (5.7 t ha^{-1}) in row-seeded plots than in water-seeded and broadcast-seeded plots. Row seeding with effective weed management was found to be the best establishment method to obtain higher yield compared with water seeding and standard broadcast-seeding methods. Water seeding was, however, the best method in waterlogged situations.

More than 70% of the farmers and extension officers who were involved in the farmer demonstration trials accepted row-seeding establishment with the use of a drum seeder as an alternative to random manual broadcast seeding for DSR in Sri Lanka. They opined that it appeared convenient, potentially reduced seed paddy requirement, facilitated weed control, and increased grain yield.

Scaling out and scaling up of better weed management practices

Twelve demonstration trials involving extension staff (>10), community leaders (>15), and progressive farmers (>6) were established in strategic rice areas across the three agroecological zones. Field days were conducted before the harvest season to highlight the results of the demonstration trials. Each field day was attended by village-level extension workers (>20), farmers (>25), and private-sector seed growers (>6). The success of this promotion led a private company to collaborate with one local manufacturer in the production of a drum seeder.

National awareness was established with more than 20 training sessions conducted with senior extension managers and, in turn, this information was relayed to district extension staff and also divisional-level extension staff. More field demonstrations, six row seedings and six water seedings, were conducted at different locations. Ongoing technology transfer (TT) activities also followed to disseminate the proven technologies to a larger number of farmers in other rice areas. Farmer leaders who previously participated in the field demonstrations encouraged other farmer organizations to provide drum seeders for their farmers. The drum seeder was considered as a common asset of farmers in the organization. Interested farmers can freely use the drum seeder and this paved the way for sustainable dissemination of this technology.

To strengthen dissemination of this technology across the island, and to introduce the technology to new areas, newly produced training manuals, videos, and PowerPoint presentations were used. Follow-up training was conducted together with the in-service training staff and training of trainers for the scaling out and scaling up of the activities to extend the developed weed management options to other communities. These trainers in turn trained farmers in these communities on direct seeding and integrated weed management.

Lessons learned

Having adopted direct seeding of rice in place of transplanting, weeds have become a major constraint faced by farmers irrespective of the agroecological zone. Farmers' field trials demonstrated the benefits of integrating herbicide with mechanical and cultural weed management. Preventive control measures demonstrated included the use of clean rice seed, cleaning of drainage channels, proper land preparation, water management, nutrient management, effective crop establishment method (transplanting, parachute method, seeder/weeder, water seeding), and correct application of suitable herbicides. Row seeding followed by rotary weeding and herbicide application was found to be an effective cultural package in DSR.

During the study period, farmers shared their ideas and views with research and extension staff. A commonly held view among the farmers was that herbicides would be a preferred way to eradicate weeds rather than relying on integrated measures that also use cultural management practices to reduce crop yield losses. It appeared that farmers lacked adequate sources of information and had poor information on which to base decisions on weed control and herbicide use. Research efforts were therefore required to focus on identifying gaps in farmers' knowledge, attitude, and information needs to improve decision making. Options that include integrated weed management, row seeding with a drum seeder, and weed control using herbicide and a mechanical weeder appear to provide good alternatives to farmers. Such packages could be included in community-based training and farmer field schools. Demonstration trials involving extension staff, community leaders, and farmers were established in strategic rice areas across the three agroecological zones and appeared to be an effective means for creating awareness as to opportunities for improving crop establishment and weed control. Field days prior to harvest served to highlight results. Further, it was envisaged that public-private collaboration could provide an opportunity to extend stakeholder partnerships. Learning about farmers' practices combined with the identification of problems and demonstrating solutions appeared to be an approach that would help provide farmers with more information, help change attitudes, and hopefully lead to better management practices, improved crop yields, and reduced losses to weeds.

References

Abeysekera ASK, Sirisena DN. 2001. Effect of green manure as nitrogen source on weed control in rice fields in Sri Lanka. Proceedings of the Asian Agriculture Congress, 24-27 April 2001, Manila, Philippines. p 201-206.

Abeysekera ASK, Bandara WMJ, Wickrame UB. 2001. Effect of continuous applications of glyphosate and paraquat on weed control efficacy, phytotoxicity and yield of wet seeded rice. Proceedings of the 18th Asian Pacific Weed Science Society Conference, Beijing, China, 28 May-2 June 2001. p 233-238.

Department of Census and Statistics, Sri Lanka. 2007. Paddy statistics of Sri Lanka. Department of Census and Statistics, Sri Lanka.

Dhanapala MP, Claridge MF. 1990. Resistance of rice to leaf folder in Sri Lanka. Trop. Agric. 146:13-20.

Herath Banda RM, Dhanapala MP, Silva GAC, Hossain M. 1998. Constraints to increased rice production in Sri Lanka. In: Proceedings of the workshop on prioritization of rice research. International Rice Research Institute, Los Baños, Philippines.

Perera BMK 1993. New herbicides for effective control of grass weeds in direct-seeded rice. Krushi 93:109-132.

Ranasinghe LL. 2003. Evaluation of factors responsible for low efficacy of farmers' weed management practices in the rice cultivation. Ann. Sri Lanka Dep. Agric. 5:199-205.

Registrar of Pesticides. 2007. Pesticide recommendations, 2007. Department of Agriculture, Sri Lanka. p 12-20.

Notes

Authors' addresses: A.S.K. Abeysekera, H.M.S. Herath, and U.B. Wickrame, Rice Research and Development Institute, Batalagoda, Ibbagamuwa, Sri Lanka; D.E. Johnson, International Rice Research Institute, Los Baños, Laguna 4031, Philippines; email: anuru@sltnet.lk.

Rice drying systems: from development to commercialization in southern Vietnam

Phan-Hieu Hien

An overview of research and extension on rice drying in southern Vietnam over the past 25 years is provided, with a focus on the contributions of Nong-Lam University, Ho Chi Minh City. The greatest success has been the evolution of flat-bed dryers; different generations of dryers evolved from the effective exchange of information and improvements between researchers and local dryer users. The latest developments (2006-08) on the rice husk automatic furnace and solar-assisted furnace for the dryer are discussed. Other types of dryers and reasons for their lower adoption are presented. Factors leading to the special commercialization of the flat-bed dryer in the context of southern Vietnam are analyzed, which include assessment of needs, the development of appropriate technology, extension initiatives, and linkages to credit and policy development.

Keywords: Dryer, flat-bed, Vietnam, furnace, commercialization

Two research units of Nong-Lam University (NLU, formerly University of Agriculture and Forestry), Ho Chi Minh City, have been involved in the development of technologies for more efficient postharvest management of rice. The first unit is the Faculty of Agricultural Engineering and Technology (FAET), which, in 1981, started activities related to research and extension of postharvest technologies, particularly the development of drying machinery. The basic principle underpinning this research and development focus has been that the research should serve the production sector, including farmers and processors. The second unit is the Center for Agricultural Energy and Machinery (CAEM), which was established in January 2001, with the mandate of research and development to serve agricultural production in three areas: (1) energy in agriculture, with a focus on renewable energy; (2) agricultural machinery for field and farmstead production; and (3) agricultural and food processing machinery. The Center continues the FAET tradition of serving the production sector, with funding and staff time mainly committed for research and extension activities.

Since 1981, research at FAET and CAEM on drying of rice has been diversified with different drying principles, capacities, and investments, which involved thousands of farmer-users, and several in-country and overseas sponsors. This paper focuses on the interaction between NLU drying research and the development of extension of the flat-bed dryer for rice in the Mekong Delta of Vietnam. The flat-bed dryer technology is chosen because it is a good example of successful adoption by end users following effective collaboration between research and production. It also describes the collaborative links with the Irrigated Rice Research Consortium (IRRC) from 2004 to 2008 with cross-country impacts.

Development of rice dryers in the Mekong Delta

In 2004-07, the Mekong Delta in southern Vietnam, with 2 million hectares of rice land, produced annually 18.2–19.2 million tons of paddy, or about 50% of Vietnam's total rice output. With 17.5 million people (2007) or about 20% of the total population, this region accounts for more than 90% of rice exports in the past decade (GSO 2008). The mean farm size is about 1 ha per household, although in some newly reclaimed districts, 3–10 ha per household is not uncommon.

In the early 1980s, rice drying became an issue in the Mekong Delta when a second crop was promoted and the harvest fell into the rainy season. Different dryer models were tried by various agencies, including tower dryers; only one model was accepted by the production sector, namely, the flat-bed dryer (FBD) (Table 1). The first FBD was installed in Soc-Trang Province in 1982 by NLU. Farmers in adjacent areas modified this FBD using cheap local materials. In 1990, there were about 300

Table 1. Number of flat-bed dryers in selected provinces of the Mekong Delta, Vietnam.

Province	1982	1986	1996	2002	2006
Flat-bed dryers					
Kien Giang		?	350	760	1,100
Soc-Trang	2	30	250[a]	500	700
Can-Tho (and Hau Giang)[b]		?	250	600	700
An Giang		1	100	490	1,400
Long An		2	30	180	400
Other provinces		5	420	470	1,900
Total	2?	38	1,400	3,000	6,200
Tower (columnar) dryer					
	1?		10–15, no operation or inefficient operation	10?	3–5 in operation
% mechanically dried wet-season harvest	<1	9	15	33	

[a] Phu Tam Commune (2,400 ha): 47 dryers in 1993. [b] In 2003, Can-Tho was split into Can-Tho City and Hau Hiang Province.
Source: Compiled from Danida Reports and interviews by author.

FBD units in the Mekong Delta, half of which were in Soc-Trang. Thereafter, other provinces began to increase their adoption of these dryers (Hien et al 1995).

In 1997, a survey indicated that there were 1,500 FBD in the Mekong Delta, with three provinces (Kien Giang, Soc-Trang, Can-Tho) accounting for 850 units (Table 1); all remaining 10 provinces shared the balance (DARD Can-Tho and Soc-Trang 1998).

The DANIDA-assisted project in Can-Tho and Soc-Trang doubled the FBD in each province from about 250 to 500 units in two years (1998-99), through a credit scheme and extension activities. The project terminated in 2001, and was replaced by a program managed by the Ministry of Agriculture, but still assisted by DANIDA, with only extension activities. The program terminated in mid-2007. The number of FBD dryers rose rapidly, from about 3,000 units in 2002 to 6,200 in 2006 (Table 1) (MARD 2004, Hien et al 2009). The dryers in the Mekong Delta account for more than 90% of all dryers in Vietnam.

Descriptions of dryers and their development

The technical development of the FBD over the past 25 years followed an interesting pattern. First, a design was released by a research institution, NLU in this case. Next, farmers or mechanics copied or modified the design. NLU monitored those modifications and came up with a major design change and improvement. The cycle was then repeated.

The following sections describe the evolution of dryer development with the timeline for the releases of the major design by NLU as well as major modifications and improvements by farmers and mechanics.

1982: conventional FBD

This is the dryer described in leaflets from Japan, the Philippines, and other countries (Yamanaka 1961). It is a technology that probably existed in the 1950s in the United States and Japan. In the 1970s, two detailed designs were released by the University of the Philippines Los Baños (1.8 t per batch) and the International Rice Research Institute (IRRI) (1 and 2 t per batch) in the Philippines. In 1982, these designs were scaled up by NLU (Hien 1993). The first 8 t per batch FBD was installed in Ke-Sach District, Soc-Trang Province, in 1983. Afterward, some 10 units (of 2, 3, 4, 6, and 8 t per batch, called the SHT-series) were installed in six other provinces. The dryer includes a box-shaped drying chamber with central air inlet to the plenum chamber, an axial fan, and a horizontal-grate box-type furnace burning wood wastes or rice husks (Fig. 1).

These dryers were designed for a grain thickness of 45–50 cm and an initial moisture content (MC) of 22–24%. In practice, the wet-season crop was harvested at a much higher MC of 25–36%. The result was a nonuniform final MC; the moisture differential might be as high as 4–7% despite one mixing during drying. Also, the rice husk furnace using a horizontal grate was complicated in fabrication and operation. Despite these drawbacks, these dryers persuaded farmers to realize that “it is possible

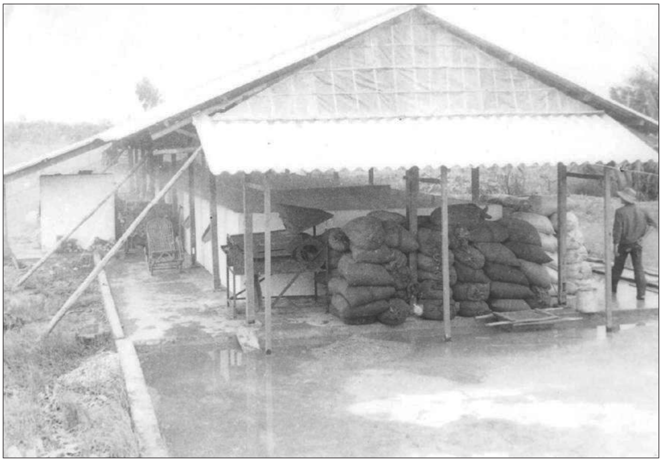

Fig. 1. The SHT-10 dryer at the Ke Sach Seed Station, 1983.

to dry mechanically." In fact, clients (from the Mekong Delta or the southeastern provinces) had come to the researchers after suffering heavy postharvest losses ranging from 20% to 60% of their crop.

1987: rice husk furnace with inclined grate

Farmers and mechanics in Ke-Sach and My-Tu (Soc-Trang Province) began to copy the models and gradually improved them. Phu-Tam Village had about 30 dryers in 1991, which dried its entire 2,400-ha wet-season crop. At that time, there were 150–200 dryers in the entire Mekong Delta. The endeavor and contribution of these mechanics was highly appreciated, worthwhile of the name "Phu-Tam dryer" or "Soc-Trang dryer" (Fig. 2). Modifications and improvements included

- A reduction in grain bed thickness down to 20 cm to fit with very high MC (with a trade-off cost of a larger floor area and more land for other use).
- A rice husk furnace with inclined grate (an idea originated from the rice husk stove), which was logical in design and convenient in operation.
- The use of low-cost local materials (cajuput tree, muddy soil, etc.) in order to lower the investment.

In 1995, about 300 units were installed in Soc-Trang Province (out of an estimated total of 600 units for the entire country). The area of rice sown for the wet-season crop in this province increased dramatically from 60,000 ha in 1992 to 110,000 ha in 1995 (Tran-Van-Hao, personal communication, 1995). The main factors contributing to this increase were better irrigation, better suited rice varieties, and mechanical drying.

A typical 4 t per batch dryer (reducing moisture content from 24–27% to 15% in 6–8 hours) required an investment of about US$1,600. This did not include the 12-HP diesel engine (costing $400), which is usually "borrowed" from other equipment (thresher, pump, or hand tractor) for use during 1 month of drying. The drying cost

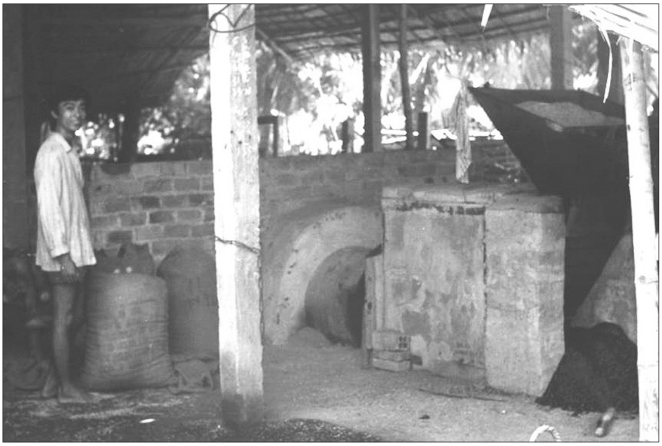

Fig. 2. Conventional FBD with central air inlet to the plenum chamber.

was about 3% of the value of the paddy, whereas the dryer owner charged a drying fee of 5%. Within each day, they operated the dryer for 20–24 hours. Assuming a 6–8-h drying time, they dried three batches per day, resulting in 12 t of daily capacity. If they had 40 days' operation per year, then the payback period for investment was only 1 year.

1994: conventional FBD with side-duct plenum

After 1993, research on the flat-bed dryer at NLU resumed; the focus was on improving the quality of dried rice. Quality issues emerged with the rapid spreading of the "Phu-Tam" dryer in the Mekong Delta since the early 1990s. Vietnamese rice exports were increasing, and importers required rice with less broken grain, uniform moisture content, and free of residues from the furnace. The drawback of "home-made, trial-and-error" dryers made by local mechanics was insufficient air pressure to overcome a paddy layer of 30 cm for more uniform air distribution; usually, these dryers operated with a layer of only 15–20 cm. Thus, although farmers continued to build more dryers, there were increasing concerns about the quality of the rice.

Results from basic experiments and pilot application by NLU led to several models with capacities ranging from 1 to 12 t per 8-hour batch (called the SHG-series). Most popular were the SHG-4 (4 t per batch; investment: $2,000) and SHG-8 dryers (8 t per batch; investment: $3,000) for grains and seeds (Fig. 3). These dryers included the following new features:

- A new rice husk furnace (Xuan et al 1995) with a patented vortex and central-pipe precipitation chamber, which resulted in complete combustion of rice husk, soot-free grain, and good fly ash separation (the fly ash is separated from the flue gas and falls back into the burning chamber) compared with box-type furnaces (Fig. 4).

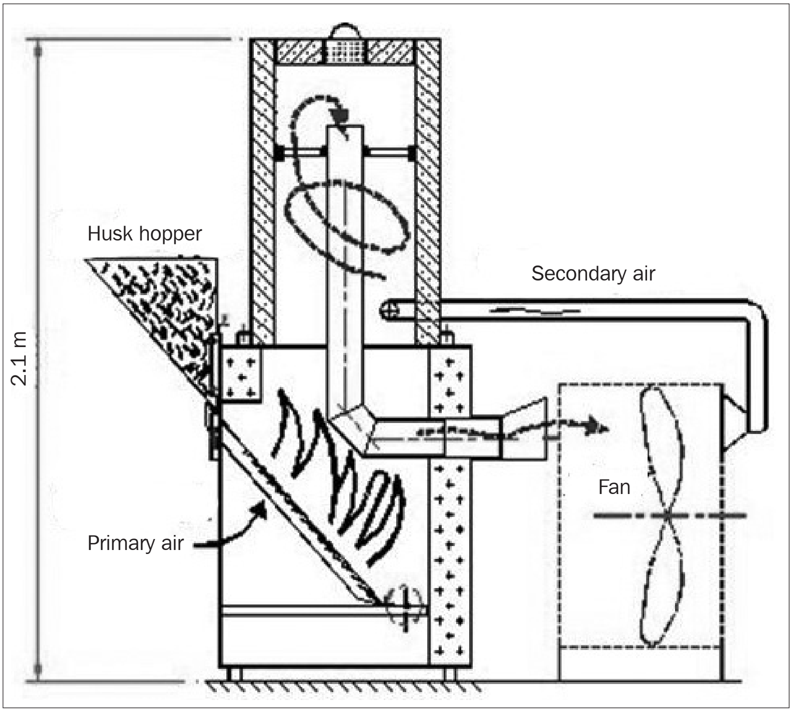

Fig. 3. SHG-8 dryer, developed in 1996; over 600 units in 2000 were in the Mekong Delta.

Fig. 4. Rice husk furnace with vortex and central-pipe ash-precipitation chamber.

- An axial-flow fan with correct air-flow and pressure for the drying requirements, which had high efficiency compared with other locally made fans.
- A new "side-duct" drying bin (Fig. 3) that held 4 t (or 8 t) of paddy. Tests with this new bin in 1994 showed that exit air velocity on the grain surface was acceptably uniform, resulting in the final grain moisture differential of less than 1.8% between any two points on the bin. This differential was from 2.5% to 5% in the "classical" SHT-series, where air enters at one end of the plenum chamber.

Roll-out and extension activities to promote these dryers

About 70 units were installed directly by FAET staff throughout the country, from the northernmost province of Ha-Giang to the southernmost province of Ca-Mau. Another 600 units were installed by transfer of the technology to 10 agencies, among which 500 units were installed in Can-Tho and Soc-Trang provinces. The design and fabrication of the fan—the heart of the dryer system—were also transferred to 15 manufacturers in the Mekong Delta. The technology was transferred to all agencies *without royalties* in order to reduce investment for farmers. One manufacturer in An-Giang fabricated more than 400 fans for SHG-dryers.

2001: reversible FBD

The SHG-4 and SHG-8 dryers were widely accepted because of their high capacity, good grain quality (including seed), low drying cost, and ease to install and operate.

A new series of flat-bed dryers was designed and successfully applied to meet the new demands of lowering the labor cost in mixing the grain, reducing the land space taken up by dryers, and drying high-moisture crops such as coffee, and sliced cassava (Hien et al 2003). These reversible-air dryers (with capacity of 1 to 12 t per batch) were named SRAs. For example, SRA-10 means a dryer with reversible air and a capacity of 10 t per batch.

The principle, construction, and operation of the RA dryers are similar to those of the current SHG-4 dryer; the only difference lies in the reversibility of the drying air (Fig. 5).

The comparative advantages of the new SRA dryers are

- No manual mixing and turning of the rice, yet the final moisture content is uniform.
- Saving of land space; 50% less than that of the conventional flat-bed dryer.
- Multicrop use, including high-moisture products such as coffee, sliced cassava, shrimp heads, and longan.

During 2000-05, about 40 SRA units (with capacities from 2 to 12 t per batch) were installed in several provinces; some have dried more than 3,000 t of paddy, maize, and coffee.

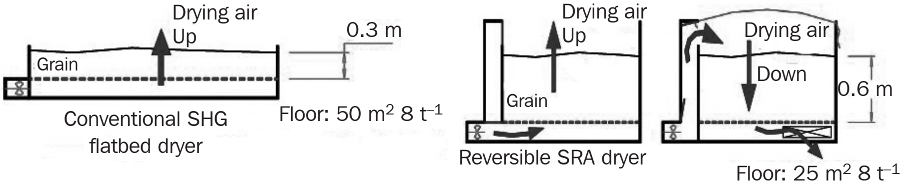

Fig. 5. Principles of action of the conventional and reversible SRA dryer. Note also the reduction in floor space required for the reversible SRA dryer.

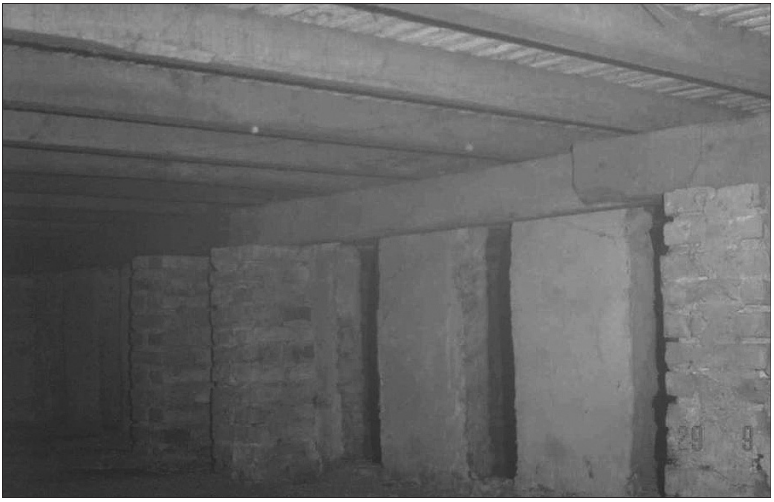

Fig. 6. The under-plenum duct inside the drying bin of an 8 t dryer ("Ong gio chim" in Vietnamese).

2004: drying bin for reversible dryer, with distributed under-plenum duct

Local manufacturers in the Mekong Delta increased the number of reversible-air dryers to about 500 units by 2008. Provinces where there was rapid development of dryers, such as An-Giang and Tien-Giang, had particularly effective manufacturers providing both a reliable product and "instant" after-sale service to farmers.

The drying bin for the reversible dryer with a distributed under-plenum duct inside the drying bin provided improved moisture uniformity with less land space for the bin (Fig. 6). There are two versions: the fixed concrete bin and the collapsible metallic bin for easy transport and fast installation.

2006: automatic rice husk furnace (model NLU-IRRI-Hohenheim)

Rice husk furnaces have significantly reduced drying costs because they are powered by an abundant low-cost by-product of the rice milling process. Rice husks provide challenges for the design of an efficient furnace because the husks are of low density, have a high percentage of volatile matter, and have high ash volume. Most rice husk

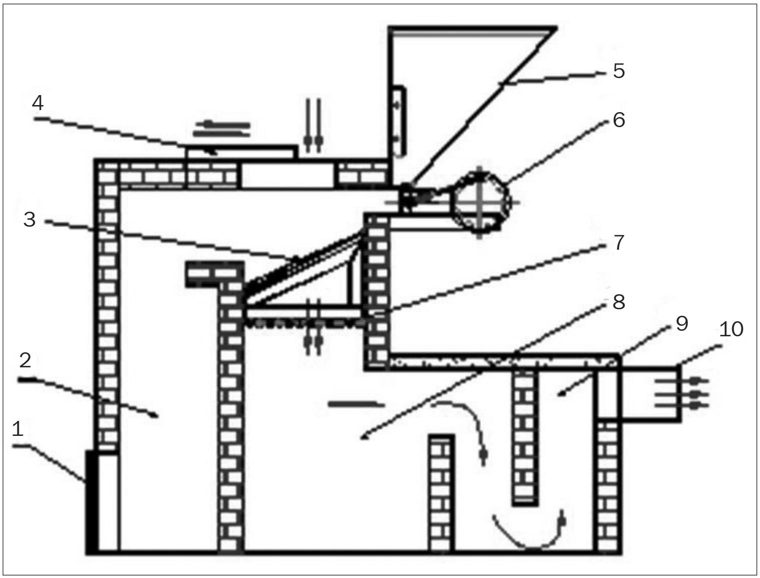

Fig. 7. Schematic of the semiautomatic rice husk furnace. (1) Ash removal port, (2) ash chamber, (3) grate, (4) air control slide, (5) husk hopper, (6) automatic rice husk feeder, (7) secondary air pipe, (8) combustion chamber, (9) ash precipitation chamber, (10) flue gas outlet (to the fan).

furnaces used in the Mekong Delta are the NLU design with a cylindrical combustion chamber, good combustion, and good removal of sparks and ash particles. However, this type of furnace requires laborious efforts to rake ashes every 5 minutes to ensure good feeding and stable combustion.

In 1996, a rice husk furnace of 5-kg-per-hour capacity, developed by Hohenheim University, Germany, in collaboration with IRRI in the 1990s, was built and tested at NLU. These tests showed the advantage of the principle of inverted-draft combustion, with the automatic feeding of rice husks. However, the furnace capacity was too small for practical applications with flat-bed dryers that have a capacity of 4 to 10 t per batch, requiring 25 to 60 kg h^{-1} of rice husks. NLU improved the feeding mode of the rice husk furnace through a semiautomatic feeding mechanism, by up-scaling the inverted-draft furnace (Figs. 7 and 8).

Rice husks are fed on the grate surface by the automatic husk feeder. The suction from the fan provides primary air, which flows downward through the husk layer to the combustion chamber. The fan suction also provides secondary air through holes for more complete combustion. The flue gases flow through the ash precipitation chamber, and cleaned gases flow to the outlet and are sucked in by the dryer fan and blown into the drying chamber.

The special feature of this furnace is the husk automatic feeder; a piston pushes the husk for a set time (in seconds), stops for a set time, and then the process is re-

Fig. 8. The automatic rice husk furnace for the SRA-4 reversible flat-bed dryer.

peated. The time settings are controlled by a low-cost microprocessor board, which was designed at NLU using electronic components available at local markets, thus being low-cost. The drying air temperature was stable within ± 1 °C. The feeding action of the piston also pushes the caked burned rice husk out, so the operator can fill the hopper with husks and dump the ash box every hour, thus significantly reducing the labor requirements. Also, the flue gases were clean, without ash particles or sparks.

In 2005 and 2006, three furnaces were promoted to three farmer cooperatives in Lam-Dong Province and Long-An Province, matched with a 4-t air-reversible flat-bed dryer. In 2008, two scaled-up furnaces were installed in Tien-Giang and An-Giang provinces. They burned 50 kg h^{-1} of rice husks and powered an 8-t reversible dryer. In 2008, each dried 100–200 tons of paddy rice.

The furnace construction cost is only 30% higher than that of current rice husk furnaces with similar capacity and combustion quality. We expect that this furnace will be accepted by users, considering the labor savings during its operation and the good combustion quality and drying efficiency.

Further research is being conducted to extend this type of furnace to bigger dryers and to brick kilns, and to optimize furnace operation.

2007: solar collector for flat-bed dryer

In 2006, to provide an alternative to the rice husk furnace, we adapted a new type of solar collector that had been developed at NLU and pioneered a 4-t collapsible dryer (Fig. 9), which consists of the following components (Hien et al 2009):

1. A two-stage axial fan, driven by a 15-HP Chinese diesel engine. With the fan test duct, the airflow is 4.6 m^3 s^{-1} at 50-mm static pressure, consuming 5.5 kW of electric power.

Fig. 9. The SDG-4 dryer using solar heat; a top cover is used for downward airflow.

2. A coal furnace as a backup in case solar radiation is insufficient, with coal consumption adjustable within 5 to 12 kg h^{-1}.
3. A drying bin, with grain floor size of 4.50 m × 3.27 m, made from bamboo slats and nylon net, supported by seven metal legs. Thus, it can be easily installed on rough land. The airflow can be switched from upward to downward with a covering tarpaulin.
4. A solar collector, consisting of two cylindrical tubes made from plastic film. Each cylinder is 27 m long. Inside a transparent plastic layer is a black plastic layer for absorbing heat. The two cylinders converge into a transition box, which also receives heat from the coal furnace.

The solar collector and coal furnace could be used separately or in combination.

Five drying batches were tested in March 2007: with coal only, with solar energy only, and with combined heat from both coal and solar energy. The capacity was 3.8–4.1 t per batch for 7–12 hours. The drying temperature was in the range of 38–44 °C using coal, and 38 °C with good sunshine or 36 °C in cloudy weather using solar heat. The head rice recovery with solar energy was comparable to, or even slightly better than, “shade” drying, possibly due to slightly lower drying temperature.

Solar energy contributed to a coal savings of 43–78% or \$3–5 per batch (\$0.70–1.30 per ton). If we assume that, in one year, the dryer is used for 100 batches or 400 tons, of which half use solar energy and half use supplementary solar energy with 50% savings, then the total savings is \$480 per year. The initial investment for the

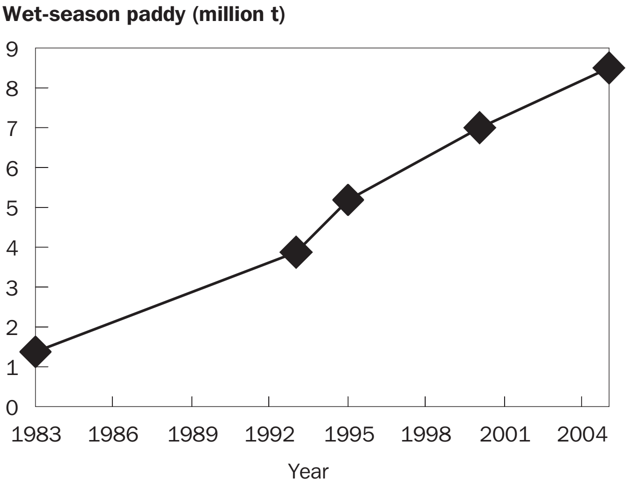

Fig. 10. Paddy harvested in the wet season in the Mekong Delta of Vietnam.

solar collector was $560 and the plastic sheet costs about $120 after every 7 months. Therefore, the payback period is about 2 years.

Thus, for the first time in Vietnam, solar energy has been used to dry paddy on a production scale with acceptable time and cost; more importantly, solar energy is clean for the environment and is a renewable energy resource.

Factors affecting dryer development in the Mekong Delta

Looking back at dryer development in the Mekong Delta over the past 25 years, we have grown from a few dryers to more than 6,000 flat-bed dryers in use. This section reviews some of the factors that have influenced adoption and diffusion of the technology.

Factor 1: the need

Paddy harvested in the wet season of the Mekong Delta increased sixfold within 22 years (Fig. 10). It is consistently about 80% of the wet-season harvest of all Vietnam, and is 40–45% of the annual paddy production of the Mekong Delta; this total was 12.9 million t in 1995 and 19.4 million t in 2005. Probably nowhere else in the world is there so much paddy at 25–35% moisture content. Thus, the need for drying is more urgent than elsewhere.

Factor 2: development of appropriate technology

The drying equipment and technology need to meet minimum requirements of sufficient capacity, quality, and cost effectiveness, whether the grain is used for milling or for seed, or whether the season is wet or dry (Hien 2000). An important measure of performance is whether, after one batch of rice is dried, farmers will commit to further drying in the next season. On the other hand, if just one batch of paddy produces a high number of broken rice, rice blackened with ashes, or lost germination capacity, then word-of-mouth could affect the future behavior of many farmers.

Ideally, an efficient dryer should generate benefits for all: lower costs for farmers and increased profit for the investor (owner) in the dryer.

At each point in time, the progression in the technology needs to meet the requirements of the end-users. Moreover, the design should be simple and suitable for fabrication by local manufacturers. Two dryers that clearly met these criteria during 1995-2005 were the SHG-4 and SHG-8 models. After 2004, the SRA-8 dryer was also successful based on these criteria.

The test fan duct at NLU is an illustration of these basic criteria. In parallel at the manufacturers' or farmers' level, a simple rotameter measures the exit velocity from the drying bin surface, leading to calculation of the rate of airflow. This provides a quantitative method for users to evaluate a key parameter of the drying process. In short, the technology is dynamic, with constant monitoring whether at the university or at the user's site.

The mechanical rice dryers in the Mekong Delta followed the mechanization philosophy of this region during the last 25 years: a not-so-small machine for small farmers. Small poor farmers with 1 ha cannot afford equipment to operate economically just for their own farm. If they buy a bigger machine and do contracting work for 100 other farmers, then they enjoy the profits developed through economy of scale. This is reflected in the progression from 2–4-t capacity in 1990-95 to 8–20-t capacity in recent years.

Factor 3: effective extension

This is the most important factor for timely adoption and diffusion of the technology. For effective promotion of mechanical dryers, extension workers need to promote dryers to farmers *before* installation, advise farmers on technical matters *during* installation, and guide dryer operation and maintenance *after* installation.

The role of the extension worker is integral and follows the model of *marketing + installation + after-sales service* for industrial goods in the city. An incentive system for extension workers based on the number of dryers successfully commissioned could help with the promotion of dryers.

Persuading farmers to invest in a dryer has not been a simple task. Questions often raised by farmers were, "*Assume we can dry for only 4–5 weeks per year, then the dryer is idle for almost 11 months; How could we generate sufficient profit given our level of investment?*" Answering this question requires extension workers to understand the drying process, to have experience in installing dryers, and to have confidence in practical operation of the dryers.

In short, the role of extension specialists for promoting dryer technology is not much different from extension of agronomic practices. They need to ensure that *farmers understand, farmers believe, and farmers act*. The difference lies in the purchase value of a $2,000–7,000 dryer, which is two orders of magnitude higher than the purchasing of seeds or insecticides. This leads to the fourth factor, which is adequate financial support.

Factor 4: credit as financial support

In 1997-99, dryer promotion in Can-Tho and Soc-Trang was favorable because of a large credit scheme of $1.2 million from Danida for establishing 600 dryers (of 4-t capacity) in each province as a revolving fund. The Provincial Bank for Agriculture managed this money through a thorough evaluation of applicants, and closely monitored loan release and payback. Features of this soft loan were a reduction in level of collateral (for example, a loan of $3,000 for the 8-t dryer needs just 1 ha of collateral, instead of 5 ha as normally applied); a low interest rate, which was 0.8% per month in 1998, or equal to the rate for the poor, and lower than commercial interest rates; and a long refunding period of 2–3 years.

From 2000 to 2009, several provinces adopted similar credit schemes to promote mechanical rice dryers; all were supported by the provincial budget. The terms were strict, for example, the farmer-investor should advance 30% of the value of the dryer. An-Giang Province had the most success with its progressive credit scheme. This province jumped from the bottom group of provinces in 1997 in terms of mechanical drying to a number-one ranking in 2009.

In essence, access to credit provides encouragement for farmers to adopt and invest in a new postharvest technology. It provides the necessary impetus for farmers to take the next step after extension specialists have demonstrated the effectiveness of the technology.

Factor 5: policy and management

This is an all-embracing factor. The previous factors become operational only if there is an appropriate policy landscape and good governance. The policy needs to be unanimously adopted and implemented among central, provincial, and local governments, and related institutions of agriculture, science, extension, and finance. A robust policy environment provides the necessary conditions for positive investment decisions by the end-users of the technology. A province with a production of 500,000 tons of wet paddy could lose $5 million if we assume a 10% postharvest loss. A positive policy environment can avoid the wait for opportunities for outside funding and losing $5 million per year while waiting.

Promoting flat-bed dryers in Asia

The flat-bed dryer technology began in the Philippines and elsewhere, and then rapidly evolved in Vietnam over 25 years. From Vietnam, the technology has been subsequently extended to several other countries in Asia. Examples of this transnational extension are outlined below.

1994: Philippines

In 1994, the SHT-4 and SHG-4 dryers were transferred to PhilRice (Philippine Rice Research Institute). Up to 2004, about 300 units had been installed in the Philippines (personal information from Dr. E. Bautista).

2002: Bangladesh

The SHG-4 flat-bed dryer was introduced and adopted in northwest Bangladesh in four steps. First, we made a short trip to identify the most appropriate design under the given conditions, and helped develop a program for the manufacture, operation, and technical training required for the flat-bed dryers. Next, from Bangladesh, three engineers and mechanics came to NLU for a 10-day hands-on training on the construction and operation of the 4-t flat-bed SHG-4 and the low-cost STR-1 dryers, and on the fabrication and installation of dryer components, including fan testing and furnace building.

Next, after returning to their home agencies in Bangladesh, the trainees instructed and supervised the fabrication and installation of dryers at Rangpur. Finally, when this fabrication and installation were finished and the harvest was ready, two NLU staff traveled to Rangpur to check the installation, conduct a trial run, make adjustments, and train the operators.

Subsequent reports from Bangladesh confirmed that further SHG-4 dryers were built, with good results in drying parboiled paddy.

2005: Laos, Cambodia, and Myanmar

A similar pattern of extension was followed in Laos, Cambodia, and Myanmar. An 11-day training workshop on "*Drying Systems and Dryer Fabrication*" was organized at NLU for seven participants from Laos, Cambodia, and Myanmar in October 2005, sponsored by the IRRC. The objective was to provide the participants with enough understanding and skills to build an SHG-4 flat-bed dryer or a low-cost STR-1 dryer in their own country, if either or both fitted their local needs.

The training included a mixture of theory (2 days), hands-on practice (shop work and laboratory work, 7 days), and field visits (2 days). Participants saw the dryer in operation, and visited different dryer types with different capacities (the largest was a 200-t dryer at Southern Seed Company near Ho Chi Minh City), a dryer manufacturer, and an export-oriented rice mill.

By April 2008, three flat-bed dryers in Laos, two in Cambodia, and 37 in Myanmar were the initial outcome from this training. Myanmar developed an active commercialization process similar to that in Vietnam, that is, the dryer was promoted through acceptance by users for their business (see Kyaw and Gummert, this volume).

Commercialization of the flat-bed dryer: lessons learned

Commercialization settings

The budget for the in-country extension of flat-bed dryers was consistently provided by client-farmers or client-agencies under the format of a purchase contract. For a new design, we at NLU usually fabricated and sold at least five units; we acted like a business for profit in the eyes of our clients. However, the real purpose was to assure clients of a guaranteed product because they had little confidence in investing in "first-release" equipment. After the production of these first units, we transferred the design to local manufacturers without royalties, but with a strict procedure to ensure that they followed the design in their first fabrication batch of 5–10 units. After that batch, they were free to modify the design. Using local materials for the drying bin and cheap local labor, their selling price was usually 15–35% cheaper than our NLU quotation. So, NLU lost the market in that province! After several transfers, we lost the market for the whole region. Still, with some scattered contracts, we had to think of some new or "breakthrough" designs. And, the cycle was repeated with the SHT-, SHG-, and SRA-series dryers that we called internally F1-series dryers; we just released the promotional units or prototype units to users.

Research funds

Research funds to constantly improve the dryer came primarily from a small percentage of the profit derived from dryer sales. This small amount of money allowed only incremental "evolutionary" design improvements; if an error was committed in developing the modified design, we could step back to the old design without much expense. Still, over several years, these improvements accumulated into new reliable designs. All the SHT-, SHG-, and SRA-series followed this pattern.

On the other hand, the major "breakthrough" designs came from government or donor funding, which in the context of the amount of subsequent promotion and adoption can be rated as a small amount of investment. Three examples can be illustrated:

1. The SHG-4 dryer stemmed from an IDRC-funded postharvest project in 1994. With $5,000 (equivalent to two 4-t dryers) and an initial objective of surveying the status of drying of rice in the Mekong Delta, we managed to start with the first unit of that improved dryer. The project terminated in 1995, and the new dryer relied on clients to develop it into the SHG-series by 1998. In 2002, there were about 1,500 dryers of that series in the Mekong Delta.
2. The SRA-8 dryer stemmed from a research project funded by the Vietnamese Ministry of Science and Technology in 2001. The budget of $15,000 had been initially intended for developing dryers at a higher level (less laborious, higher grain quality) than the then-conventional flat-bed dryer. Two different designs were tested, one of which was the reversible dryer with 1,500-kg-per-batch capacity (SRA-1.5). This capacity was successfully reached in mid-2003. Data on the pilot dryer gave us enough confidence to persuade users to invest in the

$7,000 8-ton dryer SRA-8 in the following years. Without such basic data, the SRA-series (3, 4, 6, 8, 10, 15 t per batch) could not have been developed by 2006. In 2008, about 500 SRA-series dryers were in use in the Mekong Delta and other parts of Vietnam.

3. The NLU-IRRI-Hohenheim automatic rice husk furnace began as a graduate research project. From 1996 to 2000 in Vietnam, one German student (diploma in engineering) and two Vietnamese students (B.Sc.) provided academic data that supported the potential advantages of the furnace. In 2004, things changed rapidly with an IRRC-funded postharvest project for NLU. The $20,000 budget over 4 years covered several activities, including hermetic storage, market surveys, laser leveling of rice fields, and a study on rice milling. Around $4,000 was allocated for developing the new automatic rice husk furnace. In 2006-07, the new furnaces provided testing sites for replicated measurements. Without such additional data and refinements on the furnace design, we could not have persuaded the next three users in 2008, who accepted to pay more for the furnace.

Concluding remarks

Dryers of paddy in the Mekong Delta of Vietnam were developed through drying research and extension activities at Nong-Lam University. The production sector is continuing to apply pressure for further technological developments. Together, the Faculty of Agricultural Engineering and Technology and the Center for Agricultural Energy and Machinery of NLU will continue to offer appropriate and effective solutions to farmers and rice processors, with support from various agencies; provincial, central, and local governments; international advanced research institutions; and farmers and processors themselves.

While serving the needs of farmers and rice processors for their profits, our researchers receive the benefit of feedback from users, so that improvements can be made to produce better quality rice at less cost. Although researchers freely share their research results with machine manufacturers, they still maintain their cutting-edge in appropriate drying equipment thanks to the research-extension cycle.

In summary, reliable designs can be developed to serve the production sector by careful blending of funds from research and extension-commercialization. Commercialization of research-based equipment by a university followed the model of a business company during the few first-released units; however, subsequent to the initial release of a new design, the university staff provide substantially more extension and transfer of technology than occurs with the private sector. Research is a main function of a university, but, in the context of a developing country like Vietnam, research should stem from the people's needs, be developed specifically for the people, and the mature technology transferred to the end-users so that finally the work is done by the people.

References

CARD (Collaboration for Agricultural and Rural Development Programme) 026/VIE-05. 2008. Evaluation of needs and development trends of post-harvest technologies in the Mekong Delta of Vietnam. Proceedings of the Seminar held at Nong-Lam University in April 2008. (In Vietnamese.)

Champ BR, Highley E, Johnson GI, editors. Drying in Asia. ACIAR Proceedings No. 71.

DARD (Department of Agriculture and Rural Development) of Can-Tho. 1998. Survey results on dryers and drying in Can-Tho Province. (In Vietnamese.)

DARD Soc-Trang. 1998. Survey results on the survey on dryers and drying in Soc-Trang Province. (In Vietnamese.)

GSO (General Statistics Office of Vietnam). 2008. Statistical data 2007. Statistics Publishing House, Ha Noi, Vietnam.

Hien PH, Vinh LQ, Thuy TTT, Tuan TV. 2009. Development of solar-assisted dryers for food and farm crops. Trans. ASABE 52(4):1255-1259.

Hien PH, Tam NH, Xuan NV. 2003. The reversible air dryer SRA: one step to increase the mechanization of post-harvest operations. Proceedings of the International Conference on Crop Harvesting and Processing, Louisville, Kentucky, 10-12 February 2003.

Hien PH. 2000. A systematic approach to promote the dryer as a major measure of quality assurance for rice grain. In: Johnson GI, To LV, Duc ND, Webb MC, editors. ACIAR Proceedings No. 100. p 264-271.

Hien PH, Tam NH, Vinh T, Loc NQ. 1995. Grain drying in Vietnam: problems and priorities. In: Champ BR, Highley E, Johnson GI, editors. Grain drying in Asia. ACIAR Proceedings No. 71. Canberra, Australia. p 57-66.

Hien PH. 1993. Using grain dryers for the summer-autumn crop in southern Vietnam. Proceedings of the 14th ASEAN Seminar on Grain Post-harvest Technology, Manila, Philippines, 5-8 November 1991. p 129-147.

MARD (Vietnamese Ministry of Agriculture-Rural Development), and Danida ASPS. 2004. Study on the current status and need assessment for post-harvest equipment in the Mekong Delta (compiled from reports and 12 provinces). Internal report (in Vietnamese).

Xuan NV, Vinh T, Anh PT, Hien PH. 1995. Development of rice husk furnaces for grain drying. In: Champ BR, Highley E, Johnson GI, editors. Grain drying in Asia. ACIAR Proceedings No. 71. Canberra, Australia. p 336-341.

Yamanaka I, editor. 1961. Grain dryer. In: Agricultural machinery and implements. Tokyo (Japan): The International Trade Service Bureau, Inc.

Notes

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Author's address: Lecturer, Faculty of Agricultural Engineering, and technology researcher, Center for Agricultural Energy and Machinery, Nong-Lam University, Ho Chi Minh City, Vietnam; email: phhien1948@yahoo.com and phhien@hcm.vnn.vn.

Facilitating dissemination of SSNM within the framework of ICM in Indonesia

D. Santoso, Z. Zaini, and A. Widjono

Increasing rice demand and fertilizer prices mean that rice farmers need to apply fertilizer more efficiently. Site-specific nutrient management (SSNM) technologies resulting from thorough national and collaborative research with the International Rice Research Institute (IRRI) can help farmers to efficiently use fertilizers in rice. The Ministry of Agriculture encourages SSNM dissemination within the framework of integrated crop management (ICM). Although conceptually and technically idealistic, SSNM use in the field has been hampered by social incompatibility, making it less extensive than initially anticipated. With the support of IRRI, the Fertilizer Working Group (FWG) was formed. It facilitated the development of a harmonized fertilizer recommendation across national institutions. Yet, activities of the group have been limited because its members have many other regular assignments, and no particular budget for the tasks. Consequently, the FWG formed the Fertilizer Technical Team (FTT) in response to the limited time and resources of its members. The FTT ensured quality and consistency in the materials and training provided by organizations within the Indonesian Agency for Agricultural Research and Development (IAARD). The FTT successfully produced dissemination materials such as brochures, manuals, and decision support software entitled *Pemupukan Padi Sawah Spesifik Lokasi (Location-Specific Rice Fertilization)*, referred to as PuPS, which were then provided to Assessment Institutes for Agricultural Technology (AIATs) for dissemination. To carry out FWG and FTT activities nationally, realistic budgets should be proposed through IAARD to the central government by the directors of the Indonesian Center for Agricultural Land Resources Research and Development (ICALRD) and the Indonesian Center for Food Crops Research and Development (ICFORD) as the co-chairmen of the group. Dissemination activities can be carried out provincially in collaboration with AIATs and by seeking budget support from local governments.

Nutrient management is dynamically adjusted to crop needs, depending on the location and season. The efficient use of N fertilizer is promoted by the use of a leaf color chart (LCC). Crop needs for P and K fertilizers are determined either by a soil test kit or nutrient omission plots. SSNM, through the use of the LCC and soil test kit or omission plots, was later incorporated and became a component of ICM approaches for rice management in Indonesia. An ICM package should be flexible to meet local farmers' needs, but still general enough to allow widespread adoption. The Irrigated Rice Research Consortium could develop a strong understanding of the economic, social, and cultural factors that influence the farm-level adoption process. The roles of the private sector must be fully recognized. A two-way flow of information is needed in the standardized dissemination of technical recommendations. It is proposed that provincial technical teams be formed, which can easily work across institutions to facilitate SSNM dissemination.

Keywords: rice, site-specific nutrient management (SSNM), integrated crop management (ICM), working group, technical team

Introduction

Background

Indonesia, the fourth most populous country in the world, had a population of around 225 million in 2007. With an annual population increase of 1.3%, more food is needed every year. Indonesia is the third-largest rice producer, with annual production of about 50.8 million tons from 1993 to 2007, from a harvest area of almost 12 million hectares. Average annual production increased in 1998-2002 to 52.1 million t, and it increased further to 54.9 million t in 2003-07 (CBS 2007).

In 1995-2006, Indonesia imported rice, ranging between 0.3 and 4.7 million t per year, with a mean of 1.9 million t, corresponding to 4% of annual production (CBS 2000, 2007). This consistent importation represents, in part, a lack of adoption of new technologies. Efforts have been made to increase production by improving rice farming. Indonesia is currently nearly self-sufficient in rice production. The new technologies include one or several of the 12 components of a recommended ecozone-specific integrated crop management (ICM) package for rice. Because of the incomplete adoption of the package, some farmers' benefits were affected by unnecessarily high nitrogen fertilizer applications and hence cost of inputs, with a consequent increase in diseases and the cost to control them. High rainfall and a lack of a power thresher during harvest times reduced farmers' time to harvest and they threshed the paddy as soon as possible. Thus, they were also adversely affected by traders' price penalties for substandard grain quality (Zaini 2002).

Fertilizer subsidies

The high increase in rice yields during 1975-85 was achieved through a special government program for lowland rice intensification, which consisted of intensive extension of technologies, provision of capital, and a guaranteed floor price for rice. After this period, yield increases were minimal because of decreased government support involving a reduction in extension, a reduction in pesticide and fertilizer subsidy, and uncertainty in the rice floor price. These conditions combined with frequent fertilizer unavailability in villages resulted in decreased fertilizer use (IFPA 2004).

It was reported that, after many years of experiences with fertilizer subsidies, the dual (subsidies and nonsubsidies) pricing system for fertilizers led to inefficiency and a distortion of marketing systems. Because of the subsidy, the domestic prices of fertilizer were much lower than the world price. However, the past policies of keeping domestic fertilizer prices lower than the international market prices caused two undesirable outcomes. First, this created a high budgetary burden on the government; second, it created inefficiency of fertilizer use at the farm level. Subsidized fertilizers were frequently not reaching the intended beneficiaries; they could easily be used in the nonfood crop subsector and some subsidized fertilizers were exported. Low domestic fertilizer prices have also caused fertilizer smuggling (Hanson et al 1994).

Policy changes on research and development: from centralization to decentralization

Agricultural research in Indonesia in 1994 was decentralized by establishing an Assessment Institute for Agricultural Technology (AIAT) in each province. Each AIAT was formed by integrating an Agriculture Information Center with research implementing units in the province. The main purpose of decentralization was to improve the formulation of local specific technologies and accelerate the adoption of new technologies by involving farmers in assessment activities. Agricultural technology transfer was implemented through research by national agricultural research centers (NARCs) and assessment by the AIATs. The NARCs conducted strategic research and the AIATs assessed and combined individual component technologies into a package. The packages could be used at national or regional scales according to their applicability. Some component technologies could be highly location-specific.

In accordance with the new agricultural development policies, a reorientation of agricultural research and development was undertaken to move from (1) centralized toward decentralized planning, (2) a commodity approach toward a resource-based approach through the development of farming and agribusiness systems, (3) cultivation-based research toward research balanced between strategic technological components and adaptive technology, (4) general research toward location-specific research, and (5) priorities based on production toward priorities based on market demand (Budianto and Zaini 2003).

Research-extension interface and multistakeholder partnerships

Research and development on rice fertilization

Urea supergranules (USG). Broadcast application of urea on flooded rice fields decreases its efficiency because of losses resulting from ammonia volatilization, nitrification–denitrification, runoff, and leaching. Urea supergranules and briquettes or tablets have been tested to facilitate the efficient use of N fertilizer by placing within the anaerobic soil layer. The yield obtained from smaller applications of USG or urea briquettes (58–116 kg ha^{-1}) was comparable with that of higher rates of urea (87–116 kg ha^{-1}). Field testing at eight locations showed that, for any specified rice yield, a savings of 22 $\pm$5% of urea can be achieved using urea briquettes rather than prilled urea (FAO 1999). Unfortunately, farmers could not adopt these research results because the forms of nitrogen fertilizer were not available commercially.

Development of a soil test kit. Since the early 1970s, ICALRD, formerly the Center for Soil and Agroclimate Research (CSAR), conducted research to develop soil phosphorus (P) and potassium (K) testing methods. Soil P and K extraction methods and critical levels were established for low, medium, and high levels that corresponded to deficient, adequate, and excessive levels, respectively (SRI 2004). However, the methods were not extensively used due to the relatively high cost of analysis and slow turnout of results because of limited laboratory capacity.

Because of the limitation of these laboratory methods, ICALRD in the late 1990s started to develop simple and quick soil analysis for P and K. The quick soil test kit (STK) was a qualitative measurement indicating three levels: low, medium, and high soil nutrient status. It is reproducible, rapid, easy to operate, and can be done under field conditions. Results were comparable to more sophisticated laboratory analysis.

The "paddy STK" was released in 2004. Soon after its release, several thousand units were produced based on requests, and distributed by various organizations that included AIATs, the Directorate General of Land and Water, Agriculture Offices from various provinces and districts, the private sector, fertilizer producers, and individuals. However, an impact assessment on the use of the STK is yet to be done.

Mapping of soil P and K status. Blanket P fertilizer recommendations over large areas were not efficient because inherent P supplies varied among rice fields. This prompted scientists to generate maps showing the P status of lowland rice soils. At the same time, soil K maps were also produced. Soil P and K status was categorized into low, medium, and high (Adiningsih et al 1989, Moersidi et al 1991, Soepartini et al 1991). The P and K maps became essential references for making site-specific P and K fertilizer recommendations, and were eventually released as a Minister of Agriculture Decree on SSNM.

Development of the LCC. Research activities on the use of the SPAD (Soil Plant Analysis Development) chlorophyll meter for N management in transplanted rice began in Sukamandi in 1997 (Abdulrachman et al 1999). Another output was the calibration of the leaf color chart (LCC) with SPAD. The first LCC designed by PhilRice/IRRI consisted of six green color shades—from light yellowish green (panel 1) to dark green (panel 6). It was subsequently replaced in 2005 by an IRRI four-panel LCC. On-farm trials conducted by AIATs in different provinces demonstrated the practical advantage of using the LCC for "real-time" assessment of rice crop need for N fertilizer. Results also showed the possibility of improving N-use efficiency in irrigated rice farming and the cost effectiveness at the farm and national levels.

Initiation of SSNM. SSNM was initially proposed by the Reversing Trends of Declining Productivity (RTDP) project from 1997 to 2000. Activities continued from 2001 to 2004 through the Reaching Toward Optimum Productivity (RTOP) Work Group of the Irrigated Rice Research Consortium (IRRC). The main objective was to provide rice farmers with opportunities to increase productivity and profit through wide-scale adoption of fertilizer management tailored to specific rice fields (i.e., SSNM) and other technologies through partnerships with national agricultural research and extension systems, the private sector, and NGOs.

SSNM provides an approach for supplying rice with nutrients as needed. The application and management of nutrients are dynamically adjusted to crop needs, depending on the location and season. This approach mainly advocates a wise use of existing nutrient sources such as crop residues and manures (Abdulrachman et al 2003). Efficient use of N fertilizer is promoted by the use of the LCC, which ensures that N is applied at the right time and in the right amount. While researchers at ICALRD developed the soil test kit to determine P and K fertilizer requirements, SSNM as an alternative plant-based approach to determine crop needs for P and K fertilizers was developed through RTDP and RTOP with members mainly from the Indonesian Center for Rice Research (ICRR) and ICFORD. Crop needs for P and K fertilizers are determined by rice yields of nutrient omission plots, which visually demonstrate to farmers the nutrient status of their rice crop, and help to ensure that P and K are applied at required rates. Micronutrients are applied according to local recommendations.

The concept of SSNM as developed through the RTDP and RTOP projects from 1997 to 2004 led to the development of a series of locally adapted SSNM practices for rice in specific regions of Java and North Sumatera. SSNM through the use of the LCC and nutrient omission plots also became a component of the ICM approach for rice management in Indonesia. In 2008, a decade of research findings on SSNM as well as experiences with the soil test kit and maps on soil P and K status were used to develop decision support software entitled *Pemupukan Padi Sawah Spesifik Lokasi* (*Location-Specific Rice Fertilization*) and referred to as PuPS, which was provided to AIATs for dissemination. This decision tool for irrigated rice throughout the country was designed to help extension workers and farmers quickly formulate fertilizer best management for specific rice fields. It consisted of 10–15 questions answerable by an extension worker or farmer. Based on responses to the questions, a fertilizer guideline with amounts of fertilizer required by crop growth stage was provided for rice fields.

Initiation of ICM. Five options to increase irrigated rice yield were tested at ICRR in Sukamandi during four cropping seasons in 1997-98: (1) use of young (15-day-old) and healthy seedlings, (2) basal incorporation of organic fertilizer at 2 t ha^{-1}, (3) intermittent irrigation, (4) soil test-based application of P and K fertilizers, and (5) nitrogen fertilization guided by the LCC. These options were then verified in a 1-ha block of rice field at ICRR for five successive seasons, commencing in the wet season of 1999-2000. Two packages were tested: (1) the first package (package A) combined the first four practices plus N application following national recommendations; (2) the second package (package B) consisted of the first four practices plus N application as guided by the LCC. Compared with the farmers' practice, the two packages increased rice yield and return/cost (R/C) ratio consistently and appreciably by about 30% for package A and by 50% for package B (Table 1).

The five ICRR-generated technologies were augmented by seven additional components to create a 12-component set of ICM options. The seven additional

Table 1. Results of 1-ha field trials of the five components of the selected irrigated rice production technology package at IRIR, Sukamandi, Indonesia, 1999-2002.

Season	Farmers' practice		Package A		Package B	
	Grain yield (t ha^{-1})	R/C ratio	Grain yield (t ha^{-1})	R/C ratio	Grain yield (t ha^{-1})	R/C ratio
WS 1999-2000	5.95	1.32	7.30	1.93	9.60	2.29
DS 2000	5.82	1.42	7.67	2.03	8.67	2.39
WS 2000-01	6.29	1.64	7.72	2.01	9.06	2.56
DS 2001	5.96	1.52	8.12	1.99	8.28	2.11
WS 2001-02	6.10	1.60	8.47	2.39	10.98	2.55
Mean	6.02	1.50	7.86	2.11	8.92	2.44
% increase over farmers' practice	–	–	31	34	48	56

components are (1) selection of a locally adapted high-yielding rice variety; (2) use of high-quality seed; (3) transplanting of 1–3 seedlings per hill; (4) square (20 cm × 20 cm to 25 cm × 25 cm) or paired-row (*legowo*) geometry plant spacing; (5) mechanical weeding by a rotary weeder; (6) integrated pest and disease management; and (7) threshing by a power thresher. Farmers were encouraged to try all 12 ICM components so they could freely select the options that suit their biophysical, social, and economic circumstances and the availability of resources and component technologies. The ICM technology options are thus location-specific and dynamic.

Rice yields and R/C ratios were evaluated at 13 locations in 2001-02. In 10 out of the 13 locations, rice yields in ICM fields increased by more than 10% compared with non-ICM fields in both the dry and wet seasons. In addition, the R/C ratio for ICM fields was 2.5 times higher than with non-ICM fields. Evaluation of the ICM options in the vicinity of ICRR during different seasons showed similar results. Starting in 2002, evaluation of ICM technology options started as a pilot project in 14 provinces (33 districts), with a compact block of 100 ha per location. In 2003, the pilot project was extended to 22 provinces (44 districts). Depending on farm size, the number of farmers per block of the 100-ha evaluation site varied from 160 (outside Java) to more than 800 people (in Java).

The Rice-check system in support of ICM was based on the principle that yields increased as adoption of the 10 key checks increased. The 10 key checks were (1) use locally appropriate cultivars, (2) use certified seeds with high vigor, (3) ensure effective leveling and tillage management, (4) synchronize seeding of the nursery, (5) establish sufficient plant population to ensure adequate grain-sink size for farmers' target yield, (6) achieve enough tillers at panicle initiation, (7) avoid excessive water or drought stress, (8) ensure no yield loss due to pests, (9) harvest at the right time, and (10) thresh at the right time.

The Rice-check method was used to evaluate the success of ICM in farmers' fields. Figure 1 illustrates a strong relationship between the number of key checks

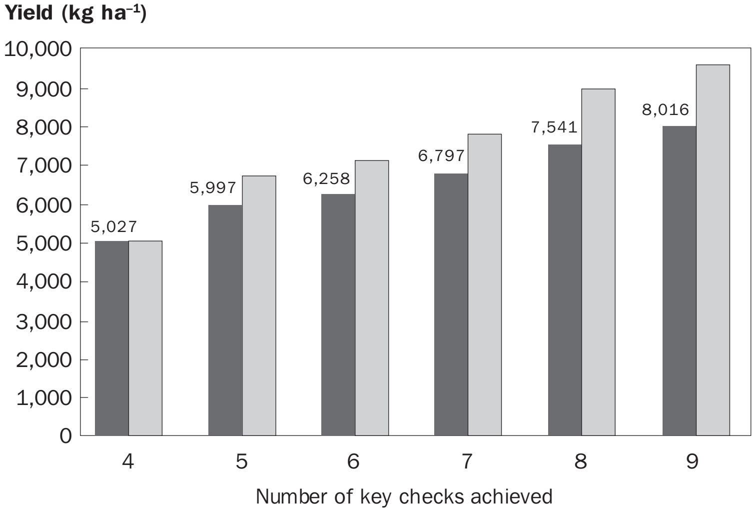

Fig. 1. Relationship between key checks achieved with grain yield and gross margin results in Rice-check farmer groups, Lampung Province, Indonesia, 2006-07 WS (N = 78 and 60 males and 18 females) (source: Zaini et al 2007).

achieved and increases in grain yield and gross margin. Farmers who achieved four key checks obtained 5.0 t ha^{-1} grain yield. Yields increased up to 8.0 t ha^{-1} as the number of key checks achieved increased from four to nine. Achievement of all nine checks resulted in a 59% increase in grain yield.

The beneficial effects of achieving more key checks for increasing gross margins could be more convincing than increasing grain yield (Fig. 2). Achievement of nine key checks resulted in a US\$916 ha^{-1} gross margin compared with \$483 ha^{-1} for farmers achieving only four checks. The achievement of nine key checks resulted in a 91% increase in gross margin.

Overall adoption of key checks was good with the exception of achieving high bunds for avoiding excessive water or drought stress, especially during the dry season (Fig. 3). Key checks adopted that generally improved across seasons were (1) use certified seeds with high vigor, (2) synchronize seeding of the nursery, (3) achieve enough tillers at panicle initiation, and (4) thresh at the right time.

Network and partnership building

The Assessment Institute for Agricultural Technology (AIAT). In Minister of Agriculture Decree No. 798/1994, agricultural research and development in 1994-95 was decentralized by establishing an AIAT in each province (Fig. 4). The main duty of the AIAT was to conduct adaptive research, and test and assemble location-specific customized technology packages. The AIAT performed five functions: (1) conducting research on location-specific, competitive, and appropriate agricultural commodities; (2) testing and assembling of location-specific, customized agricultural technology packages; (3)

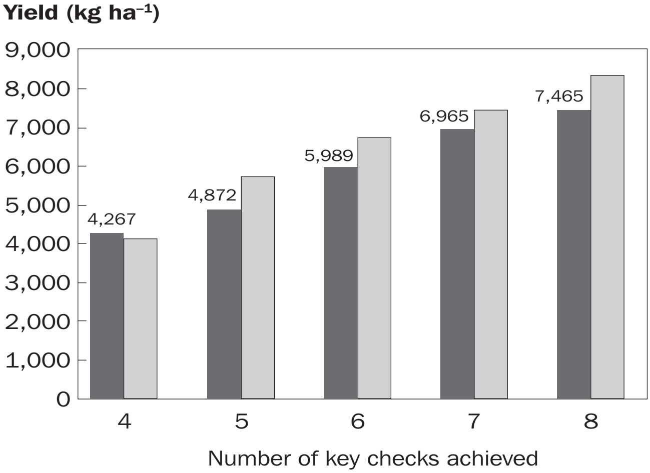

Fig. 2. Relationship between key checks achieved with grain yield and gross margin results in Rice-check farmer groups, Lampung Province, Indonesia, 2007 DS (source: Zaini et al 2007).

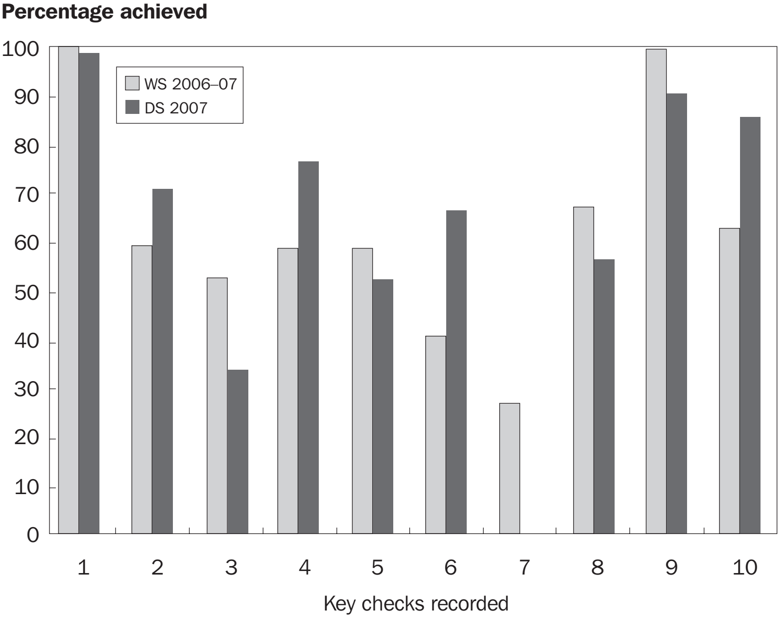

Fig. 3. Adoption of key checks in Rice-check farmer groups (N = 78 and 60 males and 18 females), Lampung Province, Indonesia, 2006-07 WS and 2007 DS.

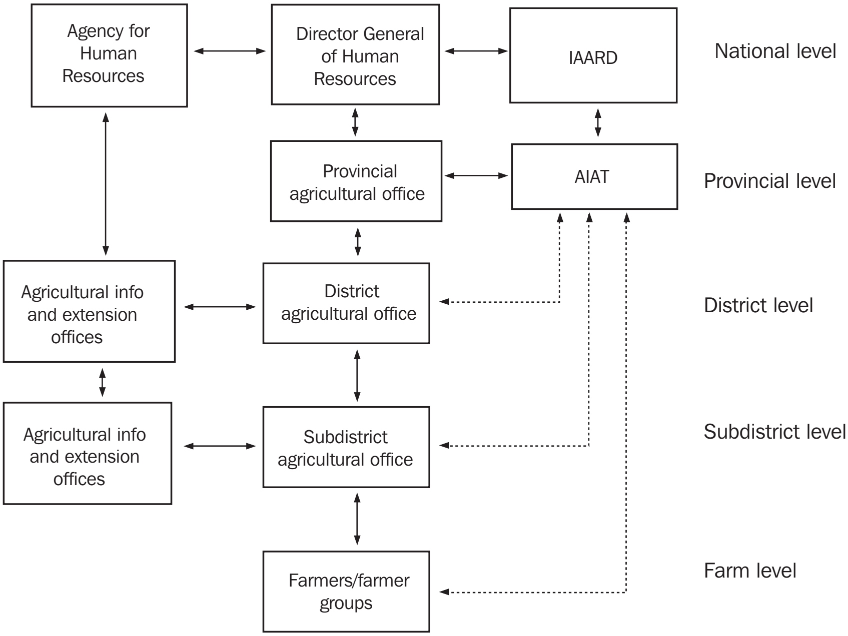

Fig. 4. A model of participatory two-way flow of information.

providing feedback on the dissemination of improved agricultural research programs; (4) providing a source of extension materials for the dissemination of successful, tested, and adapted agricultural technology packages; and (5) providing technical services on agricultural technology assessment. To support the AIATs in implementing their duties, Regional Advisory Committees and Technical Working Groups were formed. They had important roles in making decisions related to agricultural research policies, priority setting, planning, and implementation through approval of the AIAT annual work plans as depicted in Minister of Agriculture Decree No. 804/1995.

Prior to the establishment of the AIAT, there was no mechanism for planning and priority setting of agricultural research and development at the provincial level. Information concerning provincial research needs was identified by the Provincial Office of Agriculture (*Kanwil Pertanian*) and channeled through the Directorate General of the Ministry of Agriculture to the Indonesian Agency for Agricultural Research and Development (IAARD). After 1994, new mechanisms were designed and implemented at the provincial level to allow involvement of all stakeholders, including beneficiaries.

Policy formulation traditionally was centralized at and dominated by IAARD in a rather top-down fashion. Currently, research policy issues are discussed and resolved between IAARD and the institutes at different levels in a more bottom-up manner. The processes are initiated by research institutes and AIATs, and therefore involve broader groups of institutions from different levels. Applied research that aims to generate new technologies remains the major responsibility of research institutes. Adaptive research (improving production and farming systems) has mostly been assigned to the AIATs.

Linkaging with IRRI. In 2000, SSNM research in farmers' fields as part of the RTDP project was completed and the benefits became clear and consistent, but researchers did not have a clear concept on how to disseminate the approach to many farmers. From 2001 to 2004, ICRR and IRRI researchers continued to develop SSNM for dissemination to rice farmers through the RTOP project. In 2002, SSNM was integrated as a component of ICM for further evaluation and dissemination to major rice-growing areas. This project was designed to strengthen IAARD–agricultural offices (*Dinas*)–IRRI partnership for the expansion of ICM by developing and using participatory training and extension strategies to help farmers make better crop management decisions. During 2003-04, IRRI worked with the Indonesian Center for Food Crops Research and Development (ICFORD), Indonesian Center for Rice Research (ICRR), and AIATs to strengthen the implementation of the ICM expansion project. IRRI provided the needed technical support and costs for IRRI scientists.

The first workshop of SSNM for rice was conducted at Solo, Central Java, in 2002. The second workshop was conducted at Medan, North Sumatera, in June 2005. The general objective was to build a consensus on nutrient management for rice and a development action plan for the dissemination of improved nutrient management for rice. One of the specific objectives of the workshop was to discuss and formulate initiatives for the *Work Group on Soil Fertility and Nutrient Management in Rice* supported by ICFORD, IRRI, and PPI/PPIC-IPI.

The development of mature technologies in SSNM formed the foundation for the development of an IRRC Country Outreach Program (ICOP) in December 2006. ICOP is a national initiative led by the Indonesian Center for Agricultural Technology and Development (ICATAD) and ICRR. ICOP provided a focal point where IRRC can respond to and link with the initiatives of the government, such as the development of agriculture business units (*Prima Tani*) and the National Rice Production Improvement Program (P2BN, *Peningkatan Produksi Beras Nasional*), which are entry points for demonstrating new technologies at subdistrict and village levels throughout the country.

The Fertilizer Working Group. The collaboration of the Productivity and Sustainability Work Group (PSWG) of the IRRC since 2005 in Indonesia placed a greater emphasis than before on building research-extension partnership around broad-based harmonization and consensus building on nutrient best management practices. The workshop in Medan in 2005 was instrumental in building a consensus on nutrient management for rice, which led to the formation of a national Fertilizer Work Group (FWG) on 9 October 2006 co-chaired by the directors of ICALRD and ICFORD. Through this group, a workshop on SSNM in March 2007 at ICRR produced a report proposing four outputs for future SSNM activities: (1) an endorsed standard SSNM recommendation for rice, (2) a demonstration of SSNM recommendations, (3) dissemination of SSNM through existing programs, and (4) collaboration of agricultural offices with AIATs in SSNM dissemination supported by local government budget.

On 4 May 2007, the FWG endorsed a standardized SSNM recommendation for rice. The dissemination of SSNM presented an ambitious task meriting facilitation from a technical team of qualified and respected national experts representing the key partner organizations of ICATAD, ICALRD, ICFORD, and ICRR. A general consensus indicated that the FWG should continue in some form beyond 2008. However, it was also viewed that the group would be more effective if followed up by a national interinstitutional team. IRRI has been helpful to the FWG in funding, developing, promoting, and providing scientific guidance.

The technical team. In August 2007, a technical team and a work plan with expected outputs and activities for facilitating SSNM dissemination within the framework of ICM were established. The technical team formed by the FWG includes members representing four organizations: ICFORD, ICALRD, ICRR, and ICATAD. The technical team reports to the directors of these four organizations through the FWG.

The technical team made good progress with the development of training and promotional materials and the PuPS, a simple menu-driven computer module to formulate field-specific fertilizer requirements for farmers. The technical team facilitated the publication of the 2007 second edition of the guide book *Rice: A Practical Guide to Nutrient Management* in the Indonesian language, which became a standard reference on SSNM. Both PuPS and the guide book were launched by the president of the Republic of Indonesia during the National Rice Week on 24 June 2008 at ICRR-Sukamandi.

The Minister of Agriculture Decree on SSNM

The workshop in Medan in June 2005 was instrumental in building a consensus on nutrient management for rice, which led to Minister of Agriculture Decree No. 01-2006 on location-specific fertilizer recommendations for rice in January 2006. After the release of the decree, it was realized that it should be revised as soon as possible. The revision was driven by the accrual of the latest information and development, such as (1) many new or recently developed subdistricts as a result of the separation or splitting of subdistricts had not been accommodated in the decree, (2) considerable feedback or results of field verification of the decree had accumulated, (3) variation in rice production, and (4) use of compound fertilizers was increasing as a substitute for single-element fertilizers. The revision, which was based on these accumulated data, was released as Minister of Agriculture Decree No. 40-2007.

Enhancing farmers' income and livelihood through ICM expansion in Indonesia

The National Rice Production Improvement program

For more than 10 years (1995-2006), Indonesia had always been on the verge of rice self-sufficiency. On January 8, 2007, the president declared an action program called National Rice Production Improvement (P2BN, *Peningkatan Produksi Beras Nasional*) to finally make the country self-sufficient in rice. The government targeted an additional 2 million tons of rice produced in 2007, followed by 5% growth in national rice production in each succeeding year. One way to increase rice production is through the adoption of ICM in 2 million hectares of rice fields. This action program requires the involvement of all stakeholders. The P2BN program encouraged all parties to be interdependent in increasing rice production. As a result, internal communication related to rice production among research institutes within IAARD was enhanced.

Training of trainers and farmer field schools for ICM

Indonesia has a long and successful experience in assembling and disseminating rice technology packages with technical and economic components through *Intensifikasi Khusus* (INSUS), *Indek Pertanaman* 300 (IP-300), and *Sistem Usahatani Padi* (SUTPA). Those experiences built the opportunity to assist farmers in combining the best features of existing rice production expertise with that of the 12-component ICM approach to raise rice yields.

In February 2008, one senior extensionist from each AIAT and *Dinas Pertanian* at the provincial level were trained in Sukamandi for the training of trainers (ToT) in farmer field schools of ICM. A participatory and self-learning farmers' guide on the Rice-check method was released and complemented with the 12-component ICM package, which is to be evaluated using ten key checks. Training of regional extension and development staff and farmers on the proper adoption of ICM technology options is critical for its success. NARC staff trained selected individuals who in turn trained other local staff and key farmers on how to evaluate and extend ICM technologies to other farmers.

Adoption potential

In 2005, irrigated rice fields in Indonesia covered a total area of 4.75 million ha dispersed all over the country with different infrastructure quality and contrasting accessibility. In addition, land ownership and farmers' educational backgrounds also varied greatly. For example, in 1993, about 10 million farm households were managing <0.5 ha, while 9 million others managed >0.5 ha each. Consequently, dissemination and adoption of agricultural technologies varied greatly among sites.

In the case of the introduction of ICM, one could assume that farmers with small landholdings were late-adopters due to limited capital. But, in Kuningan (West Java), farmers with smaller landholdings tended to be earlier adopters of agricultural innovations because they were the ones who cultivated the lands. Those with larger landholdings (>0.5 ha) tend to hire laborers or rent the land to tenants. These observations would have to be validated in other parts of the country (Widjono and Makarim 2008). Any shift in agricultural practices, including ICM, that is related to cultural changes (i.e., values and norms) requires some time to be fully adopted. Farmers may be reluctant to adopt the newly-released SSNM technology. The success of SSNM dissemination or ICM as a whole needs intensive and continuous extension efforts.

In 2002, ICM was implemented in 33 districts of 14 provinces on a pilot project scale. Farmers adopting ICM (ICM farmers) used 40% less seeds, 60% fewer seedlings per hill, 15% less urea, the same amount of P, 77% more K, and 0.9 t ha^{-1} more organic fertilizer than non-ICM control farmers (Table 2). On average, ICM farmers

Table 2. Mean rice yield, input-output, and changes in income for ICM and non-ICM farmers in 33 districts (14 provinces) of Indonesia, 2002 DS.[a]

Item	Non-ICM farmers (N = 330)	ICM farmers (N = 330)	% change (+/–)
Seed rate (kg ha^{-1})	40	24	–40
Seedling age (days)	25	18	–28
No. of seedlings per hill	5	2	–60
N applied (kg urea ha^{-1})	255	216	–15
P applied (kg SP-36 ha^{-1})	83	83	0
K applied (kg KCl ha^{-1})	26	46	+77
Organic fertilizer (t ha^{-1})	0	0.9	NA
Highest yield (t ha^{-1})	6.08	7.29	+20
Lowest yield (t ha^{-1})	4.25	5.10	+20
Average yield (t ha^{-1})	5.24	6.27	+20
Total income (Rp. 000 ha^{-1})	6,297 ($768)	7,532 ($919)	+20
Total benefit (Rp. 000 ha^{-1})	2,659 ($324)	3,591 ($438)	+35
Increase in benefit due to ICM (Rp. 000 ha^{-1})	–	940 ($115)	NA

[a]NA = not applicable. US$1 = Rp. 8,200.

obtained 20% higher yield and income and 35% higher net benefits than non-ICM farmers. Overall, ICM farmers earned an additional US$115 ha^{-1} in profit compared with non-ICM farmers. In short, the adoption of ICM technologies increased rice yield, promoted efficient input use, and reduced cultivation cost, thus increasing farmers' net profit. In the future, well-trained and experienced ICM farmers may contribute greatly to higher national rice production and food security (Zaini and Las 2004).

Lessons learned

Harmonization among research institutes

Harmonization on technical information among institutions at the national level is important when technologies differ among institutions. The Medan workshop was instrumental in building a consensus on nutrient management for rice and led to the formation of the FWG. The workshop, conducted in collaboration with IRRI, was an important benchmark, but follow-up by the leaders is vital.

Lesson 1. IRRI or other international organizations can facilitate the harmonization of technologies like SSNM to smoothen research-extension (R-E) pathways, but follow-up by in-country leaders is vital.

A constraint in research-extension (R-E) linkage at the provincial level

The constraint in R-E linkage in the decentralized extension system was not a lack of funding but the quality and harmonization of the technical aspects of technology. At the AIAT level, capacity building, orientation to technologies, harmonization of technologies, and standardization on dissemination procedures are important. Technical training of staff and matching of AIAT staff expertise to needs are factors that influence the effectiveness of AIATs in dissemination.

Lesson 2. The R-E pathway can be supported by building and harmonizing the technical capacity and standardization of dissemination procedures at the AIAT level. A national technical team can be helpful, provided that it works in a consultative fashion within the existing organizational structure.

The use of tools (LCC, soil test kits, and software)

The use of tools such as the leaf color chart (LCC) and soil test kits was less extensive than initially anticipated based on the number distributed. In several cases, the test kits or the LCC were used for only a brief period. Funds were available for purchase, but were not sufficient for training or follow-up. The needs and perceptions of farmers may not have been properly assessed. In a study conducted by Widjono and Makarim (2008), farmers in different districts of West and Central Java implied that, in deciding the nitrogen needs of the rice crop, they trusted their own lifetime experience or visual judgment rather than the LCC. Dissemination of SSNM required training researchers, extensionists, and farmers in a harmonized way; tools (soil test kits, LCC, and software) can help facilitate dissemination. It was not guaranteed, however, that extension workers (as in the case of the soil test kit) or farmers (as in the case of the LCC) would use the tools if their circumstances and aspirations were not well understood and taken into consideration.

Lesson 3. When disseminating a tool to facilitate the extension of a technology (e.g., SSNM), a complete plan and budget package for purchase and distribution, needs assessment, training, and use of the tool are needed.

Lesson 4. Farmers' perceptions and needs should be assessed even before deciding on the tool to disseminate. An interactive assessment needs to be done on the perceptions and needs of extension workers and farmers related to SSNM tools (e.g., PuPS, the computer-based nutrient management decision module) to facilitate better understanding and adoption of these tools.

The Minister of Agriculture Decree

The Medan workshop was useful in building a consensus across national research organizations on fertilizer recommendations for rice. The Minister of Agriculture Decree was a good idea and was needed at the time to provide a policy for a national fertilizer recommendation. But, it did not ensure the application of SSNM by rice farmers. The harmonization of research and extension organizations during and after the workshop was partial and limited only among research and assessment organizations, while linkages between research-assessment organizations and agricultural offices, at the national, district, or subdistrict levels, were overlooked. Representatives of the

Directorate General of Food Crops could have been asked to participate in the process of formulating the fertilizer recommendation and preparing the decree. It would have developed a strong sense of belonging that would have enhanced the dissemination of the technologies. After the Minister of Agriculture Decree was released, a complete dissemination program should have been planned and implemented.

Lesson 5. Along with the formulation of SSNM, which was then released as a Minister of Agriculture Decree, a follow-up dissemination program with definite goals, including the number of farmers that should adopt and the extent of lowland rice areas to be covered with the recommendation over a certain period of time, was required.

Lesson 6. The highest priority should be given to completely disseminate SSNM from AIATs to district and subdistrict agricultural offices and eventually to farmers. Harmonized partnership and concerted efforts need to be established between AIATs and agricultural offices (and extension workers) at district and subdistrict levels.

The Fertilizer Working Group (FWG)

The FWG was instrumental in the follow-up of the Medan workshop and the harmonized fertilizer recommendation across institutions was a major accomplishment. It also provided an effective mechanism by which an international scientist (from IRRI) can quickly meet and consult with key persons in key organizations related to the development of nutrient management guidelines. But, the FWG activities on the promotion, monitoring, and evaluation of SSNM—as their responsibility when the group was formed—were limited because the members have many other regular assignments. In addition, there was no particular budget for the tasks. The technical team was formed in response to this.

Lesson 7. A team comprising key representatives from key organizations (as in the FWG) merits continuation as a vehicle when working with an international organization for harmonizing technologies across organizations. The use of a technical team to facilitate dissemination and to free up time for the FWG merits continuation.

Lesson 8. An international organization (e.g., IRRI) can help to efficiently use national senior experts to facilitate dissemination, thereby easing the burden of scientists (such as those in the FWG) and enhancing the skills and capabilities of junior staff.

Future prospects

Dissemination strategies

Dissemination of innovational messages from researchers to farmers will be effective only if messages are delivered effectively. The top-down dissemination approach of the past seems to have shifted more to one of dialogue and participation. Figure 4 shows a model of two-way arrows that represent participatory communication, which is not only among R-E organizations but also carried further down to farmer groups. Structurally, an AIAT collaborates with provincial *Dinas* to support provincial agricultural development. To a limited extent, an AIAT might work directly with district *Dinas*, similar bodies of subdistricts, or farmer-groups (broken lines), but it would be capable of effectively handling only a very few groups in a particular province.

Recommendation. A two-way flow of information is required for effective dissemination of agricultural innovations. In this approach, farmers' aspirations are taken into account not only on substances to be disseminated but also on how dissemination should be carried out. A training of trainers (ToT) approach involving the public and private sector and fertilizer producers can be considered.

Budget for technology dissemination

At present, there is concern about the R-E linkage. The flow of technology exists from the AIATs to the *Dinas* at the district level because there is budget through IAARD. But, there is no flow of technology from the *Dinas* at the district level to the Agricultural Extension Office (*Balai Penyuluhan Pertanian*, BPP) at the subdistrict level and the farmer groups because there is no specific budget for technology that is not related to new rice varieties. A source of budget for SSNM technology dissemination at the subdistrict level is needed. Nevertheless, budget is not the only constraint. The autonomy system of the local government must also be considered. Figure 5 shows the weak link (connected by broken lines) between the AIAT and the agricultural offices at the provincial, district, or subdistrict levels because the latter offices report to or are under the coordination of (connected by solid lines) the Internal Affairs Department at each respective level where they belong.

Recommendation. SSNM should be included in the ICM training materials at the subdistrict level. Field demonstrations and multiplication of tools and printed materials are also needed. A budget must be requested by ICATAD for new technologies. For new rice technology, the budget can come from ICATAD in the first year, and then from the Directorate General of Food Crops (DGFC) in the following years.

Dissemination target

Among the identified targets are local leaders and policymakers at the provincial and district levels, extension workers, the private sector (such as fertilizer companies), fertilizer traders, rice millers, nongovernment extensionists, and rural producer organizations. SSNM and PuPS may be applicable for rainfed rice. The SSNM approach is probably useful in favorable rainfed areas with no problem soils but where yields are still low. It is also worth considering whether the target groups are landowners or tenants, and males or females. Java now has more tenants than owners. New fertilization technologies may be perceived differently by landowners than by tenants because they have different backgrounds, experiences, and motivations. For example, tenants are less interested in organic fertilizers because their effect is not immediately visible.

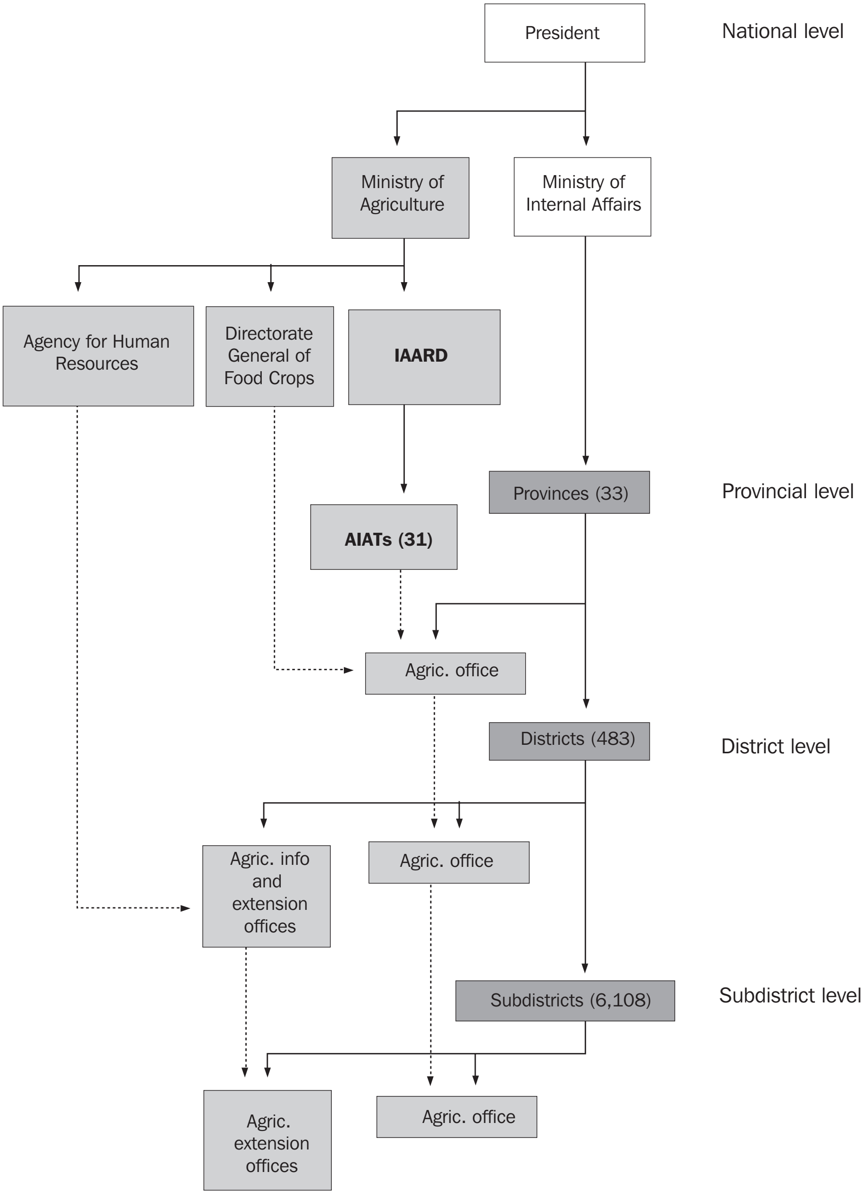

Fig. 5. Diagrammatic flow of agricultural information in Indonesia.

References

Abdulrachman S, Juliardi I, Balasubramanian V. 1999. Nitrogen use efficiency in irrigated, lowland rice at Sukamandi, West Java, Indonesia: an assessment using chlorophyll meter and other methods. Paper presented at the 2nd CREMNET Workshop Cum Group Meeting at Soil and Water Management Research Institute, Thanjafur, Tamil Nadu, India.

Abdulrachman S, Buresh RJ, Witt C. 2003. Increasing productivity in intensified lowland irrigated rice in Indonesia: use of site-specific nutrient management. In: Book II. Rice Policy and Technology Innovation. Indonesia: Central Research Institute for Food Crops. p 193-204. (In Indonesian.)

Adiningsih JS, Moersidi S, Sudjadi M, Fagi AM. 1989. Evaluation of phosphorus requirements of intensified lowland rice in Java. In: Proceedings of National Workshop on Fertilizer Use Efficiency. Cipayung, Indonesia, November 25, 1988. Bogor (Indonesia): Center for Soil and Agroclimate Research. p 241-252. (In Indonesian.)

Budianto J, Zaini Z. 2003. Identifying local specific technologies and problems for increasing production and added value of agricultural products in Indonesia: the Integrated Rice Improvement and Integrated Crop-Livestock-Synergy Improvement Programme. Proceedings of 2nd Seminar in APEC-ATC on Working Group Agricultural Technology Transfer and Training, 24-26 July 2003. Bali (Indonesia): Indonesian Agency for Agricultural Research and Development.

Central Bureau of Statistics (CBS). 2000. Statistical year book of Indonesia. Jakarta (Indonesia): Central Bureau of Statistics.

Central Bureau of Statistics (CBS). 2007. Statistical year book of Indonesia. Jakarta (Indonesia): Central Bureau of Statistics.

Food and Agriculture Organization (FAO). 1999. Final report: improvement of efficiency and environmental impact of nitrogen fertilizers in irrigated rice cropping in Southeast Asia. Rome (Italy): FAO. 44 p.

Hanson RG, Sudjadi M, Hardjono A, Sudaryanto T, Dhanke W. 1994. Soil fertility and fertilizer use study in Indonesia. Report and proposal prepared for the Agricultural Research and Development Agency and the World Bank. 170 p.

IFPA (Indonesian Fertilizer Producers' Association). 2004. Indonesian fertilizer industry. Jakarta (Indonesia): Indonesian Fertilizer Producers' Association in collaboration with the Ministry of Industry and Trade. 283 p.

Moersidi S, Prawirasumantri J, Hartatik W, Pramudia A, Sudjadi M. 1991. Second evaluation of phosphorus requirements of intensified lowland rice in Java. In: Proceedings of the 5th National Workshop on Fertilizer Use Efficiency, Cisarua, Indonesia. 12-13 November 1990. Bogor (Indonesia): Center for Soil and Agroclimate Research. p 209-201. (In Indonesian.)

Soepartini M, Didi Ardi S, Tini Prihatini, Hartatik W, Setyorini D. 1991. Potassium status of lowland rice and response of rice to potassium application. In: Proceedings of the 5th National Workshop on Fertilizer Use Efficiency, Cisarua, Indonesia. 12-13 November 1990. Bogor (Indonesia): Center for Soil and Agroclimate Research. p 187-207. (In Indonesian.)

SRI (Soil Research Institute). 2004. Working principle of paddy soil test kit. Bogor (Indonesia): Soil Research Institute. 24 p. (In Indonesian.)

Widjono A, Makarim AK. 2008. Compatibility and adoption of ICM of lowland rice in West Java and Central Java. ICFORD Seminar, 10 July 2008.

Zaini Z. 2002. The current research activities and future direction to realize sustainable food production in Indonesia. Paper Presented at the Symposium on Research and Development of Sustainable Agriculture and the Second Working Group Meeting of the ASEAN-JAPAN Project on Multifunctionality of Paddy Farming and its Effects in ASEAN Member Countries, 25 February-1 March 2002, Kuala Lumpur, Malaysia.

Zaini Z, Las I. 2004. Development of integrated crop and resource management options for higher yield and profit in rice farming in Indonesia. Proceedings of the APEC-ATC Working Group in Training Workshop on Agricultural Technology Transfer and Training, Bandung, Indonesia, 18-22 July 2004. Indonesian Agency for Agricultural Research and Development. p 252-257.

Zaini Z, Erythrina, Woodhead T. 2007. Agronomic and economic assessment of an adaptation of the Australian rice-check procedure. Paper presented at a national seminar of the North Sumatera AIAT, Medan, Indonesia, 5 June 2009. Indonesia: ICATAD.

Notes

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Authors' addresses: D. Santoso, Indonesian Center for Agricultural Land Resources Research and Development, email: sas_santoso5@yahoo.com; Z. Zaini and A. Widjono, Indonesian Center for Food Crops Research and Development, email: zulkiflizaini@yahoo.co.id, adiwidjono@yahoo.com.

Scaling out communication to rural farmers: lessons from the "Three Reductions, Three Gains" campaign in Vietnam

K.L. Heong, M.M. Escalada, N.H. Huan, H.V. Chien, and P.V. Quynh

Scaling out communication of resource management information to be adopted by millions of farmers requires the integration of agricultural and social sciences. Agricultural technical information needs to be distilled and communicated in a format that is well understood and motivating to be effective. Scaling out involves multiple stakeholders ranging from research and extension to governments (both central and local), mass media, and civil societies. The "Three Reductions, Three Gains" campaign in Vietnam initiated in 2003 enjoyed success in reaching millions of rice farmers, motivating them to change their attitudes and practices. The Ministry of Agriculture and Rural Development had also adopted the "Three Reductions" practices as national policy, provided new resources for its implementation, and also extended it to "Five Reductions." We used a multistakeholder process to develop high-quality partnerships, build social capital, and formulate project objectives within institutional objectives. To facilitate the development of communication strategies, we integrated theories and frameworks from social marketing, strategic extension campaigns, behavioral decision making, and social psychology with agricultural sciences. In this chapter, we describe the processes, theories, and frameworks used and the key lessons learned.

The wide knowledge gap between what rice farmers know and what they should know often translates into poor and inefficient management of resources, resulting in reduced profits, exposing them to unnecessary health risks and environmental pollution. Most modern rice cultivars, if well managed, can easily yield more than 5 tons per hectare when grown in favorable environments, but millions of farmers in these favorable environments often get less than 5 tons using the same inputs. In other cases, farmers use resources suboptimally, causing wastage and pollution from runoff. Rice farms in China, for instance, apply more than 300 kg of nitrogen ha^{-1} but have poor recovery rates. Witt (2003) estimated that about 70% of the fertilizers Chinese farmers apply are lost into the environment. Most farmers believe that more fertilizer is better, perhaps since the local terms for fertilizer are often translated to mean "fattening" in many countries. Similarly, in the case of seeds, farmers often believe that higher seed rates will give higher yields. In pest management, rice farmers often use pesticides unnecessarily because they apply them as prophylactics or they base their decisions on visual cues, which often lead to a more than tenfold overestimation of potential damage by pests (Heong and Escalada 1999). In the Philippines, about 80% of farmers' insecticide sprays were unnecessary because they were applied at the wrong time, for the wrong pests, or both (Heong at al 1995). Using the wrong chemicals at the wrong dosages is also common. Highly visible symptoms such as leaf damage are often cues that stimulate farmers to spray.

Farmers usually rely on their own beliefs and perceptions as most technical information, although transmitted through extension services, may not be appropriately framed for comprehensive reception. Although there are strengths in farmers' indigenous knowledge, there are also weaknesses and what farmers do not know cannot help them (Bentley 1989). If some of these misperceptions are modified through well-planned communication strategies, farmers' resource management decisions and skills can be improved. Thus, discovering the key weaknesses in their decision making is a vital first step in order to develop the appropriate intervention and communication strategy to introduce new information to reach and help the millions of rice farmers. The "Three Reductions, Three Gains" (in Vietnamese, *Ba Giam, Ba Tang*)[1] campaign in Vietnam launched in 2003 had significant impact on seed, fertilizer, and insecticide use by farmers in the Mekong Delta (Huan et al 2008). The campaign was planned as an incremental extension to a "no early spray" campaign launched in 1994 in the Mekong Delta that reduced farmers' insecticide use by 53% (Heong et al 1998, Escalada et al 1999) and spread throughout the Mekong, reducing farmers' insecticide use by as much as 70% in some provinces (Huan et al 1999). Similarly, the *Ba Giam, Ba Tang* campaign reached more than 2 million farmers and reduced their use of seeds, fertilizer, and insecticides by 10%, 7%, and 30%, respectively. Huelgas and Templeton (this volume) estimated that farmers adopting 3R had US$44 per ha profit. In 2006, the Vietnamese minister of agriculture and rural development, Dr. Cao Duc Phat, proclaimed *"Ba Giam, Ba Tang"* a national priority and provided additional resources to all provincial governments for its implementation. This policy contributed to scaling up *"Ba Giam, Ba Tang"* to the whole of Vietnam. In this chapter, we discuss the theoretical frameworks and implementation processes we used to facilitate the development of the quality partnerships that had been vital to the policy adoption and scaling up. We will also discuss our experiences and the lessons we learned.

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[1] The "Three Reductions, Three Gains" program in Vietnam was selected as a "Best Practice" in 2008 by the Dubai International Award for Best Practices. Other awards received by the program were the Ministry's Golden Rice Award in 2004 and Can Tho City's Best Technology Award in 2005. See http://cps-connex/irribulletin/bulletin/2009.03/default.asp#Three.

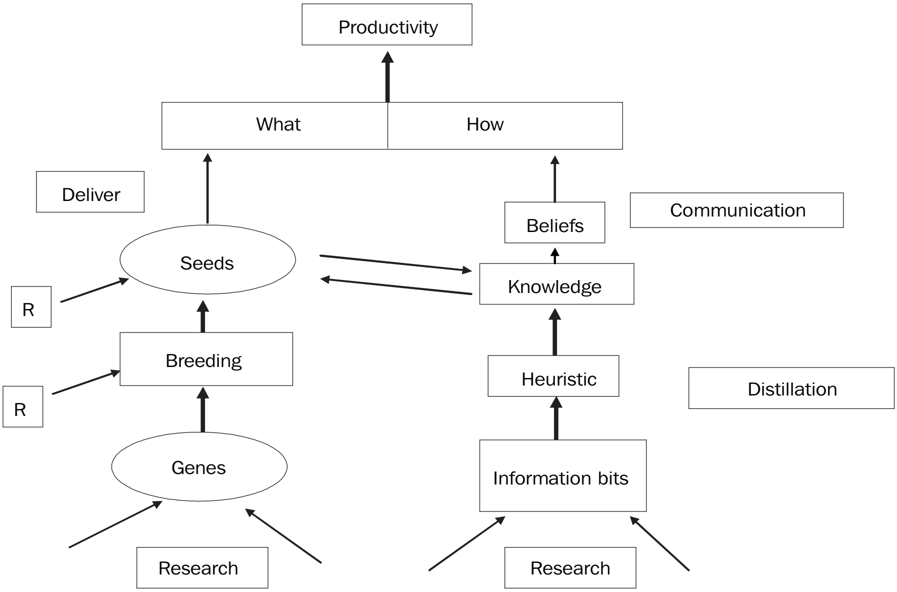

Fig. 1. Seeds and knowledge. Farmers require both seeds and knowledge for increasing productivity. Integrating them requires different mechanisms.

Seeds and knowledge

In their efforts to increase productivity, farmers often encounter two major sets of decisions: "what" varieties to use for the season and "how" to grow them (Fig. 1). Varieties are developed through research to discover genes and understand their functions. Plant breeders then incorporate these genes through plant breeding processes into new varieties. The new seeds are then delivered to farmers through normal extension channels or seed growers. Many of the modern rice varieties are capable of yielding more than 5 t ha^{-1} and making reasonable profits when the crop is well managed. However, most farmers obtain lesser yields and profits even though their input resources are adequate, probably because of inefficient management practices due to knowledge gaps and poor decision making (Mumford and Norton 1984).

Unlike seeds, which can be easily delivered and received by farmers, knowledge is acquired differently and requires different communication strategies. Resource management research often ends up with research reports or scientific papers, highly specific to a discipline, such as entomology, plant pathology, and agronomy. Such information per se, although contributing to the scientific community, does not contribute much to improve farmer knowledge. These are important "bits" to be integrated into decisions. For these information bits to be useful, we need to synthesize and "distill" them into entities that can be used in decision making and practice. Since most decision makers use simple heuristics or decision rules in making decisions (Gigerenzer et al 1999), the entity may be developed into a heuristic that is simple, testable, and easy to communicate. For instance, research has shown that the leaffolder damages leaves in the early crop stages but seldom causes yield loss because of plant compensation effects and natural biological control regulating the insect's population growth (Graf et al 1992, Heong and Schoenly 1998). Spraying to control this apparent pest will instead destroy the pest regulatory service in the rice ecosystem, rendering the rice crop vulnerable to invading adult leaffolders and planthoppers after the sprays. All of this information was synthesized and distilled into a heuristic, "Spraying for leaffolders in the first 40 days of the crop is not necessary." Farmers who tested this heuristic resolved their cognitive dissonance, modified their perceptions, and reduced insecticide use (Heong and Escalada 1997).

Decision making, bounded rationality, and heuristics

Literature from the 1970s on agricultural decision making (e.g., Raiffa 1970, Halter and Dean 1971, Anderson et al 1977) focused on the prescriptive aspects that indicate how decisions should be made according to a set of well-defined criteria. Studies on human judgment and choices have shown that these prescriptive models are unable to account for how people make decisions (Slovic et al 1977, Simon 1978). Most people violate these prescriptive principles because decision making is behavioral in nature (Einhorn and Hogarth 1981). Behavioral decision research is increasingly being used in fields such as public health management, business management, and public policy management, making important contributions in the design of services, information environments, and decision systems (Payne et al 1992), and we applied these principles to quantify and understand farmers' decisions (Heong and Escalada 1999).

In making resource management decisions, farmers always face uncertainty and often adopt the bounded rationality approach, just like most decision makers. In this approach, as opposed to unbounded rationality, farmers will tend to "satisfice" rather than "optimize." Satisficing, a combination of sufficing and satisfying, is a word of Scottish origin used by Simon (1956, 1982) to characterize decision making in conditions of limited time, knowledge, and computational capacities using simple rules. "Heuristic" is a term introduced by Tversky and Kahneman (1974) to refer to an informal rule-of-thumb used in decision making. Heuristics are developed through experience and guesswork about possible outcomes and may thus have inherent faults and biases. Research to understand farmers' current heuristics and reasons for their adoption will help scientists frame new heuristics that are "actionable." For instance, in the leaffolder example, farmers spray insecticides to control the larvae (often called "worms") because of the highly visible symptoms. They strongly believe that leaf damages will lead to yield loss and that the worms will multiply quickly and thus need to be killed immediately. These beliefs might stem from farmers overestimating potential losses and their loss aversion behavior as described in the Prospect Theory (Kahneman and Tversky 1979), in which the potential of loss has a disproportionately higher influence on decisions.

From the ecological and sociological information, three heuristics were developed for *"Ba Giam, Ba Tang"*: "no early spray for leaffolders" and "reduced recommended seed rates" and "reduced recommended fertilizer rates" that were communicated to farmers to motivate them to adjust their resource inputs.

Theoretical frameworks

In developing the campaign approach and media materials, we drew largely from theoretical frameworks such as the strategic communication campaign framework (Adhikarya 1994), behavioral decision-making theories (Einhorn and Hogarth 1981), and the Theory of Planned Behavior (TpB) (Ajzen 1988). The TpB asserts that an intention to perform a certain behavior is determined by the individual's attitude toward performing the behavior and by the subjective norm held by the individual. This theory has been applied to determine which factors influence individuals to act in certain ways and to identify better ways of effectively communicating the message in campaigns relating to health, breastfeeding, AIDS, anti-smoking, seat belt usage, and anti-drugs. TpB helps to explain why some media campaigns have limited success. Increasing knowledge alone does not help to change behavior, whereas campaigns aimed at attitudes and perceived norms in making decisions produce better results. Studies of behavioral intentions suggest that we can predict the likelihood of the intended audiences' adopting desired practices. By assessing and understanding the factors, we can then develop messages to modify their attitudes and perceptions of benefits of the practices and how their peers will view their new behavior. Research by Fishbein and Ajzen (1975) supports the idea that individuals' and society's (perceived) attitudes are important determinants of action. Therefore, an important step toward influencing behavior is an assessment of the attitudes of the intended audience. We continued to monitor these attitudinal changes together with changes in practices at the beginning and some months after the launch of *Ba Giam, Ba Tang* to determine adoption.

Implementation phases

To facilitate the development of quality partnerships and local ownership, we adopted a multistakeholder participatory planning and review process involving research, extension, mass media, universities, NGOs, and local governments. This process involved a series of workshops in five phases of the project cycle (Fig. 2) focusing on jointly identifying problems, needs, and opportunities, developing and evaluating intervention options and prototype materials, and developing hypotheses, instruments, and data for research (see Snapp and Heong 2003 and Heong and Escalada 2005 for more details).

The initial phase is identifying the problem and the associated ecological and sociological issues, and conducting research to better understand them. This first workshop reviews the research information on farmers' current attitudes and practices, and the potential of modified practices. The group then brainstorms for intervention ideas and develops a consensus on using a mass media approach. Understanding the root causes besides the direct causes of the problem is important. It is also important

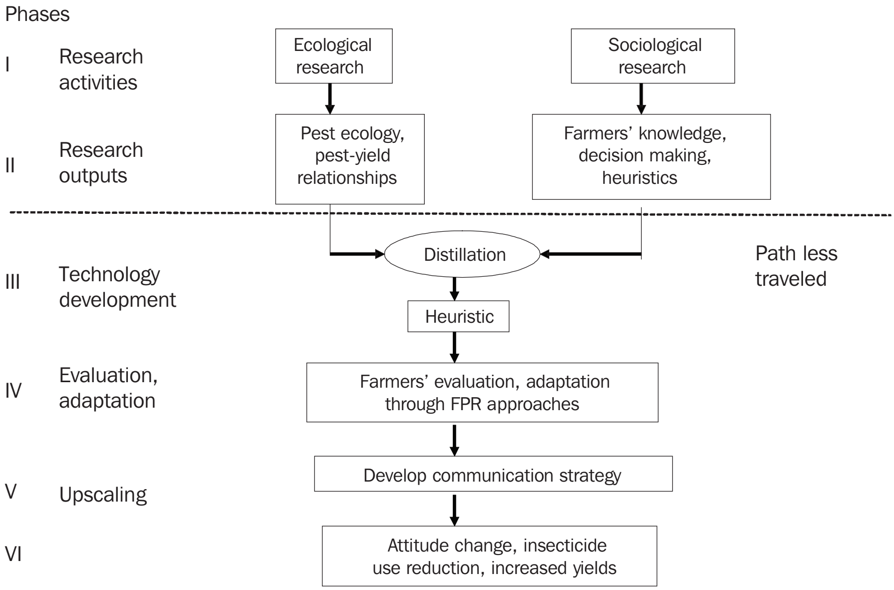

Fig. 2. Pathways to impact. Most research and development programs focus on the first two phases. The remaining phases are often "paths less traveled."

at this phase for all stakeholders to gain a common understanding of the various issues.

The findings are then used as inputs into the second and third phase, "technology development," in which technical information is distilled into actionable entities expressed in the form of a heuristic. The three heuristics for communication in *Ba Giam, Ba Tang*, no early spray for leaffolders and reduced seed and fertilizer rates, were established from scientific rationality described in Huan et al (2008). In most cases, research and development place more emphasis on these two phases, leaving the other phases as "paths less traveled." We found that increased emphases on or investments in the next three phases can add a lot more value to research.

The fourth phase encourages farmers to evaluate whether the *Ba Giam, Ba Tang* heuristics are true through farmer participatory research. This is equivalent to providing samples to consumers for testing in marketing campaigns. Heong and Escalada (1997) found changes in farmers' perceptions after evaluating conflicting information. We developed a simple field experiment that farmers themselves can conduct in their own fields. Next, we invited farmers to perform the experiment. The motivations of *Ba Giam, Ba Tang* were reduced input costs, increased profit, less work, and reduced exposure to toxic pesticides. In this process, the heuristics may also be modified and adapted to suit local conditions. Some 951 volunteer farmers in several provinces participated and they found that the reduced inputs had no effect on yields and gave them higher incomes—about US$58 per ha in the winter-spring and $35 in the summer-autumn seasons, respectively (Huan et al 2005). After farmers' evaluations, the new heuristics are then ready for scaling out, especially in areas where applications of seed, fertilizers, and pesticides are in excess.

The fifth phase is developing a communication strategy and selecting a pilot site. It is important to conduct this pilot project through partnership with local research, extension, mass media, local government, NGOs, and other implementing agencies. The key stakeholders participated in a "Message Design Workshop" (Fig. 3). They used the research results and baseline data to develop, first, a strategy for scaling out the message, and, second, the media and prototype materials required for motivating farmers into action. The messages were positioned in "gain" frames in the media materials to have higher motivational effects. For instance, increased profits are emphasized and the symbol of a "piggy bank" or a stack of bank notes was used. These prototypes were pretested before the final versions were mass produced and distributed. In addition, we emphasized the "trialability" of new practices. Interviews with farmers who had carried out the experiment were broadcast over radio and TV to encourage other farmers to test the three messages. An important element of the strategy is to hold a high-profile launch day to coincide with significant events, such as World Environment Day or Earth Day or a local festival, at which government officials, such as the vice minister, provincial governor, and directors of agriculture, and the media are invited to attend. Farmers who have carried out the evaluation experiments are also invited to share their experiences. Such publicity will help to focus attention of the campaign and can have significant multiplier effects by motivating neighboring provinces to conduct similar campaigns. The *Ba Giam, Ba Tang* pilot campaign in Can Tho Province stimulated local governments of the Mekong provinces to provide about $345,000 additional resources to launch similar campaigns (Huan et al 2008).

The sixth phase is documenting the impact, which is conducted in parallel with the fourth phase. A rigorous research framework was planned at this phase to accurately quantify effects of the intervention. A management monitoring survey (MMS) was carried out about 2 months after the launch to enable the team to make adjustments as needed. Baseline and posttest data (collected before and after the launch) relating to farmers' beliefs, attitudes, and practices were then analyzed and documented. A show-and-tell press conference or workshop is another important event that can enhance adoption by other provinces and create multiplier effects. By involving policymakers in these high-profile events, policy change that can favor widespread adoption is also enhanced.

The mass media approach to scaling out can be highly successful when it communicates a single or only a few interventions or messages. One can start with one intervention and, when success is obtained, the incremental approach can be applied by adding one or two heuristics. It is also useful to "brand" the new intervention for easy communication and recall. In the campaign to reduce insecticide use in the first 40 days, we branded it *"No early spray"* (Escalada et al 1999). In the subsequent campaign to include the reduction of seeds and fertilizers, we branded it *"Three Reductions, Three Gains."* Since savings from insecticide reduction constituted a high proportion of farmer earnings (Huan at al 2005), the campaign motivated farmers to further reduce insecticides by using less seed and fertilizer at the new recommended

Fig. 3. Artist employed in Message Design Workshops to develop prototype materials.

rates. High seed rates tend to promote a denser crop canopy. Coupled with high fertilizer rates, the crop canopy would become conducive to the development of pests and diseases. Thus, farmers using the new seed and fertilizer rates would tend to observe fewer pest and disease symptoms and spray less. The three gains from the campaign are profits, improved human health, and improved environmental health. Because of the credibility built from the earlier "no early spray" campaign, farmers readily adopted the *"Three reductions, three gains"* practices. Rigorous research is an imperative before establishing a new heuristic. Then, extensive evaluation by farmers is necessary before a scaling-out strategy is contemplated to avoid negative impacts.

Managing multistakeholder participation

A multistakeholder partnership of high quality is essential to ensure success of the scaling-out process. We achieved this using a participatory style of leadership to stimulate creative problem solving and to promote high morale, satisfaction, local ownership, and commitment. Group decisions and supportive relationships based on mutual trust and respect were strongly emphasized in meetings and workshops. We also emphasized flexibility in our discussions, decision making, and relationships. Initially, the team establishes a "common stake" in the project, which helps various stakeholders establish their own stakes, roles, and commitments. We did this through developing a "common understanding of the various issues," a "consensus of the approaches," and a "common view of likely impacts and their measurements." The partnership was given the important task of branding the campaign to suit local language and culture. In addition, we made special efforts to share all data, analyses, results, publications, financing, credits, and awards.

To achieve large diffusion of the heuristics, strong commitment and support of local government authorities and agencies are essential. The goals of the project will need to satisfy the priorities of the local government as well as those of local implementing agencies. For instance, if the wages of extension agents in the area were dependent on the amount of farm chemicals they sold to farmers, this conflict would significantly compromise implementation plans. Thus, at the start of the project, a stakeholder analysis would be useful to understand stakeholder relationships to decide whether to proceed or make necessary adjustments before proceeding.

Rapid adoption of *Ba Giam, Ba Tang* in An Giang Province

The commitment and support provided by the An Giang government is exemplary of the multiplier effects that our process was designed to achieve. In 2003, An Giang Province launched its own campaign, distributing 200,000 leaflets and 12,000 posters and erecting 31 billboards in the rural community (Fig. 4). Media materials were fashioned after the prototype materials developed at the "Message Design Workshop" but had an "An Giang identity" (Fig. 5). Between 2003 and 2008, the provincial government provided about $1.5 million in support. This funded 1,031 training ses-

Fig. 4. Posters used in the "*Ba Giam, Ba Tang*" campaigns in Vietnam. On the left was the final version used in the Can Tho pilot project, while the one on the right was used in An Giang Province.

sions, 827 demonstration plots, numerous farmer contests, and promotional activities resulting in rapid adoption of *Ba Giam, Ba Tang* practices over 85% of the rice area in An Giang (Fig. 6). Details can be found at http://devcompage.com/2009/02/28/rapid-adoption-of-three-reductions-in-an-giang-province-vietnam/.

Lessons learned

The *Ba Giam, Ba Tang* campaign in Vietnam has enjoyed huge success in reaching millions of farmers, leading to substantial changes in farmers' attitudes, practices, and incomes (Huan et al 2008). *Ba Giam, Ba Tang* seems to have become part of the agricultural vocabulary being discussed at all levels, from policymakers to farmers to children. An independent impact analysis conducted by Huelgas et al (2008) showed that the Ministry of Agriculture and Rural Development (MARD) established a line item in its 2005 extension budget and that some provinces such as An Giang are continuing to allocate resources to *Ba Giam, Ba Tang*. In 2008, the An Giang provincial government extended this idea by adding two more "reductions," reduce water use and postharvest losses, which is coined *"Five reductions and one must do."* The *one must do* is to use certified seed. *Ba Giam, Ba Tang* was proclaimed a national priority by the minister of agriculture and rural development in 2006, which helped propel the

Fig. 5. Billboard used by An Giang Province to promote "Five reductions, one must do," a further modification of the "*Ba Giam, Ba Tang*" campaign.

campaign further. The initial operating budget allocated to this initiative through the Irrigated Rice Research Consortium funded by the Swiss Agency for Development and Cooperation (SDC) was less than $50,000, yet it leveraged more than $1.8 million from various local sources. In 2008, this campaign gained the recognition of the Dubai International Award for Best Practices (DIABP) and is included in the world's database of best practices (http://beta.irri.org/news/bulletin/2009.03/).

The key lessons we learned from the *Ba Giam, Ba Tang* project, its multiplier effects, its reach, and its impact on farmers are summarized as follows:

- The use of a systematic multistakeholder participatory planning and review process from project conception to implementation.
- The participatory leadership style of management of the multistakeholders focusing on quality partnerships, local ownership, mutual trust, and respect.

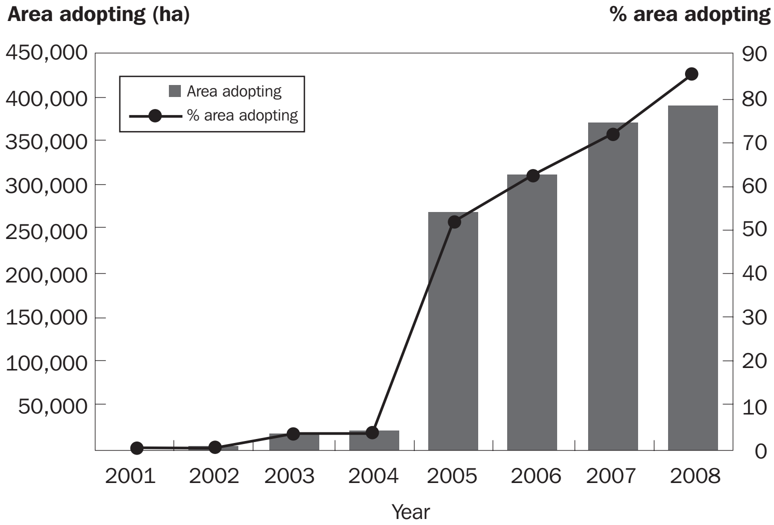

Fig. 6. **Adoption rate of "*Ba Giam, Ba Tang*" in An Giang Province from 2002 to 2008. Data from An Giang Department of Agriculture, Long Xuyen, Vietnam.**

- The integration of ecological, agricultural, and social sciences, particularly communication and decision sciences, in a trans-disciplinary manner.
- The application of social marketing techniques, such as branding, framing of messages, and motivating adopters.
- After the campaign has made progress, follow-up is needed in order to sustain the initial impacts to avoid or slow down discontinuance.
- The use of a comprehensive research framework throughout the project to monitor progress and track changes in farmers' inputs, behavior, and attitudes, which in turn allows us to document impacts.

References

Adhikarya R. 1994. Strategic extension campaign: a participatory oriented method of agricultural extension. FAO of the UN, Rome, Italy.

Ajzen I. 1988. Attitudes, personality and behaviour. Milton Keynes (UK): Open University Press.

Anderson JR, Dillion JL, Hardaker JB. 1977. Agricultural decision analysis. The Iowa State University Press, Ames, Iowa.

Bentley JW. 1989. What farmers don't know can't help them: the strengths and weaknesses of indigenous technical knowledge in Honduras. Agric. Human Values 6:25-31.

Einhorn HJ, Hogarth RM. 1981. Behvioural decision theory: processes of judgement and choice. Annu. Rev. Psychol. 32:53-88.

Escalada MM, Heong KL, Huan NH, Mai V. 1999. Communications and behavior change in rice farmers' pest management: the case of using mass media in Vietnam. J. Appl. Commun. 83:7-26.

Fishbein M, Ajzen I. 1975. Belief, attitude, intention and behavior: introduction to theory and research. Reading, Mass. (USA): Addison-Wesley.

Gigerenzer G, Todd PM, ABC Research Group. 1999. Simple heuristics that make us smart. New York: Oxford University Press.

Graf B, Lamb R, Heong KL, Fabellar L. 1992. A simulation model for the population dynamics of rice leaf folders (Lepidoptera: Pyralidae) and their interactions with rice. J. Appl. Ecol. 29:558-570.

Halter AN, Dean GW. 1971. Decision under uncertainty. Cincinnati, Ohio (USA): Southwestern.

Heong KL, Escalada MM. 1997. Perception change in rice pest management: a case study of farmers' evaluation of conflict information. J. Appl. Commun. 81:3-17.

Heong KL, Escalada MM. 1999. Quantifying rice farmers' pest management decisions: beliefs and subjective norms in stem borer control. Crop Prot. 18:315-322.

Heong KL, Escalada MM. 2005. Scaling up communication of scientific information to rural communities. J. Sci. Commun. 4:2-3.

Heong KL, Schoenly KG. 1998. Impact of insecticides on herbivore-natural enemy communities in tropical rice ecosystems. In: Haskell PT, McEwen P, editors. Ecotoxicology: pesticides and beneficial organisms. Chapman and Hall, London. p 381-403.

Heong KL, Escalada MM, Lazaro AA. 1995. Misuse of pesticides among rice farmers in Leyte, Philippines. In: Pingali PL, Roger PA, editors. Impact of pesticides on farmers' health and the rice environment. San Francisco (USA): Kluwer Press. p 97-108.

Heong KL, Escalada MM, Huan NH, Mai V. 1998. Use of communication media in changing rice farmers' pest management in South Vietnam. Crop Prot. 17:413-425.

Huan NHH, Chien V, Quynh PV, Tan PS, Du PV, Escalada MM, Heong KL. 2008. Motivating rice farmers in the Mekong Delta to modify pest management and related practices through mass media. J. Int. Pest Manage. 54:339-346.

Huan NH, Thiet LV, Chien HV, Heong KL. 2005. Farmers' evaluation of reducing pesticides, fertilizers and seed rates in rice farming through participatory research in the Mekong Delta, Vietnam. Crop Prot. 24:457-464.

Huan NH, Mai V, Escalada MM, Heong KL. 1999. Changes in rice farmers' pest management between 1992 and 1997 in the Mekong Delta, Vietnam. Crop Prot. 18:557-563.

Huelgas ZM, Templeton DT, Castanar P. 2008. Three Reductions, Three Gains (3R3G) technology in South Vietnam: searching for evidence of economic impact. Paper presented at the 52nd Annual Conference of the Australian Agricultural Resource Economics Society, 5-8 February 2008, Rydges Lakeside, Canberra ACT, Australia. Electronic copy available at http://agecon.lib.umn.edu/cgi-bin/pdf_view.pl?paperid=29730&ftype=.pdf.

Kahneman D, Tversky A. 1979. Prospect theory: an analysis of decision under risk. Econometrica 47:263-291.

Mumford JD, Norton GA. 1984. Economics of decision making in pest management. Annu. Rev. Entomol. 29:157-174.

Payne JW, Bettman JR, Johnson EJ. 1992. Behavioural decision research: a constructive processing perspective. Annu. Rev. Psychol. 43:87-131.

Raiffa H. 1970. Decision analysis. Menlo Park, Calif. (USA): Addison-Wesley.

Simon HA. 1956. Rational choice and the structure of environments. Pyschol. Rev. 63:129-138.

Simon HA. 1982. Models of bounded rationality. Cambridge, Mass. (USA): MIT Press.

Simon HA. 1978. Rationality as process and as product of thought. Am. Econ. Rev. 86:1-16.

Slovic P, Fishhoff B, Lichtenstein S. 1977. Behavioural decision theory. Annu. Rev. Psychol. 28:1-39.

Snapp S, Heong KL. 2003. Scaling up and out. In: Pound B, Snapp S, McDougall C, Braun A, editors. Managing natural resources for sustainable livelihoods – uniting science and participation. London (UK): Earthscan Publications Ltd. p 67-83.

Tversky A, Kahneman D. 1974. Judgment under uncertainty: heuristics and biases. Science 185:1124-1131.

Witt C. 2003. Fertilizer use efficiencies in irrigated rice. In: 2003 IFA Regional Conference for Asia and the Pacific, Cheju Island, South Korea, 6-8 October 2003.

Notes

Authors' addresses: K.L. Heong, International Rice Research Institute, Los Baños, Laguna, Philippines; M.M. Escalada, Visayas State University, Baybay, Leyte, Philippines; N.H. Huan, Plant Protection Department, Ho Chi Minh City, Vietnam; H.V. Chien, Southern Regional Plant Protection Center, Long Dinh, Tieng Giang, Vietnam; P.V. Quynh, Department of Agriculture, Can Tho Province, Can Tho City, Vietnam. Email: kheong@cgiar.org.

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The development and extension of “three controls” technology in Guangdong, China

Xuhua Zhong, Shaobing Peng, Nongrong Huang, Roland J. Buresh, Ka Tian, Grant R. Singleton

Guandong Province is one of the main rice producers in South China. In a survey of 500 farmers from 10 counties, we found that overuse of fertilizers, especially nitrogen, is a common practice of rice farmers in Guangdong. The main problems in rice production in Guangdong are low nitrogen-use efficiency, a large number of unproductive tillers, lodging, and damage from diseases and insects. The “three controls” technology was developed based on the following: (1) a more efficient use of nutrients, especially nitrogen, by following the principles of site-specific nutrient management (SSNM), which often results in about a 20% reduction in N input; (2) reduced unproductive tillers and lodging of the rice crop through avoiding luxury N uptake and mid-season drainage; and (3) reduced sprays of fungicides and insecticides because of a healthier rice canopy. The “three controls” technology was released in Guangdong in 2007. It became a government-recommended technology in 2008 and has been widely used in “high-yield creation” and super-rice demonstration activities. The new technology is welcomed by farmers as an effective, reliable, cost-saving, and easy-to-use technology. By using the new technology, farmers can typically save 20% of fertilizer-N input and achieve a 5–10% increase in grain yield.

Keywords: “three controls” technology, rice, site-specific nutrient management, extension

Guangdong Province is located in the southeast of China’s mainland (20°13′–25°31′N, 109°39′–117°19′E), where it occupies an area of 179,800 km^2. It has a population of about 100 million and produces only 40% of its rice needs. To feed its ever-increasing population, it imports rice from abroad or from other provinces every year (Hong et al 2004).

Site characteristics of Guangdong Province

Guangdong is one of the major rice producers in China. Rice occupies about 2 million hectares of planted area in Guangdong Province. It is mainly planted in the plains near Zhujiang, Hanjiang, Jianjiang, and Nanduhe rivers, and in basins in hilly regions. Huizhou, Jiangmen, Guangzhou, and Zhaoqing are the main districts for rice cropping. Rice is the most important food crop in Guangdong. More than 90% of food production is from rice (Guangdong Year Book Editing Committee 2006).

Guangdong has two rice-growing seasons: early rice from March to July and late rice from July to November. Either inbred or hybrid cultivars are planted. Rice is mainly established by either transplanting or seedling throwing. However, direct seeding is adopted in Zhanjiang District located in the southwest part. The climate is subtropical with warm temperatures and adequate rainfall. A majority of the counties have no snow days throughout the year. Annual total sunshine hours are 1,746 for the province, ranging from 1,500 in the north part to 2,300 in the south. Sunshine hours are 600–800 for early-season rice and 850–1,050 for late-season rice. Total annual irradiance is 4,200–5,400 MJ m^{-2}. Annual mean temperature is 22.3 °C (19–24 °C). Guangdong has a long period for rice production, with 220–280 days for most parts of the province. The annual mean rainfall is 1,777 mm for the province, ranging from 1,500 to 2,000 mm for most parts of the province (Zhong 2006).

Economically, Guangdong is one of China's relatively more developed provinces. It is easy for young farmers to find a job in the cities. Farmers are willing to invest in more chemicals for their crops for high yield. Labor-saving technologies are preferred because of the high labor cost. Women farmers play an important role in rice production. Despite the favorable climate and high inputs in rice production, the grain yield per unit planting area in Guangdong is among the lowest in China. Mean grain yield was only 5.4 t ha^{-1}, which is 16% lower than the national average.

Problems in rice production in Guangdong Province

In 2005, we conducted a survey in which fertilizer practices of 500 farmers from 10 counties in the north, east, and west parts and Zhujiang Delta of Guangdong Province were recorded. The main problems in rice production in Guangdong were as follows (Zhong 2006):

1. Too high fertilizer N input for both early- and late-season rice. Total N input is 197 kg ha^{-1} for early rice and 191 kg ha^{-1} for late rice. The mean recovery efficiency of N is only 23%. The low recovery efficiency of fertilizer N could have been one of the reasons for the serious water pollution in Guangdong. Eutrophication is now a problem for the water bodies in the Zhujiang delta (Tang et al 2002).
2. Too much fertilizer N applied at the early growth stage. Farmers apply fertilizer N 2–3 times within 15 days after transplanting and >80% of fertilizer-N was used as basal and at tillering stage (Liang et al 1996). This results in not only low N-use efficiency but also large numbers of unproductive tillers.

3. Too many unproductive tillers. As a result of heavy N input during tillering stage, large numbers of unproductive tillers are produced. Typically, productive tiller percentage is only about 50% or even lower. Half of the tillers die during panicle initiation stage. The dead tillers absorb and waste nutrients. Moreover, plants in such a "crowded" canopy are vulnerable to lodging because of their thin and weak stems. Lodging is a prevailing problem causing a yield loss of 10–30% in the coastal region in the province, especially in Zhanjiang District, where direct seeding is widely practiced. Grain quality is also degraded as a result of on-panicle sprouting. Once lodging happens, farmers must harvest their crops by hand instead of using a contractor with a mechanical harvester.
4. Too much fungicide and pesticide use. Unproductive tillers make the crop canopy dense. This causes low light intensity and high humidity at the base of the canopy, which is favorable to the development of diseases and insects. Farmers must spray more fungicides and pesticides to protect their crops from disease and insect damages.

The high input of chemical fertilizers, fungicides, and insecticides results in not only high production cost and low profit but also environmental pollution and uncertainty of food safety. Environmental protection and food safety are attracting more and more concern. Of special concern is how to increase grain yield with less release of pollutants and improved food safety through improved nutrient and crop management.

Development and description of "three controls" technology

Development

The "three controls" technology was recently developed by the Rice Research Institute of Guangdong Academy of Agricultural Sciences (GDRRI) and the International Rice Research Institute (IRRI). The main purposes for developing such a technology were to increase grain yield and reduce yield uncertainty from lodging, diseases, and insect damage; to increase fertilizer-N-use efficiency and reduce environmental pollution; and to reduce fungicide and pesticide use through improved crop management. The new technology was released by the Department of Science and Technology of Guangdong Province in 2007.

"Three controls" technology has three components: (1) control of fertilizer-N input, especially that as basal or at tillering stage (i.e., "control of N"), to improve N-use efficiency and to reduce environmental pollution; (2) control of unproductive tillers and maximum tiller number (i.e., "control of tillers") to improve productive tiller percentage and canopy quality; and (3) control of diseases and insects through better crop management (i.e., "control of diseases and insects") to reduce fungicide and pesticide use (Zhong et al 2007a). The control of N input and delay of N application are essential for improved N-use efficiency. The control of unproductive tillers is the key to a higher productive tiller percentage and a healthier crop with less lodging, diseases, and insects. The control of diseases and insects is the result of the control of

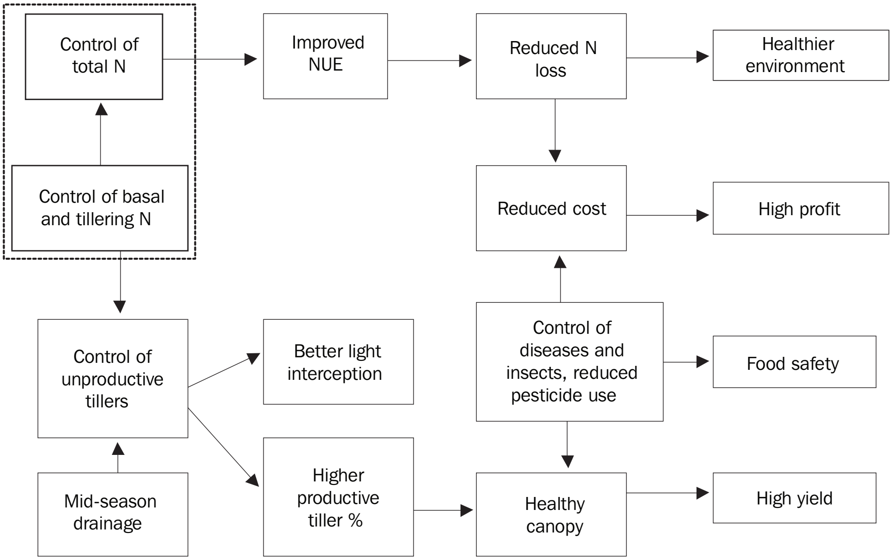

Fig. 1. The "three controls" approach and the benefits that arise from its use. N = nitrogen; NUE = nitrogen-use efficiency.

N input and unproductive tillers. The outline of "three controls" technology is shown in Figure 1.

Description

"Three controls" technology is simple, effective, and easy to use for farmers (Zhong et al 2007a). The steps follow:

1. *Determining total N input*

   The total amount of required fertilizer N (FN in kg N ha^{-1}) is determined from the target yield (Y_T in t ha^{-1}) and the yield without applied N in zero-N plots (Y_{0N} in t ha^{-1}):

   $$FN = (Y_T - Y_{0N}) \times C_N/RE$$

   In the equation, C_N is the total N in aboveground biomass of a mature rice crop producing 1 t of grain yield. The C_N values are about 19 kg N per ton of grain for early-season rice and 21 kg N per ton of grain for late-season rice (Zhong et al 2007b). RE is the recovery efficiency of fertilizer N, with a typical value of 0.4 g g^{-1} of applied N. As a rule of thumb, for every 1 t of yield gain from applied fertilizer N ($Y_T - Y_{0N}$), about 50 kg fertilizer N ha^{-1} should be applied. The yield target is set as 80–90% of the yield potential for a given variety, location, and season, which can be obtained from yield records.

The equation can be further simplified by replacing C_N/RE with AEN, which is the target agronomic efficiency of fertilizer N expressed in kg increase in grain yield per kg applied fertilizer N (IRRI 2010):

$$FN = (Y_T - Y_{0N}) \times 1{,}000/AEN$$

A target AEN of 20 kg kg^{-1} corresponds to the application of 50 kg N for each ton of yield gain from applied fertilizer N, whereas an AEN of 16 kg kg^{-1} corresponds to the application of 63 kg N for each ton of yield gain from applied fertilizer N.

2. *Splitting N rates for key growth stages*
   Predetermined ratios can be used to determine N doses at key growth stages, that is, 40% as basal, 20% at mid-tillering (MT), 30% at panicle initiation (PI), and 10% at heading (HD). The actual N doses at MT, PI, and HD can be adjusted just before N topdressing according to chlorophyll meter (SPAD) or leaf color chart (LCC) readings or, roughly, by sight. Less N should be applied as basal for varieties with strong tillering ability, and vice versa.
3. *Phosphorus and potassium fertilizers*
   With site-specific nutrient management (SSNM), the requirements for fertilizer P and K are estimated using a nutrient balance approach (Buresh et al 2010). In the case of Guangdong, the fertilizer P and K rates recommended with SSNM are sufficient to match the net removal of P and K in harvested grain and crop residues. Fertilizer P and K are adjusted for inputs from added organic materials and carryover of excess fertilizer from winter crops. All P is applied as basal. For K, 50% is used as basal or at mid-tillering, and another 50% is applied at panicle initiation. Fertilizer K rates are adjusted for the fraction of residues retained from the previous rice crop because rice residues are high in K content.
4. *Crop establishment and mid-season drainage*
   Plant density for “three controls” technology is 25–30 hills per m^2. Two seedlings are transplanted for each hill for hybrid rice. For inbred varieties, four seedlings per hill are needed. This is necessary to ensure enough panicles per unit of ground area. Mid-season drainage, in addition to reduced N input during tillering stage, is adopted to avoid the production of unproductive tillers.

Some principles of “three controls” technology

“Three controls” technology is based on the following: (1) more efficient use of nutrients, especially N, by following the principles of SSNM, which often results in a 10–30% reduction in N input; (2) reduced unproductive tillers and lodging of the rice crop through avoiding luxury crop N uptake (especially during tillering stage) and the use of mid-season drainage; productive tiller percentage increases significantly and the rice crop canopy becomes healthier; (3) reduced sprays of fungicides and insecticides because of a healthier rice canopy (Zhong et al 2007c).

Strategy to improve nitrogen-use efficiency

Introduction and evaluation of site-specific nutrient management technology. The SSNM technology was developed by the International Rice Research Institute in the mid-1990s and evaluated from 1997 to 2000 on 205 irrigated rice farms at eight sites in Asia, including Jinhua in Zhejiang Province of China. SSNM is aimed at dynamic field-specific management of N, P, and K fertilizers to optimize the supply and demand of nutrients. The need for N fertilizer was determined from the gap between the supply of N from indigenous sources, as measured with an N omission plot, and the demand of the rice crop for N, as estimated from the total N required by the crop to achieve a yield target for average climate conditions (Buresh et al 2004). The total N was then divided into 3–4 splits at certain growth stages, that is, basal, mid-tillering, panicle initiation, and heading. The predetermined N dose at a given growth stage was then adjusted downward or upward according to either SPAD or LCC readings.

SSNM technology was introduced into Guangdong and evaluated in field experiments conducted in Gaoyao or Xinxing counties from 2001 to 2003. Total N input for SSNM ranged from 100 to 110 kg N ha^{-1} compared with 200 kg N ha^{-1} for the farmers' practice (FFP). Average grain yield was 6.8 t ha^{-1} for SSNM and 6.4 t ha^{-1} for FFP, with a 7.3% yield advantage for SSNM. The recovery efficiency of N was 61% for SSNM and 41% for FFP. Agronomic efficiency of fertilizer N was much higher for SSNM than for FFP (Peng et al 2006).

Factors determining nitrogen-use efficiency. Nitrogen-use efficiency (NUE) can be expressed as recovery efficiency (RE), agronomic efficiency (AE), and N harvest index (NHI) expressed as kg of N in grain per kg N in total aboveground biomass at maturity (Peng et al 2002). Field experiments conducted in Guangdong during 2001-03 showed that RE, AE, and NHI decreased as total N input increased (Fig. 2).

There were strong and negative correlations between RE, AE, and NHI and fertilizer N applied as basal or at tillering stage. However, no significant relationships were found between RE, AE, and NHI and N applied after panicle initiation. If higher NUE is to be achieved, then total N input should be reduced first, and, with a given N input, more N should be applied after basal and tillering stages (Zhong et al 2007c).

A further study was conducted in Guangzhou during 2004-05 and RE of N applied at different growth stages was measured. On average, RE of N applied as basal, at tillering stage, and after panicle initiation was 31%, 18%, and 71%, respectively (Zhong et al 2007d). This again highlights the merit of delaying the application of some N.

Control of unproductive tillers and improvement in productive tiller percentage

Nitrogen is a key factor determining rice tillering (Zhong et al 1999, 2001). It has been reported that the relative tillering rate (RTR) increases linearly as leaf N concentration (N_{LV}) increases (Yoshida and Hayakawa 1970). Leaf N concentration or leaf color is

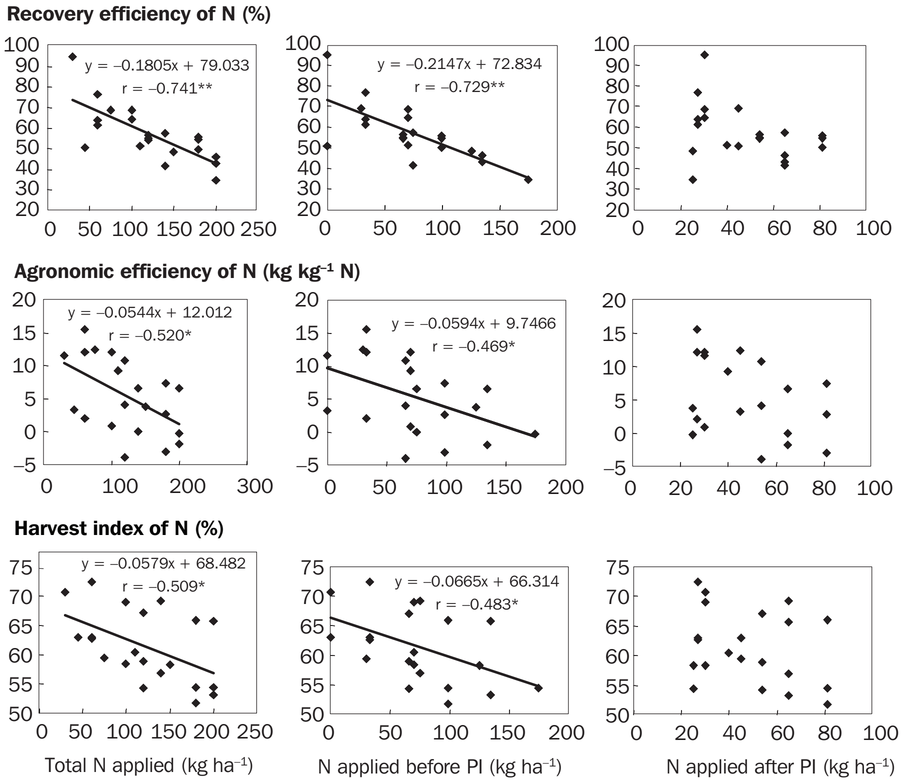

Fig. 2. Relationships between recovery efficiency, agronomic efficiency, and harvest index of N and total N input, N applied before panicle initiation (PI), and N applied after PI.

often used as a diagnosing index in crop management. On the other hand, leaf area index (LAI) has negative feedback on the emergence and survival of tillers (Zhong et al 2002). The interactive effects of N_{LV} and LAI on tillering in irrigated rice were quantified in field experiments. N_{LV} explained a large part of the variation in number of tillers m^{-2} among treatments. In addition, LAI plays an important role in determining tillering rate. The relationship between RTR and N_{LV} and LAI can be expressed as $RTR = a(N_{LV}\ e^{-k\ LAI} - b)$, where a, b, and k are parameters. Under certain conditions, tillering rate is a function of the current number of tillers m^{-2}, N_{LV}, and LAI: $dY/dt = a\,Y\,(N_{LV}\ e^{-k\ LAI} - b)$, where Y is the current tiller number. The critical N_{LV} and critical LAI for tillering to stop depend on each other: higher N_{LV} is needed to prevent tillers from death when LAI is high, and vice versa (Zhong et al 2003).

In the farmers' practice, productive tiller percentage (PTP) is only about 50%. A negative relationship occurred between PTP and maximum tiller number. To increase PTP, maximum tiller number should be reduced. Another way to increase PTP is to prevent the death of existing tillers. Higher N_{LV} and lower LAI are helpful for maintaining existing tillers. Delay of N input helps to improve PTP in two ways: either by reducing maximum tiller number through reduced N_{LV} at the active tillering stage

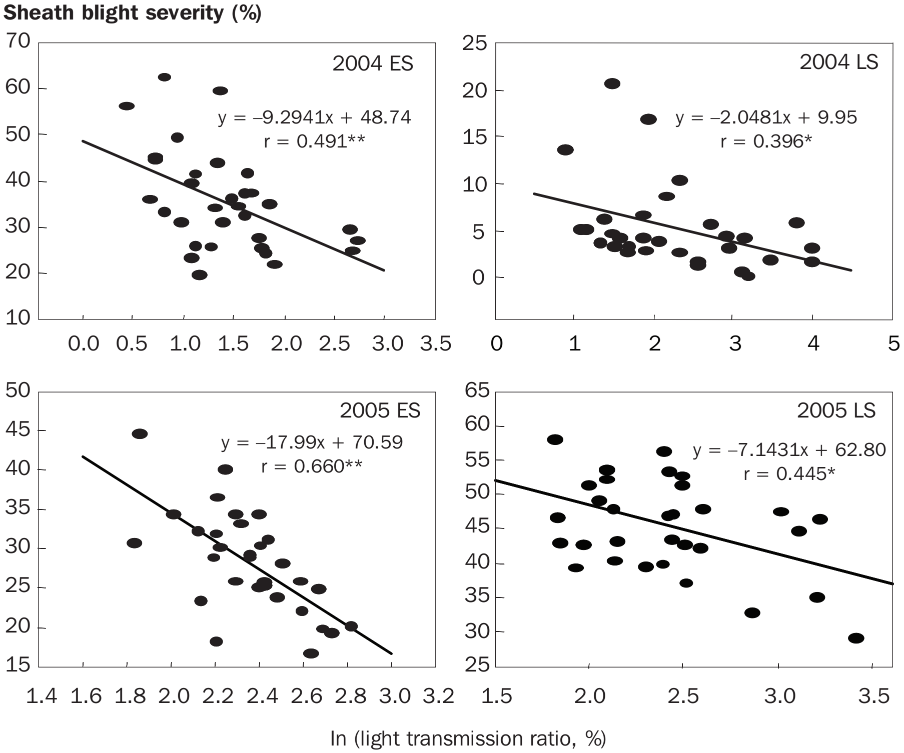

Fig. 3. The relationship between sheath blight severity and light transmission ratio at heading for four cropping seasons. ES = early-season rice crop; LS = late-season rice crop.

or by preventing existing tillers from dying through increased N_{LV} and reduced LAI during panicle initiation stage (Zhong et al 2007c).

Control of plant diseases and insects through improved crop management

The relationship between disease severity (DS) of sheath blight and several canopy indices, that is, stem number at panicle initiation (TILPI), chlorophyll content at panicle initiation (SPADPI), stem number at heading (TILHD), leaf area index at heading (LAIHD), and chlorophyll content at heading (SPADHD), was investigated in four field experiments conducted at Guangzhou, China, during early and late seasons of 2004 and 2005.

A stepwise regression analysis showed that TILPI, SPADPI, TILHD, LAIHD, and SPADHD were the main canopy indices influencing DS (Zhong et al 2006). They explained 45% of DS variation among years, seasons, and N treatments. DS was also affected by climate factors such as daily mean temperature (Tav) and relative humidity (RH). A multiple regression equation with TILPI, SPADPI, LAIHD, SPADHD, Tav, and RH as independent variables explained 83% of DS variation. DS decreased as light transmission ratio of the canopy at heading (LTR) increased (Fig. 3). LTR, Tav, and RH explained 80% of DS variation. Reduced maximum tiller number, lower leaf N concentration, smaller LAI at heading, and greater openness of the canopy are the way to reduce sheath blight occurrence (Zhong et al 2006).

Demonstration and extension of "three controls" technology

The "three controls" technology passed official appraisal in January 2007. Immediately after the appraisal, on-farm demonstrations were conducted during the early season (from March to July) and late season (from July to November) in 2007 at Boxi Village, Liantang Township, in Gaoyao County, and Shuibei Village, Yamen Township, in Xinhui County. Farmers were trained before the demonstration was implemented. At each site, a 7-ha demonstration plot was established. In the demonstration plot at Gaoyao, seven field blocks were divided into two equal parts, one for "three controls" and another for the farmers' practice. Fertilizer rates and grain yield for each treatment were recorded. At Xinhui, the "three controls" technology was compared with the farmers' practice for the same field and the same season of the previous year (2006). Officials, agricultural officers of different levels (township, county, municipal, and provincial), village leaders, farmers, and representatives of newspapers and TV programs were invited to visit the demonstration plot at the key growth stages of rice.

The demonstration in 2007 was a great success. For both sites and seasons, N and P fertilizer rates were lower for "three controls" than for the farmers' practice. However, the potassium rate was higher for "three controls" than for the farmers' practice at Gaoyao in both the early and late seasons. For the two sites in the two seasons, fertilizer cost decreased and grain yield increased for the "three controls" technology compared with those for the farmers' practice (Huang et al 2009a, b). Gross profit was significantly higher for "three controls" technology than for the farmers' practice.

In 2008, "three controls" technology was announced by the Department of Agriculture of Guangdong Province as a government-recommended technology in Guangdong. Demonstrations extended into 11 counties throughout the province. The performance was consistent across different sites. On average, "three controls" technology saved 25% of fertilizer cost, increased grain yield by 7.5%, and gained 14% more income for farmers in comparison with the farmers' practice (Wu et al 2008, Dai et al 2009, Huang et al 2009, Li et al 2009, Liang et al 2009, Xiong et al 2009). Lodging decreased significantly for "three controls" technology at all sites. The length of elongated internodes at the base of the stem was 15–43% shorter for "three controls" technology than with the farmers' practice. This might be the basis for reduced lodging (Wu et al 2008). Disease and insect occurrence was also significantly lower for "three controls" technology. In the 2008 late season at Gaoyao, for example, the number of planthoppers and damaged leaves per hill was 22% and 48% lower for "three controls" technology than for the farmers' practice (Huang et al 2009b).

In 2009, "three controls" technology was officially recommended by the Department of Agriculture of Guangdong Province to 40 counties for "high-yield creation" activity. More than 5,000 one-page guidelines explaining the new technology were distributed to local officials, extension technicians, and farmers. Recently, about

10,000 colorful technical posters have been distributed. The application area of the new technology is expanding quickly. Newspapers such as *Science and Technology Daily of China*, *Guangzhou Daily, Yunfo Daily, South China Countryside,* and *South China Science and Technology* and television programs such as *Guangdong News, Zhaoqing News, Gaoyao News,* and *Yunfo News* reported the performance of the new technology and progress in its extension. Some neighboring provinces have started field trials of this technology.

Conclusions

"Three controls" technology is based on reduced N input at the early stage, fewer unproductive tillers, and reduced diseases and insects through improved crop management. The extension of the new technology has been quite helpful in solving problems in rice production in Guangdong such as lodging, overuse of N fertilizer and pesticides, heavy disease and insect damage, low N-use efficiency and environmental pollution, and low yield stability. "Three controls" is welcomed by farmers as an effective, reliable, simple, and easy-to-use technology. With the use of "three controls" technology, farmers can typically save 20% of fertilizer-N input, save one or two sprays, get a 5–10% yield increase, and achieve \$220 ha^{-1} additional income. Local government officials in Guangdong Province are more and more involved in extending the new technology.

References

Buresh RJ, Pampolino MF, Witt C. 2010. Field-specific potassium and phosphorus balances and fertilizer requirements for irrigated rice-based cropping systems. Plant Soil. DOI: 10.1007/s11104-010-0441-z.

Buresh RJ, Peng SB, Huang JL, Yang JC, Wang GH, Zhong XH, Zou YB. 2004. Rice systems in China with high nitrogen inputs. In: Mosier AR, Syers JK, Freney JR, editors. Agriculture and nitrogen cycle: assessing the impacts of fertilizer use on food production and the environment. Washington, D.C. (USA): Island Press. p 143-153.

Dai YX, Huang NR, Li JY, Chen RB, Huang BL, Zhong XH, Chen WF, Zhong ZH, Xu TJ, Liu YH. 2009. Application of the 'three controls' nutrient management technology of rice at Xinhui county. Guangdong Agric. Sci. 2009(3):20-21,30.

Guangdong Year Book Editing Committee. 2006. Guangdong year book 2005. Guangdong Year Book Press.

Hong K, Zhou JH, Jiang H. 2004. Studies on food safety of Guangdong province. South China Countryside 6:4-6.

Huang NR, Zhong XH, Chen RB, Chen WF. 2009a. Yield increase for "three controls" technology and its mechanisms. China Rice 3:54-56.

Huang NR, Liang XM, Li JM, Zhong XH, Chen RB, Zhong ZM, Chen WF, Ma WX, Tang YH, Tian K. 2009b. Application of the 'three controls' nutrient management technology of rice at Gaoyao of central Guangdong. Guangdong Agric. Sci. 3:17-19,24.

Huang YJ, Zheng BN, Xie ZS. 2009. Application of the 'three controls' nutrient management technology of rice at Yangjiang district. Guangdong Agric. Sci. 2009(3):22-24.

IRRI (International Rice Research Institute). 2010. Site-specific nutrient management. www.irri.org/ssnm. Accessed on 7 June 2010.

Li LZ, Jiang ZZ. 2009. Application of the 'three controls' nutrient management technology of rice at Maonan county. Guangdong Agric. Sci. 2009(3):25-26,35.

Liang GC, Li XT, Du M. 2009. Application of the 'three controls' nutrient management technology of rice at Shantou district of East Guangdong. Guangdong Agric. Sci. 2009(3):29-30.

Liang YQ, Cai HX, Li KH. 1996. Specification of seedling throwing technology for irrigated rice in Guangdong. Guangdong Agric. Sci. 1996(3):15-18.

Peng SB, Huang JL, Zhong XH, Yang JC, Wang GH, Zou YB, Zhang FS, Zhu QS, Buresh RJ, Witt C. 2002. Research strategy in improving fertilizer-nitrogen use efficiency of irrigated rice in China. Sci. Agric. Sin. 35:1095-1103.

Peng SB, Buresh RJ, Huang JL, Yang JC, Zou YB, Zhong XH, Wang GH, Zhang FS. 2006. Strategies for overcoming low agronomic nitrogen use efficiency in irrigated rice systems in China. Field Crops Res. 96:37-47.

Tang JD, Ye XY, Rao GL. 2002. Present status of fertilizer use for rice in Guangdong and its evaluation. Soil Environ. 11:311-314.

Wu HR, Ding WC, Cai TY, Huang NR, Zhong XH. 2008. Application of 'three controls' technology at Leizhou of Guangdong province. Guangdong Agric. Sci. 2008(12):79-80,86.

Xiong ZG, Pan XX, Hua HM, Xu RJ, Guan YZ. 2009. Application of the 'three controls' nutrient management technology of rice at Qujiang county of north Guangdong. Guangdong Agric. Sci. 2009(3):27-29.

Yoshida S, Hayakawa Y. 1970. Effects of mineral nutrition on tillering of rice. Soil Sci. Plant Nutr. 16:186-191.

Zhong XH, Peng SB, Sheehy JE, Liu H, Visperas RM. 1999. Parameterization, validation and comparison of three tillering models for irrigated rice in the tropics. Plant Prod. Sci. 2:258-266.

Zhong XH, Peng SB, Sheehy JE, Liu HX. 2001. Relationship between productive tiller percentage and biomass accumulation in rice (*Oryza sativa* L.): a simulation approach. Chinese J. Rice Sci. 15:107-112.

Zhong X, Peng S, Sheehy JE, Visperas RM, Liu H. 2002. Relationship between tillering and leaf area index: quantifying critical leaf area index of tillering in rice. J. Agric. Sci. (Camb.) 138:269-279.

Zhong XH, Peng SB, Sanico AL, Liu HX. 2003. Quantifying the interactive effects of leaf nitrogen and leaf area on tillering of rice. J. Plant Nutr. 26:1203-1222.

Zhong XH. 2006. Establishment and application of integrated nutrient management system for irrigated rice in Guangdong. In: Shen JB, Zhang FS, editors. Theory and practice of integrated nutrient management for irrigated rice. Beijing (China): China Agricultural University Press. p 265-306.

Zhong XH, Peng SB, Buresh RJ, Huang NR, Zheng HB. 2006. Some canopy indices influencing sheath blight development in hybrid rice. Chinese J. Rice Sci. 20:535-542.

Zhong XH, Huang NR, Zheng HB, Peng SB, Buresh RJ. 2007a. Specification for the 'three controls' nutrient management technology for irrigated rice. Guangdong Agric. Sci. 2007(5):13-15,43.

Zhong XH, Huang NR, Zheng HB. 2007b. Nitrogen consumption of double-season hybrid rice and influence factors in South China. Plant Nutr. Fert. Sci. 13:569-576.

Zhong XH, Huang NR, Zheng HB. 2007c. Some principles for the 'three controls' nutrient management technology for irrigated rice. Guangdong Agric. Sci. 2007(5):19-22.

Zhong XH, Huang NR, Zheng HB, Peng SB, Buresh RJ. 2007d. Effect of nitrogen application timing on grain yield, nitrogen uptake and use efficiency of hybrid rice in South China. Hybrid Rice 22:62-66,70.

Notes

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Authors' addresses: Xuhua Zhong, Nongrong Huang, and Ka Tian, Rice Research Institute, Guangdong Academy of Agricultural Sciences, Guangzhou 510640, China; Shaobing Peng, Roland J. Buresh, and Grant Singleton, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines. Email: xzhong8@163.com.

SMART farmer: a farmer-to-farmer extension approach for widespread adoption

Kukiat Soitong

An important challenge is to increase the adoption of innovations by Thai farmers. This chapter reports on new approaches for delivery that were developed and validated to facilitate the transfer of agricultural technologies for rice to both extension specialists and farmers. Although there has been wide interest by farmers and farmer groups, the actual transfer and acceptance of information and technologies are generally low. To overcome this, several collaborative and advocacy programs were established, including an innovative program that operates in partnership with national agricultural research and extension systems. Strengthening links between national and international research and extension organizations that reinforces the capacities of end-users of agricultural research is seen as a way forward to increase the adoption of new technologies by farmers. Extension programs in many Southeast Asian countries, which have a large number of grass-roots extension specialists, are being weakened by a reduction in the number of government services due to changes in agricultural policies. In Thailand, a farmer-to-farmer extension approach has been applied to strengthen and sustain an effective extension program that facilitates the widespread adoption of new agricultural technologies. A "SMART farmer" model has been developed, and selected and well-trained farmers act as an important intermediary for transferring technology relevant to the farmers in their district. The success of the program depends on their competency. We have learned that the farmer-to-farmer extension approach provides an effective systematic process for transferring technology to target farmers over a wide area. Keys to this success are developing an effective mechanism to facilitate extension, and establishing a functionally active network that generates stronger empowerment for both extension officers and farmers. The extension program should be integrated among agencies both nationally and locally. An important platform of such a program is an effective research and extension linkage through strong end-user participation, particularly for decision-making. Regular meetings and monitoring programs are essential. The key successes to applying SMART farmer as a tool for the farmer-to-farmer extension approach are effective farmer selection, better design for both training programs and extension networking systems, high-quality empowerment activities for both extension officers and farmers, and regular monitoring and assessment of the program.

Keywords: SMART farmer, SMART farmers' competency, farmer field school, participatory extension approach, extension system, monitoring and assessment

In developing countries in Asia, agriculture is the foundation of the national economy. More often than not, priority policies nationally are to increase crop production and farm incomes in an environmentally sustainable framework. To achieve these ends, several supporting factors are needed to enable effective implementation of policies at the field level. One important limiting factor is the bottleneck of new scientific advancements resting with research institutes, while extension agencies grapple with how to package and promote specific technologies. Consequently, new technological advances in agriculture often take 10–15 years from validation to widespread adoption. To facilitate quicker adoption of new agricultural technologies, better extension approaches are required to place more emphasis not only on the improvements provided by the new methodology or technology, but also on how best to integrate extension systems with research institutes. We require better linkages between research and extension, and more participatory involvement of end-users such as farmer groups, individual farmers, and those involved in the preparation of an agricultural product for market (e.g., millers). A challenging task is to promote and campaign for the widespread adoption of new recommendations. This will require recent and current approaches to agricultural extension to be modified.

In Thailand, rice is the major agricultural commodity. In 2008, 9.2 million ha were planted to rice and some 8.7 million ha were harvested, providing 23.2 million t, with an average yield of 2.7 t ha^{-1} (Office of Agricultural Economics 2009). In 2008, Thailand was the number-one exporter of rice on the world market. The mean yield of rice in Thailand is 1–2 t ha^{-1} lower than the estimated attainable yield for rice in the different regions of the nation. Research is progressing on new technologies to close this yield gap; such research is important for Thailand to strengthen its position in the world export market for rice. Therefore, effective and efficient "research to impact" pathways for rice technology development and adoption are of paramount importance to the country.

Thailand's current transition phase in technological development is limited by the capability of the agricultural extension service. An imperative for agricultural extension specialists in Thailand is to develop effective pathways that promote structures that encourage greater participation by farmers in the system. This chapter will review recent developments in Thailand aimed at strengthening research-extension partnerships in rice production and in increasing the involvement of farmer groups early in the process. The main model that will be considered is SMART farmer; I will document experiences from the SMART farmer approach and some lessons learned.

Current status of agricultural extension in Thailand

In the government sector, agricultural extension in Thailand is decentralized. At the national level, the Department of Agricultural Extension is responsible for policy and developing national and regional training programs. However, the responsibility for funding on-the-ground extension rests with provincial and local government. The extension personnel who interact most with farmers are those who are part of the extension agencies at the subdistrict level. Unfortunately, this is also one of the weaknesses of the Thai system because one extension agent is responsible for 1–3 subdistricts.

The Rice Department and Thai universities are both strongly involved in agricultural research. The Rice Department has 17 Research Centers located throughout the main agricultural zones and these provide important nodes for linking with the Department of Agricultural Extension. These Research Centers have regular information sessions with extension specialists drawn from the district and subdistrict levels, which are aimed at transferring knowledge on new rice technologies or on processes for improving rice production. Subdistrict extension specialists then work directly with farmers.

In 2004, the government made it clear that the rate of adoption of research on rice in the agricultural sector was not as widespread as it desired (Department of Agricultural Extension 2004). In 2006, as a result of these concerns, a new program titled the SMART farmer was implemented as part of a concerted effort to strengthen the efficiency of technology transfer from research to extension, and from extension agencies to farmers. A key objective of the SMART farmer program is to establish an influential subset of farmers who provide an important avenue for transferring research products, policy developments, research needs, and reporting of significant biotic and abiotic events, and who provide rapid feedback on the practicalities of technology packages. The SMART farmer model requires the following partners: the Rice Department as a research provider, local government agencies to facilitate improved food production and livelihoods for their rural community, and community rice centers (CRC). The CRCs consist of groups of rice farmers (minimum of 25 members) who are registered with the government extension office at the district level and who interact with extension specialists at the subdistrict level. The SMART famer model will be considered in more detail in the next section.

Development of the SMART farmer approach

Development of an innovative model for rice extension

In Thailand, there is a need to develop an agricultural extension system that is self-supporting and thus more sustainable. The way forward needs to offer a lead role for farmers by complementing their own indigenous knowledge with access to particular technical knowledge through explicitly designed training programs. In this way, the farmers themselves will act as resource persons without having to depend on people from outside. In simple terms, the farmers must be their own extension agents if the agricultural extension service is to progress in the 21st century. Once trained, these farmers become the "smart" farmer of the village.

In developing the SMART farmer approach, specific strategies were developed to motivate the farmers to participate. The following incentives were developed. First, the costs associated with training the farmers were met by the Thai government. Second, each farmer received a certificate of completion at the end of the training course. Third, graduates were bestowed the honor of being officially termed a SMART farmer, which provided them with high esteem in their local community. Fourth, most SMART farmers improve their own production efficiency as a result of what they learned in the course. Finally, some graduates from the SMART farmer courses are recruited to assist in projects run by the Rice Department and the Department of Agricultural Extension. These selected graduates get paid a monthly honorarium.

The role of extension

Farmers in developing countries have been left behind by the rapid change in agricultural technology and information. For farmers to keep track of these changes, agricultural extension will play a big role in terms of developing the knowledge, attitudes, and practices of farmers. To strengthen the capacity of small-scale farmers, it is necessary to develop a comprehensive agricultural extension program that integrates knowledge on a range of factors such as agricultural credit, production inputs, and organized marketing strategies.

Extension specialists also have to empower the farmers to be able to facilitate farmer-to-farmer extension. Since 2006, the approach in Thailand has to be to train a core group of farmers in practical skills of how to be good trainers, and how to develop good communication skills. These farmers are trained to act as extension agents for their neighboring farmers. The selected farmers are also expected to establish demonstration and teaching fields for their neighbors, which focus on improved rice production. In effect, it follows the farmer field school (FFS) approach.

SMART farmer—a farmer-to-farmer extension approach

The SMART farmer approach was developed in 2006 specifically to promote farmer-to-farmer extension. A SMART farmer is selected from a pool of lead farmers. These are experienced farmers. The choice of locality and the key credentials of SMART farmers are both important for developing a strong platform for successful farmer-to-farmer extension. The factors that influence these choices are described in the following sections.

Selection of sites and lead farmers. The diffusion of the extension process begins at a specific site, which provides a target for new activities. Such an area is termed a nucleus site. Under this model, the main pathway for communication of new technologies or production processes is systematic social diffusion. The aim is to achieve widespread adoption of the new information at a subdistrict scale through a minimal investment of resources.

The first step is selection of the nucleus site. These are villages that have been selected to be pilot community rice centers (CRC). The CRCs are farmer groups formed in villages in areas targeted for increased productivity of rice. The farmers in these villages are encouraged to join the SMART farmer project. A key incentive for the farmers is that the active CRC groups have priority access to government initiatives for rice production. For example, they would be the first to receive the release of new rice seeds and be invited to participate in training programs associated with innovative rice production technologies.

Once a CRC has agreed to become involved in the SMART farmer initiative, a participatory rural appraisal (PRA) is conducted on the needs of that village and to assess household circumstances. Farmers then act as partners in a participatory site selection process. The criteria for a nucleus site include ready access by other farmers to the field(s) where activities are established, the field(s) are representative of the needs identified from the PRA, the farmer is keen to cooperate, and local extension officers are willing to participate. The participating farmer is selected by other members of a CRC. The selected farmer needs to be prepared to undergo SMART farmer training so that he/she can take responsibility for on-farm testing and verification. Technical advice and support will be provided during the cropping season by extension agents and collaborative agencies, such as the Rice Department. However, SMART farmers need to meet a minimum set of criteria before their selection is ratified by the extension agent and the CRC at the subdistrict level. Under the Rice Department's SMART farmer selection standard, these criteria follow:

1. Must be a land owner who lives in the community.
2. Has good health and is over 25 years of age.
3. Is educated beyond grade 4.
4. Is knowledgeable and experienced in rice production.
5. Is prepared to participate in training to become a SMART farmer.
6. Is prepared to act as a resource person for his/her fellow farmers.
7. Will be accessible to other farmers as well as CRC members.
8. Is willing to work closely with an extension agent.

These criteria were set following focus group discussions with CRCs and extension agents. Criteria 5 to 8 in particular were identified by the CRC representatives.

Process of selection of SMART farmers. The origin and distribution of SMART farmers as core farmer-trainers in the rural community in Thailand are based on three approaches:

1. *Community rice center approach*—The CRC committee in a given village is requested to select 10 representative farmers to be trained by the project. The remaining village members are expected to learn from the farmers that they select.
2. *Subdistrict approach*—The names of the 10 farmers selected by the CRC are presented to the Tambol Technology Transfer Center (TTTC), a local government unit responsible for agricultural development at a subdistrict level. The TTTC will then select 5 of the 10 farmers to be a representative of each village and these will be trained.

3. *Individual farmer approach*—An individual farmer who may not be a member of a CRC and is keen to be involved in the SMART farmer training can provide the government agencies with his or her credentials.

Training of SMART farmers

Once selected, the lead farmers have to go through a 3-day residential training program. The objective is to equip these farmers with technical knowledge, communication skills, and resource material in order to prepare them as effective SMART farmers. The course focuses on preparing them to become resource persons for technology transfer associated with their day-to-day rice production activities. The course content includes the following:

- Effective communication skills, including how to make good presentations.
- Roles of the SMART farmer in the CRC and in the village.
- A package on technologies and practices that constitute good agricultural practice (GAP) for rice.
- How to develop and implement curricula for FFS.
- Preparing teaching materials, particularly those relating to technologies that address the key needs for increasing rice production in the village.
- Empowerment activities, skills for helping people change their behavior, participatory problem analysis, and the development of associated opportunities to tackle these problems.

At the completion of the course, the farmers are ratified that they are SMART farmers. A ceremony is conducted at which they are presented with a SMART farmer certificate, and then they take an oath to be a SMART farmer.

Implementation of the SMART farmer approach

The SMART farmers play a pivotal role in training and influencing other farmers in their village. The “egg yolk–egg white” analogy of how the system works is shown in Figure 1, which describes a particular training program aimed at increasing the adoption of quality rice seed. A number of similar training programs have been set up and run by the SMART farmers with assistance from a local extension agent.

The farmer-to-farmer extension approach has been emphasized to encourage the amplification of the involvement of farmers in conducting their own field studies, sharing knowledge and experiences, learning with each other, and using the field as the primary learning base. The farmers “learn by doing” through comparing different rice production management processes and technologies. Consequently, they become experts on the particular practice they are investigating. The extension worker facilitates the learning process. He is a resource person and he also provides assistance. The five SMART farmers selected for training by the TTTC become trainers of famers at the village level. One SMART farmer is assigned to take care of 10 “egg white farmers.” Thailand has 7,000 CRCs, so the aim is to develop 35,000 SMART farmers, who in turn will each train and develop 10 other farmers. The goal is to use the CRC-SMART

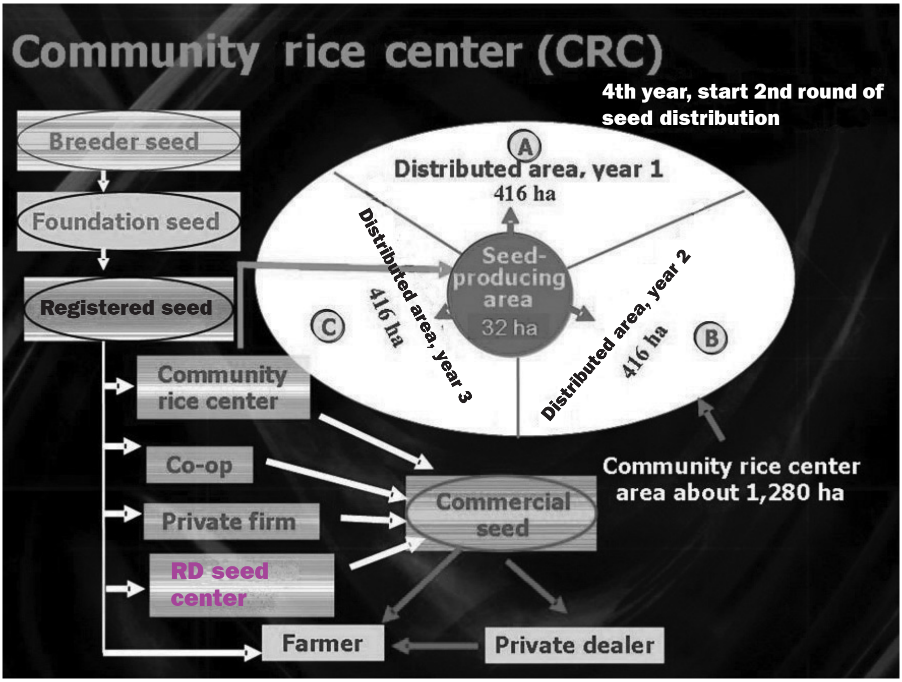

Fig. 1. The SMART farmer model as a nucleus for farmer-to-farmer extension within a community rice center (CRC) and for amplifying the distribution of quality rice seed. The CRC is a learning center of the community under the support of the project. A core group of farmers is trained and they provide knowledge on quality rice seeds to other farmers. The village name is "seed producer farmer" or "egg yolk farmer." A seed production training program is organized. The member farmers in the village are called "egg white farmers."

farmer network to rapidly diffuse new technologies or advances in GAP for rice to 350,000 farmers (Fig. 2).

Establishing a rice farmer field school

After the training program, the SMART farmers are asked to establish a rice farmer field school (RFFS) and prepare some teaching materials on their farms and for their CRC. Therefore, the SMART farmers host the RFFS, and the extension agent acts as a facilitator. The RFFS provides a group-based learning process, bringing together concepts and methods from experiential education and community development. During the rice-growing season, SMART farmers conduct participatory learning activities that help their fellow farmers to better understand the ecology of their rice fields. These activities involve simple experiments, regular field observations, and group analysis. The knowledge gained from these activities enables participants to make their own locally specific decisions about crop management practices.

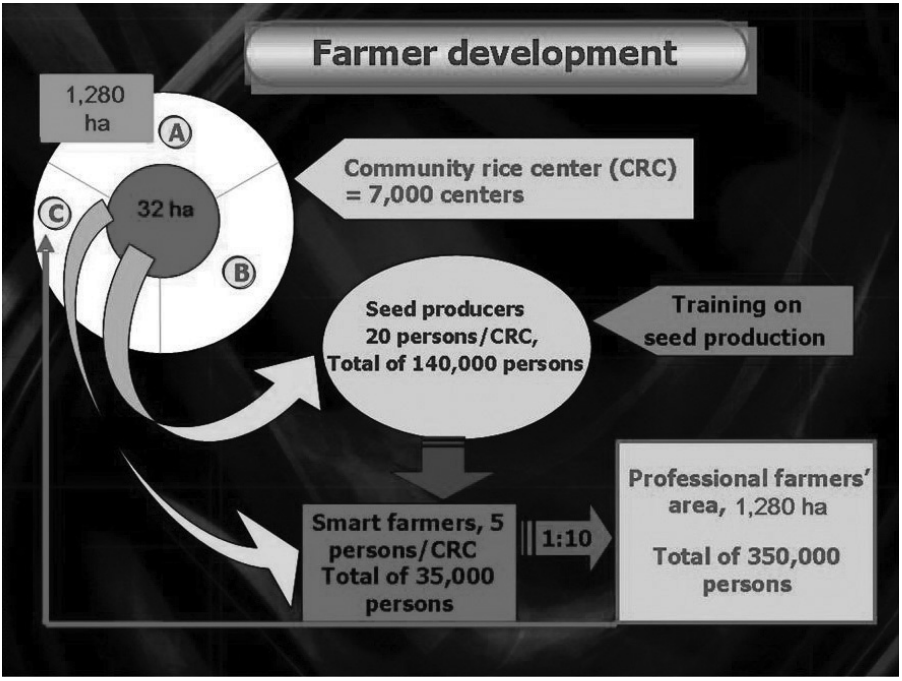

Fig. 2. Farmer-to-farmer extension approach: The CRC members are a core, or nucleus of the village "egg yolk farmers," for learning and for the dissemination of rice technologies and good agricultural practices to neighboring or surrounding "egg white farmers" for widespread adoption. The volunteer SMART farmers lead the training of other farmers.

Monitoring and assessment of the approach

Competency assessment

Progress of the farmer-to-farmer extension approach under the SMART farmer model was assessed by focusing on the attained competency levels of the SMART farmers. A survey was conducted on the "knowledge, experiences and skill, and attitude" of the SMART farmers.

The overall competency of the SMART farmer was assessed as high, at level 4, on a scale of 0–5, where 5 is the highest level. These findings suggest that the SMART farmers have sufficient experiences, skills, and attitude to be highly competent role models for their fellow farmers. However, although they were scored as having a high level of attitude, they scored only at a medium level (2.62) for knowledge of good practices for rice production (Table 1). According to our findings, the SMART farmers need more instruction on training skills and knowledge on GAP for rice. An encouraging finding was that the farmers who were chosen through the CSR/TTTC process have a very high potential to be SMART farmers, to thus be successful agents for transferring agricultural knowledge (Table 2).

Table 1. Competency assessment of SMART farmers in the Thailand program. There are five levels of competency: level 1 = competency less than that of other SMART farmers, level 3 = competency slightly higher than that of other SMART farmers; level 5 = competency higher than that of other SMART farmers.

Competency component	Number of SMART farmers assessed					Competency
	Level 1 1.00–1.80	Level 2 1.81–2.60	Level 3 2.61–3.40	Level 4 3.41–4.20	Level 5 4.21–5.00	
Knowledge	22 (13.2)	48 (28.7)	68 (40.7)	24 (14.4)	4 (2.4)	2.62, level 3 Medium
Experiences and skill	2 (1.2)	8 (4.8)	29 (17.4)	66 (39.5)	62 (37.1)	4.07, level 4 High
Attitude	–	4 (2.4)	6 (3.6)	35 (21.0)	122 (73.1)	4.65, level 5 Very high
Average	–	2 (1.2)	52 (31.1)	63 (37.7)	50 (29.9)	3.96, level 4 High

Table 2. Levels required for the development of specific competencies (GAP = good agricultural practices).

Level 1, less than average (1.00–1.80)	Level 2, average or slightly less (1.81–2.61)	Level 3, slightly higher (2.61–3.40)	Level 4, higher (3.41–4.20)	Level 5, much higher (4.21–5.00)
Trainer skill		Requisite GAP, rice knowledge	Average competency attitude for a technology transferring agent for skills on rice cultivation	Attitude to SMART farmers

SWOT analysis

We conducted an analysis of the strengths-weaknesses-opportunities-threats (SWOT) of the farmer-to-farmer extension approach (Table 3). We identified four strategies to overcome the risks identified with the system. These are a development strategy, a rectify strategy, a protection strategy, and a risk management strategy. Table 3 describes these four strategies.

Lessons learned

During the implementation of the SMART farmer process in 2007 and 2008, we learned that the first priority is to select a good site to implement the trial program. The site must have a group of farmers who are interested in the program. The rigor of good

Table 3. SWOT analysis on farmer-to-farmer extension system approach.

	Strengths	Weaknesses
Opportunities	**Development strategy**	**Rectify strategy**
	1. SMART farmer competency development continuously	1. Increase efficiency of core trainer
	2. SMART farmers program should be concerned with participatory approach for all stakeholders	2. Have a cooperation system among agencies involved
	3. Develop the rice research center as a learning base	3. Develop monitoring, evaluation, and supervision system
Threats	**Protection strategy**	**Risk management strategy**
	1. Cost reduction, technology transfer	1. All-level strategy planning for both national and local government
	2. Rice value added	2. Build a new rice generation
	3. Advanced research and development	3. Set up a Risk Warning System (RWS)
	4. To succeed, promote rice culture for the new generation	4. Have cost reduction program

site selection and farmer group selection can be relaxed once effective demonstration sites for the SMART farmer approach have been established.

A key to the sites that have been successful is strong adherence to the selection criteria established for SMART farmers. The monitoring of the competency of the selected farmers then provides another layer in determining what training is required for farmers to become highly effective trainers in the farmer-to-farmer extension system. This in turn indicated that we need to develop a better curriculum for the training program, a program that is more in line with the competencies that need to be strengthened.

Summary and conclusions

The farmer-to-farmer extension approach has been applied to develop and sustain an effective extension program for rice production and to facilitate rapid widespread adoption of new technologies and production processes. The success of the program depends on providing the right support and incentives for a subset of farmers who themselves become effective trainers of other farmers. These lead farmers are designated as SMART farmers who will be local technology transferring agents. The success of the program will depend on the competency of these SMART farmers, and the training programs that aim to strengthen those other farmers that were identified as having relatively inferior capacities and capabilities for extension.

A lead farmer selection process and good farmer training program have also been established. We have learned from pilot studies that the farmer-to-farmer extension approach for rice production in Thailand can be highly effective, particularly if the guidelines for selection of SMART farmers are strictly followed. The effort in developing a better and more innovative farmer training program has been effective in empowering farmers to adopt and experiment with new technologies, and in influencing the attitudes and practices of other farmers.

The extension program should be integrated among agencies at both the national and grass-roots level. Specific activities to strengthen the linkage between research and extension are also needed. Ideally, this would be accomplished in a participatory context, particularly for decision-making.

Regular meetings are required to review progress and examine issues that arise for a particular cropping season. An effective monitoring program that incorporates focus group discussions and occasional surveys of competencies of the SMART farmers will provide important feedback to those who are implementing the program nationally and locally. The key to the success of the program relies on the implementation of SMART farmer as a foundation for catalyzing effective farmer-to-farmer extension. The SMART farmer program is designed around strong involvement of farmers to select their own key farmer representatives, a better design for both training programs and extension networking systems, effective empowerment for both extension agents and farmers, and the implementation of a monitoring and assessment program.

References

Department of Agricultural Extension. 2004. Monitoring and evaluation report. Thailand Department of Agricultural Extension, Bangkok.

Office of Agricultural Economics. 2009. Agricultural statistics of Thailand. Agricultural Economics, Ministry of Agriculture. Bangkok.

Notes

Author's address: Rice Department, Phaholyothin Road, Chatuchak, Bangkok 10900, Thailand. Tel. (66)8-1827-7420, email: ksoitong@hotmail.com.

Experiences from the Private Sector

Public-private partnership: a case study for the introduction of flat-bed dryers through the private sector in Myanmar

Myo Aung Kyaw and Martin Gummert

Experiments conducted by the Postproduction Work Group of the Irrigated Rice Research Consortium (IRRC) have shown that the use of mechanical dryers can minimize physical losses and double head-rice recovery compared with the traditional practice of sun-drying. Nevertheless, mechanical dryers were not widely used in Myanmar for drying rice until 2004. The technology was brought to Myanmar after the main author (MAK) participated in a training course in Vietnam sponsored by the IRRC on drying systems for rice. In Myanmar, we championed the introduction of the Vietnamese design of a flat-bed dryer with 4-t capacity. The target audience was farmers and rice millers, and the facilitating institution for promoting the technology was the Myanmar Rice and Paddy Traders' Association (MRPTA). Four dryers have been installed at the village level, where the target end users were individual farmers, who benefit by implementing the technology through a group scheme. This paper describes the dissemination process, the technology champions, and the public and private stakeholder partnerships that facilitated the introduction. By October 2008, 47 dryers were installed and it is estimated that they can service annually between 3,525 and 5,640 households. The prospect of steady annual growth in the number of dryers installed is promising, so the anticipated impact in future years is an order of magnitude higher. We present lessons learned from the introduction and diffusion of this new technology, and conclusions for future developments in postproduction technologies.

Keywords: dryer, flat bed, Vietnam, rice husk furnace, public-private partnership

Rice is the staple food for 56 million Myanma people and is an export crop. Rice production plays a major role in the life of most farmers and for the economy of the nation. Rice is grown on more than 7 millions ha, of which approximately 5 million ha are rainfed and 2 million ha are irrigated summer rice cultivation, respectively (DAP-MOAI 2008).

For food security reasons, government policy has paid much attention to extending the area of rice production and land development in order to increase production. Postharvest operations in Myanmar are characterized by high losses that occur throughout the postharvest chain from the time of harvest to the selling of rice in the market. Postharvest losses in Southeast Asia range from 10% to 25% and, combined with qualitative losses, may even reach a 50% loss of value at the point of sale (Rickman et al 2005). This significantly reduces the already low income of smallholder farmers. Profits from rice farming are so low that in some areas farmers often do not plant rice and leave their fields idle instead. Therefore, it as an imperative to reduce postharvest losses in order to increase farmers' income and to ensure a food supply for poor rice consumers.

In lower Myanmar, the harvesting period for rainfed rice is October to December, and for summer rice it is March to May. In middle and upper Myanmar, summer rice is harvested from June to August. In those harvest periods, farmers face episodic early rainfalls and their harvested crops can become significantly damaged because of rain and improper drying. Consequently, the price of their paddy often declines to about 50% of that of properly dried paddy. This problem is more serious in summer rice-cultivating areas where facilities are limited for drying paddy.

The Myanmar Rice and Paddy Traders' Association (MRPTA) became aware of the significance of losses to rice during postharvest operations after one of the authors (MAK) participated in a 3-week Postproduction Training Course sponsored by the Irrigated Rice Research Consortium (IRRC) and held at the International Rice Research Institute (IRRI) in October 2004. In early 2005, the MRPTA developed one unit of a large commercial dryer in West Bago Division and one unit of an IRRI-designed flat-bed dryer with 1-t capacity (Gummert and Rickman 2005) for demonstration purposes. Although the operating performance of the IRRI 1-t flat-bed dryer was good, its capacity was too small for economic operations and the performance of the locally designed large-scale commercial dryer was not satisfactory because of improper design and fan fabrication.

In Vietnam, on the other hand, flat-bed dryers with 4–10-t capacity were commercialized successfully, and by 2004 more than 6,200 units had been installed in the Mekong Delta (Phan Hieu Hien 2008). With support from the Postproduction Work Group (PPWG) of the Irrigated Rice Research Consortium, the MRPTA had a representative sponsored to attend the Drying System and Dryer Fabrication Training at the Center for Agricultural Energy and Machinery (CAEM) of Nong Lam University (NLU) in Vietnam in October 2005. By the end of 2005, MRPTA had begun local production of Vietnamese-type flat-bed dryers with 4-t capacity, called the SHG-4 dryer, and promotional activities in the major rice-producing states and divisions of Myanmar.

The paddy dryers were new to Myanmar millers and farmers; therefore, the following facts had to be considered before starting dryer development in Myanmar:

- Who would be targeted during the first phase of dryer promotion, millers or farmers? And why?
- How long would it take for the dryer to be adopted by users?
- What would be the best pathways to approach potential users to generate awareness?
- Which geographic areas need to be emphasized?

The majority of rice millers in Myanmar are conservative in nature; therefore, they would like to rely entirely on sun-drying although they know about the problems and losses in the harvest season due to rain. On the other hand, Myanmar farmers have little knowledge about postharvest technology and the potential benefits. Therefore, they did not consider losses to their rice during postharvest operations to be serious despite the problems they face during the harvest season. They just considered those problems as unavoidable and a fact of life for smallholder-farmer agriculture. As a result, the MRPTA realized that potential technological solutions for challenging postharvest problems had to be introduced step by step to raise the awareness of all stakeholders. This chapter describes the steps we followed and the partnerships we developed for the transfer of a technical postharvest product emanating from international research to its practical validation and hence rapid adoption by end users in Myanmar.

Research and extension interface and multistakeholder partnership

Networking and partnership building

International partners. Through the PPWG of the IRRC, the MRPTA developed an effective partnership with an international research institution. Formal collaboration between the MRPTA and IRRI began in 2005. Another key collaborator was CAEM of Nong Lam University in Ho Chi Minh City, Vietnam, which assisted with the transfer of the dryer fabrication technology from Vietnam to Myanmar.

Subsidiary associations. After the training at IRRI, the MRPTA conducted training and demonstrations in collaboration with MRPTA subsidiary associations, including state and divisional associations, and district- and township-level associations, in the major rice-producing areas of Ayeyarwaddy, West and East Bago, Yangon, Sagaing, Mandalay, and Magway divisions.

Other rice-related NGOs in Myanmar. In Myanmar, rice-related nongovernmental organizations include the MRPTA, Myanmar Rice Millers' Association (MRMA), and the Myanmar Rice Producers' Association (MPPA). These are organized under the Union of the Myanmar Federation of the Chamber of Commerce and Industry (UMFCCI). Dryer demonstrations and talks at workshops or seminars were presented to these organizations, especially at their annual conferences. This raised awareness among business entrepreneurs.

Public organizations—Myanma Agricultural Services. Myanmar has an extensive national agricultural extension network under the management of Myanma Agricultural Services (MAS) of the government of Myanmar. One of the mandates of this extension arm of MAS is to facilitate the transfer of agricultural technologies to farmers. The MRPTA in collaboration with MAS held capacity-building training for extension staff at least twice a year.

Public organizations—general administrative departments. Other networking partners are government administrative bodies. We conducted presentations and demonstrations to government bodies at the divisional, district, and township levels. Once staff from these partners understood the significance of postharvest losses, they

Table 1. State and divisional distribution of flat-bed paddy dryers in Myanmar (February 2006 to September 2008).

States and divisions	No. of dryers	Remarks
West Bago Division	17	Irrigated
Ayeyarwady Division	10	Rainfed
Mandalay Division	5	Irrigated
Sagaing Division	4	Irrigated
Magway Division	4	Irrigated
Nay Pyi Taw	4	3-t capacity/irrigated
Yangon Division	2	Rainfed
Southern Shan State	1	Rainfed/highland
Total	47	

realized that a major technical solution for grain drying in adverse weather is the use of mechanical paddy dryers. Getting support from government authorities for the introduction of the technology at an early stage of dryer use is important for promoting and disseminating the dryers through public extension channels.

Evolution of partnership and historical engagement

Because of the lack of an appropriate technology, a dryer developed in Myanmar for rice paddy could not dry paddy according to our intended capacity. The MRPTA received the dryer fabrication technology from Vietnam in October 2005, when MAK participated in Dryer Manufacturing Training organized and sponsored by the IRRC and conducted by NLU in Ho Chi Minh City, Vietnam. The training included sessions on dryer component manufacturing, dryer testing, and field visits to commercial dryer installations in the Mekong Delta. In early 2006, the MRPTA started to introduce the Vietnamese-type dryer in Myanmar. Promotional activities initially targeted the millers of major rice-producing divisions for the following reasons:

- They can more easily afford to invest in dryers than farmers.
- They are better able to obtain economic benefit from using that facility in their business by selling better-quality milled rice.
- In the wet season, the option for farmers of sun-drying during wet weather conditions is not possible. Therefore, millers buy wet paddy from farmers directly after it has been threshed in the field. Although the millers at the time had no machine-drying facility, they could not refuse to buy wet paddy because they were long-term partners in the supply chain. However, the most vulnerable persons in this kind of situation are the farmers. They have to agree to the wet paddy price that is decided by the miller, whether it is reasonable or not. The ones suffering the highest losses are therefore the farmers.

Within 3 years, a total of 47 dryer units were built. They were installed in seven divisions and one state (Table 1).

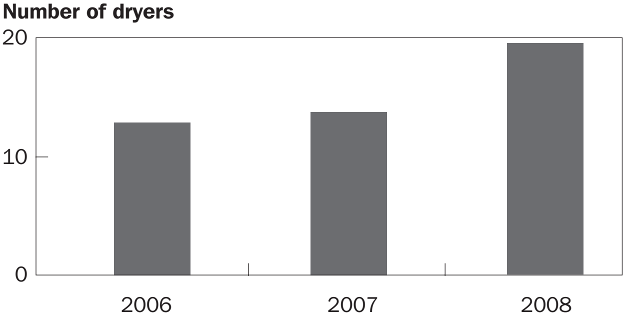

Fig. 1. Annual increase in dryer installations from January 2006 to August 2008.

Dynamics of partnerships

The MRPTA is a nonprofit as well as nongovernmental organization; therefore, it cannot provide long-term promotional, installation, and after-sales services. For example, promotional activities require funding to conduct demonstrations and to advertise through multimedia channels. Therefore, we developed a business-oriented approach by organizing a community-based organization, namely, the Pioneer Postharvest Development Group (PPHDG), for the long-term and sustainable development of dryers through self-financing and self-reliance.

The number of dryers installed increased year by year, with a dynamic growth pattern over a three-year period (Fig. 1).

As the number of dryers increased, the nature of dryer ownership also diversified (Table 2).

Once the technology was demonstrated to be effective in performance and economic competitiveness, the dryer became popular, especially in irrigated rice areas such as West Bago, Mandalay, and Sagaing divisons, which have three crops each year (summer rice, monsoon rice, and pulses), with one rice crop harvested during the wet season. The more the dryers' efficiency became known, the greater the interest by people to copy and even start manufacturing them as a business. About 20 to 25 units of copied dryers have been constructed in those areas. Although they are not as effective as the dryers fabricated according to the Vietnamese standards, we still expect quality improvement in their grains compared to sun-drying under adverse weather conditions.

Functions of partners

Technical dissemination and recommendations and facilitation of these technologies are done by the partners. Some promotional activities were not effective without their support. For instance, in August 2007, a one-day presentation and demonstration of dryers was implemented in Nay Pyi Taw-Pyin Ma Na District. The organizers were the Nay Pyi Taw-Pyin Ma Na District Myanma Agricultural Services and the PPHDG. That occasion was attended by the divisional commander of Nay Pyi Taw and more

Table 2. Distribution of nature of dryer ownership and background.

Nature of ownership	Number of dryers	Percentage	Remarks
Rice miller	30	64	Including miller community, 1 unit
Private seed farm	4	9	
Farmer community	7	15	5 units—partly funded by the Embassy of the Federal Republic of Germany
Bean (chickpea) processing	3	6	
Government seed farm	1	2	
Cooperative	1	2	
Paddy contractor (agent)	1	2	
Total	47	100	

than 200 farmers, millers, and traders of that area. From the presentations, the commander and local authorities realized the significance of postharvest losses and how these could be overcome by using paddy dryers. As a result, they decided to construct a 3-t-capacity Vietnamese-designed flat-bed dryer in one township of Nay Pyi Taw-Pyin Ma Na District. In 2008, the commander then authorized the construction of one dryer in every township. The MRPTA was subsequently commissioned to construct three flat-bed dryers of 3-t capacity, and one mobile dryer. In addition to drying paddy, they also have the potential to dry maize and green mungbeans.The local authority arranged a 2-year loan at low interest for the construction of these dryers.

The PPHD, on behalf of the MRPTA, has provided technical support to partner organizations and individual users as follows:

- Promotion of dryers to millers and farmers *before* installation,
- Advice on technical matters *during* installation, and
- Guidance on dryer operation and maintenance *after* installation.

Innovations

Some of our clients requested modifications of the design and layouts of the dryer. However, our Vietnamese partners instructed us not to modify their design because we were novices in dryer development. If we modified the dryer design and it performed poorly, this could undermine our positive promotional messages. Instead, the MRPTA collaborated with our Vietnamese counterparts to develop innovations suited for Myanmar conditions. For instance, a semiautomatic rice husk furnace has been developed for commercial operation in Vietnam. This type of furnace appears well suited for Myanmar so we are in the process of developing a similar furnace under the direction of our NLU collaborators.

However, some adaptation in fabrication was required because of differences in the availability of construction materials. For instance, in Myanmar, brick measurements are 9 × 4.5 × 3 inches. In Vietnam, measurements are in imperial units. The bricks in Myanmar are larger. This led to the construction of a larger furnace than those in Vietnam. Another modification was related to the assembly of the inner brick layer inside the cylindrical combustion chamber of the furnace: we had to affix these bricks with nuts and screws to the outer cover in order to prevent them from becoming loose during the long-term operation of the furnace.

The dryer was effective in drying other crops, including beans, maize, ground nuts, coffee, etc. One good example was chickpea processing. Chickpeas are normally dried in the sun. As with rice, sun-drying of chickpea is usually not possible during the rainy season. We found the SHG-4 dryer to be highly reliable and effective for drying chickpeas, taking 3 to 4 hours for achieving acceptable quality. More dryers are planned for chickpea processing.

Dissemination of rice technologies

We have mainly emphasized effective postharvest handling of rice in order to minimize quantitative and qualitative losses. The emphasis depends on the nature of the operation, the level of education of the stakeholder, and their underlying facilities. Technology dissemination strategies are tailored to users' (farmers or millers) needs, their access to finance, the nature of their work load, and the location of their fields relative to the dryer. We disseminated the technology to end users via demonstrations, promotional material, and training. These three activities can be combined, and the sequence may change according to the situation. For example, for dryer development, millers were informed about the new rice dryers at the Annual Conference of the Rice Millers' Association. In this event, we demonstrated a small-scale paddy dryer and made brief presentations about postharvest technology and dryers suitable for Myanmar. In addition, handouts and pamphlets were distributed.

Media promotion of the dryer was also an integral part of its dissemination. Interviews were conducted with the developers of the dryers and with the first adopter end users, advertisements were placed in well-known journals, newspapers, and magazines, and articles were published in agricultural magazines (e.g., MNA 2006).

Training was conducted for one day in rice-producing areas. Those who attended were local authorities, local extension officials, and local association partners. We aimed to foster effective public-private partnerships. The content of the training included information on the application of the mechanical dryer, and instruction on how to operate it, maintain it, and troubleshoot potential problems. The training developed a strong commitment and confidence in those interested in adopting the new technology.

From 2005 to 2008, the PPHDG team of the MRPTA, with support from the IRRC Postproduction Work Group, conducted 37 postharvest and dryer extension activities across seven divisions and one state. Apart from the one-day training activities, a few 3- to 5-day training courses were also conducted. On some occasions, training was conducted in collaboration with governmental organizations such as the Ministry of Agriculture and Irrigation (MOAI), Ministry of Commerce, and Ministry of Cooperatives; nongovernmental organizations such as UMFCCI, MRMA, and

MPPA; and international organizations such as the Japan International Cooperation Agency (JICA).

Myanmar people are conservative in nature and very reluctant to change their traditional practices. An important message to emerge from our training and media activities was the need to repeat our promotion, demonstration, and training to reinforce the advantages of the new technologies. Some people who attended the training for the first time were not fully convinced of the need to change from sun-drying, which to them is an inexpensive (although labor-intensive) and familiar practice. They required follow-up activities to change their attitude.

Impacts

In Myanmar, the average capacity of each dryer ranged from 10 to 15 tons per 24-h operation, equivalent to the amount of rice produced from 2.5 to 4 ha. In each year, if we assume 60 days of operation, one dryer would be able to process rice harvested from 150 to 240 ha. Therefore, the 47 units in operation would annually cover an area of 7,050 to 11,280 ha. In Myanmar, the mean farm size is 2 ha; therefore, the 47 units can service annually from 3,525 to 5,640 households. Moreover, the presence of the dryers significantly reduces the risk of rain toward the end of a cropping season reducing farmers' income. Therefore, the dryers provide an important surety to the value of their harvest that had been previously lacking. This is a major development for traditional Myanmar farmers, who are risk-averse.

The collaborative MRPTA and IRRC initiative had a major impact through building capacity of farmers, millers, traders, business entrepreneurs, MAS extension staff, and village heads. The 37 training presentations and dryer demonstrations involved 3,500 participants.

Case studies on adoption and impact

After 3 years, it became clear that the potential for adoption of the rice dryer technology was highest in the irrigated areas in West Bago and Mandalay divisions, especially where there are three crops a year. In this section, we provide details on some on the success stories with the dryer technology.

Success story 1

This dryer is located in Sin Ywa Gyi Village, Patheingyi Township, Mandalay Division, where rice is cultivated on 720 ha. The dryer owner is a rice miller and the capacity of the rice mill is 1 t /h. This dryer was constructed in July 2007. In the 2007 wet season, the dryer had been completed just in time for 1 month of operation, which led to the drying of 200 tons of paddy. In November and December 2007, the paddy volume dried by the machine increased to 400 t. Although it was the cold season with dry weather conditions, the rice miller sun-dried his paddy to 18% moisture content (MC) and then used the flat-bed dryer for final drying to 14%, which is suitable for milling.

One unit of this 4-t-capacity dryer could not cover the 720 ha of rice in the village. The miller, who was pleased with the success of his first unit, then constructed another dryer with 4-t capacity in April 2008. This dryer was operational for the 2008 summer rice harvest (June to August), when the miller was able to dry 1,000 t of paddy using his two dryers.

Besides the reduction in losses associated with the risk of wet weather, the miller reported higher head-rice recovery and higher milling returns than with sun drying. This led to a higher market price and better financial returns. The owner understood these advantages and capitalized on the technology. He reported an increase in price of new milled rice compared to ordinary sun drying of US$0.50 to $0.80 per 50-kg sack, which increased to $1.50 when the market had higher demand. The miller was quite pleased by the increase in his profit from using the new mechanical rice dryer technology.

From a market perspective, traders also benefit from evenly dried rice. Traders prefer to buy 1,000 sacks of rice with an MC of 14%. If the rice has higher MC, they need to spread the sacks out to prevent them from getting too hot; this necessitates more floor space and concomitant reductions in profit.

Other advantages for using dryers for paddy drying are better management for grain handling, lower shattering losses, and better monitoring of losses due to human activity (theft by laborers) by checking weight loss and MC. If millers do not have a dryer, they need to arrange for and organize laborers, and find places for sun-drying (e.g., monastery compound, football field, and tar roads), possibly leading to high losses in quantity and quality.

Success story 2

This dryer is located in Kan Tee Lay Village, Myit Thar Township, Mandalay Division. The owner is a private seed grower who owns 80 ha of rice fields for seed production. This seed grower has to organize many hired laborers for sun-drying because good germination of rice seeds depends on the moisture content during storage. Moreover, good germination rates are essential for taking advantage of episodic rains for good crop establishment during the summer rice season. Prior to the use of a mechanical flat-bed dryer, seed growers had regular losses in seed quality because of unfavorable weather, despite careful handling.

In October 2006, the PPHDG developed a 4-t-capacity Vietnamese flat-bed dryer at the site. When the dryer was operational, the PPHDG representatives trained a seed grower to carefully maintain the dryer temperature at 40 °C and to reduce the moisture content of the rice to 13%. The seed grower understood the potential benefits that effective drying could generate through quality improvement compared to past practices. These included better germination rates, acceptable moisture content, cleaner and healthier seed, shiny seed color, and attractive seed appearance. Most importantly, the grower no longer had to worry about inclement weather.

When the mechanically dried rice seeds were sent to the market, client demand increased unexpectedly and growers increased their seed price by 40% compared with the previous season. In July 2006, 1 kg of sun-dried seed brought $0.266; in

November-December 2006, growers sold 1 kg of mechanically dried seed for \$0.38. Therefore, they received a >\$100 price increase for 1 t of seed sold to the market. The price of ordinary rice seed at that time was about \$304 per t. Therefore, seeds dried by a machine realized >25% more returns. Four months later, a grower decided to construct another dryer unit for his seed farm located in another area, Patheingyi Township of Mandalay Division.

By using machine drying, he got both an economic benefit and could also save labor and re-allocate laborers to crop production activities. This seed producer was also trained to manage his production output and to monitor the unit cost of drying.

Lessons learned

Bridging research and extension

The MRPTA, through partnerships with NLU and the IRRC Postproduction Work Group, validated the technology under Myanmar conditions, and provided extension and fabrication services to users. It was not easy to gain confidence from users unless they were technically strong. Thus, continuous networking and exchange of ideas and lessons learned were crucial for providing reliable service to users and for further development and acceptance of the technology. The development of a strong partnership with international partners was essential for the research knowledge to be successfully adopted by end users in Myanmar.

Although we were offering support in building capacity of end users, we learned that the extension activity had to be need based, with the priority varying according to the location, traditional knowledge and practices, and the technical background and attitude of recipients (Palis 2006, Vanclay 2004).

Partnership with stakeholders

The partnership among stakeholders becomes dynamic and active when there was a common interest for the development of an innovative technology. The interest and cooperation of partner organizations within Myanmar played an important role in implementing successful extension activities.

The MRPTA scaled out the technology and disseminated it to the end users, the millers and farmers, with the collaboration of public organizations and non-governmental organizations. The collaborating organizations played important roles, according to their mandate, through recommendations, appropriate referrals, and the facilitation of matters in order to obtain wider coverage and effective dissemination of the technology.

One example of successful public-private partnership in dissemination of the technology was in Nay Pyi Taw District (the capital of Myanmar) described in the section “Functions of partners.”

On the other hand, the promotion of dryers faced some limitations. Some millers and traders did not want to invest in the technology before they understood and saw the dryer in action. For example, when promotion took place for rice millers of upper Myanmar, Sagaing Division, a majority of millers thought they had sufficient time to dry their paddy in the field and that weather limitations were negligible, and the operation period for the dryer was too short. They therefore did not want to invest in dryers. The first 4-ton-capacity dryer was constructed in June 2007 in that area and, although the miller could dry his paddy for only 1 month, he quickly realized the advantages of the technology: better quality, better efficiency in milling recovery, a more marketable product, a higher sales price, and lower labor requirement for drying. The miller responded by saying that he did not want to share those advantages with other millers in that season in order to have a better return on his investment!

Another constraint was that small-scale dryers at the farm level with 1-t capacity, which were also promoted, needed electricity to run the motor for driving the fan. Therefore, it was not possible to introduce these so-called low-cost dryers in Myanmar. We do plan, however, in 2009-10, with assistance from the IRRC, to introduce a small-scale flat-bed dryer powered by a combustion engine. The aim is to produce a unit that is affordable to smallholder farmers or small groups of farmers.

Extension strategies

As a guiding principle, we assumed that each dryer needed at least one extension activity.

When one dryer was installed in an area, a short training program on operation and maintenance was provided to dryer owners and their operators. We invited other farmers and millers to these short training activities so as to introduce them to the technology and for them to understand the advantages of using the technology for grain drying. Farmers were also informed about the planned operation of a newly installed dryer so that they could negotiate access for drying their crop.

Local champions for extension

Some dryer owners are very good local champions of the technology because they understand its importance for improving the quality of their rice, and because they are often highly regarded by local farmers. When there was an extension activity in the proximity of their dryer, they were invited to speak about their experiences using the dryer. This is a most effective pathway for extension to users.

The MRPTA requested feedback from the owners of the 47 dryers after they had had at least one full season of operation. We encouraged them to provide suggestions for improvement and new ideas on postproduction technologies. This also provided an opportunity to develop an informal network that included the service providers and various clients. In 2009-10, the PPHDG plans to develop a formal postharvest network and to conduct follow-up capacity building using a needs-based approach that will include substantial input from local champions, and will foster future local champions.

Government staff can also be highly effective local champions for a representative area. For example, the deputy MAS supervisor from Patheingyi Township introduced the postharvest technology to farmers whenever she visited different field areas under her responsibility. She was provided with vinyl posters and pamphlets to support her extension activity.

The role of multimedia

The dissemination of the technology among stakeholders was strengthened by the use of vinyl posters, pamphlets, and fact sheets on postharvest technology. These were displayed and handed out during promotional activities and training events. The extension activities were reinforced through the publication of articles in local newspapers related to grain drying, machine drying, and other postharvest technologies.

Approach

The MRPTA is a nonprofit and nongovernment organization. It therefore had limited funding for promotional activities. Apart from the mandatory one training session for each new unit, we were opportunistic in using field days, media coverage, etc., to sustain the exposure of potential stakeholders to the new technology. We aimed to gradually generate changes in their concepts and attitude.

The PPHDG, on behalf of the MRPTA, is now an established service provider for the mechanical grain dryer in Myanmar, and it also provides information on the development of other postharvest technologies. We adopt a business-oriented approach focusing on long-term sustainable development through self-financing and self-reliance.

Future prospects

Opportunities

Mechanical dryers are an imperative in Myanmar to increase the quality of rice for milling, and for rice seed production. Dryers are essential when the weather is inclement at harvest, and in areas where irrigated rice has to be harvested during the wet season.

In 2008, irrigated rice was grown on more than 2.2 million ha, out of 8.1 million ha cultivated for rice (DAP-MOAI 2008). These areas are located mainly in West and East Bago, Sagaing, Mandalay, and some areas of Magway Division. These are priority areas for agricultural production and they provide an opportunity for the further development of dryers.

During 2005-08 (IRRC Phase III), we gave much attention to the development of the 4-t-capacity SHG-4 dryer, primarily for rice millers. During 2009-12 (IRRC Phase IV), PPHDG plans to develop different sizes of dryer for the different requirements of stakeholders: 0.5 t for smallholder farmers, 2 t and 3 t for farmer groups or small millers, and up to 8 t per batch. The promotional activities will focus on the resources and requirements of farmers, such as affordable price, mobility and ease of transport of their paddy rice (e.g., with tractors), and availability of a power source (a fan has to be powered by a diesel engine).

Create strong linkages between partner organizations and users

Technology changes from time to time. The MRPTA, through the facilitation of the IRRC, will continue to link with CAEM of Nong Lam University to explore other developments of postproduction technologies relevant for Myanmar.

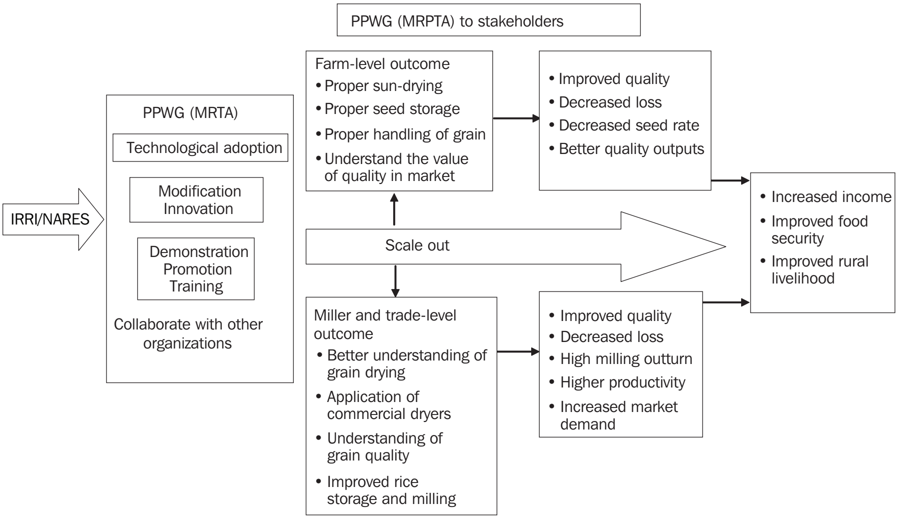

Fig. 2. The research-to-impact pathway model developed for postproduction technologies in Myanmar.

Based on what we learned from 2005 to 2008, we have developed a research-to-impact pathway model, which will be our guide for further strengthening the partnership between the public- and private-sector organizations in Myanmar (Fig. 2). This pathway will have as its foundation a local network for postproduction technologies. The local champions are the key players as well as focal points for extension of technologies in their local areas. Capacity building for the local champions and government public-sector extension staffs will include training on the use of grain quality kits, low-cost moisture meters, a temperature-measuring apparatus, air flow/velocity measuring meters, hygrometers and thermometers, and digital scales. Our aim is to develop more effective and efficient widespread dissemination of innovative postproduction technologies.

Conclusions

Annual paddy rice production in Myanmar is nearly 30 million t. Postharvest losses in quantity can be 10% to 25% of production. If we can reduce losses by just 1%, we will be able to feed an additional 0.9 million people in Myanmar. For quality improvement, the potential benefits are even higher. Together, the improvement in rice quality and decreases in postharvest losses offer the potential of considerably more income to the millions of vulnerable farmers in Myanmar. Thus, a reduction in qualitative and quantitative losses to rice postharvest could significantly improve the livelihoods of poor smallholder farmers. If this transpires, the economic structure of the country will be considerably strengthened. The MRPTA has a strong commitment to continue to verify and validate new technologies that could help further develop the rice industry of Myanmar.

References

DAP-MOAI (Department of Agricultural Planning, Ministry of Agriculture and Irrigation). 2008. Myanmar agriculture at a glance. Department of Agricultural Planning, Ministry of Agriculture and Irrigation, Nay Pyi Taw, Myanmar. 132 p.

Gummert M, Rickman J. 2005. Flat-bed dryer, 1 t. Fact sheet from www.knowledgebank.irri.org/postproductioncourse/factsheetsNRefences/Drying/Flat%20Bed%20Dryer%20-%201t.doc.

MNA. 2006: Methods on crop drying and quality control explained. The New Light of Myanmar. XIII(351):Sunday, 2 April 2006. Front page.

Palis FG. 2006. The role of culture in farmer learning and technology adoption: a case study of farmer field schools among rice farmers in Central Luzon, Philippines. Agric. Human Values 23(4):491-500.

Rickman J, et al. 2005. Postproduction course. IRRI E-learning course, from www.knowledgebank.irri.org/postproductioncourse/.

Vanclay F. 2004. Social principles for agricultural extension to assist in the promotion of natural resource management. Austr. J. Exp. Agric. 44(3):213-222.

Notes

Authors' addresses: Myo Aung Kyaw, Myanmar Rice and Paddy Traders' Association No. 100, B/T Wadan & Lanthit St. Port Compound, Seik-kan T/S, Yangon, Myanmar, e-mail: drmakmrpta@gmail.com; Martin Gummert, International Rice Research Institute, DAPO Box 7777, Manila, Philippines, e-mail: m.gummert@cgiar.org.

The roles of change agents and opinion leaders in the diffusion of agricultural technologies in Vietnam: a case study of ACIAR–World Vision collaborative adaptive research projects

Le Anh Tuan, Grant R. Singleton, Nguyen Viet Dzung, and Florencia G. Palis

Diffusion of innovation in agriculture is a complex process. The success of this process is governed by the various factors—technology characteristics, socio-cultural factors, participation of stakeholders, and environment—that enable and sustain effective interaction between these stakeholders. Previous studies in technology diffusion in agriculture indicate that not all technologies that have their advantages over others and are compatible to users' setting and simple and testable are adopted by end-users. When a technology is tested, the trial process also requires effective facilitation of change agents and opinion leaders combined with sufficient timing and financial support before the technology is eventually owned and adopted by the target users. In this chapter, using the theory of diffusion of innovation, we reviewed the success of two projects implemented by World Vision International in Vietnam under an adaptive research program funded by the Australian Centre for International Agricultural Research. With the presence of a 10-year development program (namely, the Area Development Program), we argued that the likelihood for success in the diffusion of innovation is more likely for adoption when the trial of the introduced technology has sufficient time, financing, and a commitment by all stakeholders.

Keywords: diffusion of innovation, stakeholders, agricultural extension, change agent, opinion leaders

The ultimate goal of innovation diffusion in agricultural extension is to improve the well-being of farming people. Extension activities are typically done through validating and promoting the use of agricultural technologies that could potentially improve crop productivity and farmers' income. Technologies introduced, however, are put into use differently. The rate at which a new technology is adopted depends on the technology traits, the personal characteristics of farmers, and the local setting in which the technology transfer process takes place.

Given numerous achievements in agricultural research and development, new technologies are regularly becoming available for farmers' adoption. However, in some situations, farmers fail to adopt a technology because of various socioeconomic, cultural, and technological constraints. Success in innovation diffusion is subjected to a wide range of factors—social norms, networks, attitudes, beliefs, knowledge, practices, to name a few. Bohlen argued: "The adoption of a new idea or practice is not a simple unit act, but rather a complex pattern of mental activities combined with actions before an individual fully accepts or adopts a new idea" (Bohlen 1964, p 268). For Buttel et al (1990), the more complex an idea is, the more likely the farmers have to change their attitude and belief to receive timely information before adopting the innovation. In contrast, the easier an innovation is for farmers to test, the more likely the innovation will be adopted.

Understanding the nature of the innovation diffusion process in agriculture and the factors that affect it helps predict the likelihood of adoption of an innovation. Without a good understanding of how an innovation and users interact in their own context before and during an innovation process, an attempt to transfer an innovation to the target users will likely fail. Unexpected consequences may arise as a result of that. Understanding of the process of innovation, as such, is useful for projecting whether a new technology will succeed (Sevcik 2004).

Review of literature

Rogers (2003) defined diffusion of an innovation as the "process by which an innovation is communicated through certain channels over time among the members of a social system," whereas an innovation itself is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 2003, p 6). According to Rogers, innovation diffusion is a type of communication in which the new idea is expected to be diffused to the target audience to achieve a desired social change in the structure and function of a social system. He argued that five critical attributes of an innovation could be used to explain and predict the rate of adoption: *relative advantages, compatibility, complexity, trialability,* and *observability*. In reality, however, other exogenous factors may affect the decision to adopt a new technology, irrespective of whether or not the technology is tested and its advantages (over an existing technology) are evident. Change agents and opinion leaders are two among those exogenous factors.

A *change agent* is "an individual who influences clients' innovation-decisions in a direction deemed desirable by a change agency" (Rogers 1995, p 27). Change agents generally encourage adoption of a new idea. However, they also may be ones who, in some cases, slow down or even hold up the adoption of an innovation that is, in their own opinion, undesirable. Change agents usually work with opinion leaders to enhance the impact of their diffusion activities in a social system. They are typically more innovative than others and their communication may pose challenges to the diffusion process.

In a community, those who usually provide advice and information to other people and maintain a high level of credibility are usually referred to as opinion leaders. According to Rogers (1995), opinion leadership is "the degree to which an individual is able to influence other individuals' attitudes or overt behavior informally in a desired way with relative frequency" (Rogers 1995, p 27). In a modern social system, opinion leaders are innovative. However, in traditional social systems, opinion leaders may be indicative of traditional behavior and norms—adhering to local values and practices—and are, in some cases, even strongly against changes or external influences. Opinion leaders, however, are sometimes influenced by change agents. When opinion leaders exhibit a level of change that is no longer a tradition in that social system, they may be at risk of losing credibility and influence on their former followers.

Overview

In this chapter, we argue that, when an effective, demand-driven collaboration between change agents (exogenous) and opinion leaders (endogenous) is fostered throughout an innovation diffusion process, this innovation diffusion effort is more likely to be successful when it is first tested, and is more likely to be sustained if the demand remains. To demonstrate, we reviewed the results of two adaptive research projects implemented by World Vision (WV) International in Vietnam with financial support from the Australian Centre for International Agricultural Research:

a) Rodent Control in Rice-Based Farming Systems (with technical support from the National Institute of Plant Protection, Southern Institute of Agricultural Sciences (Vietnam), Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the International Rice Research Institute (IRRI); and

b) Soil Fertility Improvement project (with technical support from the National Institute of Soils and Fertilizers (Vietnam) and the University of Queensland). An add-on project (namely, Soil Capability Classification) was linked to the completed soil fertility project and was conducted with technical support from the National Institute of Soils and Fertilizers, Southern Institute of Agricultural Sciences (Vietnam), and the Queensland Department of Natural Resources and Mines.

As mentioned earlier, consultation with target farming communities (as part of a technological screening process) indicates that five attributes of the technologies to be diffused under the above projects were supportive to the innovation diffusion process. With this assumption, we reviewed to see whether change agents and opinion leaders had a significant impact on the outcome of the adoption of the introduced technologies among the target communities. In the context of our projects, we categorized World Vision and participating research institutions (as mentioned above) as change agents, whereas local community leaders and innovative farmers were categorized as opinion leaders. The target groups of these projects are farming communities and local extension centers (at the provincial and district level).

In the next section, we present an overview of the two projects. We discuss the advantage of this participatory adaptive research model, highlighting the role of change agents and opinion leaders in enhancing the likelihood of project success. We then conduct a comparative review to highlight outcomes that benefit the target com-

Area Development Programs as a Model for Dissemination of Natural Resource Management in Rice-Based Agriculture

Word Vision Vietnam (WVV) is a Christian nonprofit and humanitarian organization working through transformational relief to improve the quality of life of people, especially children who are marginalized and are living in poverty. Established in 1950, the organization has projects in areas such as agriculture, micro-enterprise economic assistance, disability, capacity building, and emergency relief and mitigation. WVV encourages community participation and ownership so people become agents of their own development.

The Area Development Program

The Area Development Program (ADP) is WV's preferred manner of working throughout the world. A typical ADP duration is 10–15 years. Because poverty is multifaceted and often deeply rooted, the alleviation of poverty by people themselves takes a substantial period of time. It is also the reason why a typical ADP integrates agriculture, health, education, economic development, micro-enterprise, disaster mitigation, and capacity building. The major focus of the ADP is building capacity for local people to undertake their own development. Initial activities involve subsidies from donor and funding institutions. However, as the project goes farther, the level of subsidy decreases to a point at which WV phases out and the community takes responsibility. The major advantage of the ADP is that it can integrate sponsorship funding, grant funding, research, and type of resources. The ultimate intent of the ADP is for the community to be able to sustain activities, processes, and structures once WV leaves the community. A set of indicators is used to determine the appropriate timing and manner of exiting a community.

In Vietnam, ADPs are focused within one administrative district of a province, providing a manageable area where activities can be effectively and efficiently implemented. Currently, WV operates 31 ADPs in Vietnam, 26 of which are located in mountainous areas where the majority of the population are ethnic minorities. One of the unique components of the ADP is that team members are based in their assigned localities, thus enabling them to work more closely with local government partners and with the community on a daily basis.

WVV's ADPs use a variety of methods to incorporate the community in their work. Some of these methods include the use of DSGs (Development Solidarity Groups), CDGs (Community Development Groups), VDBs (Village Development Boards), farmers' clubs, children's clubs, and animal-raising groups. WVV does not seek to mandate any particular structure as the only correct one. However, it makes sure that each structure ensures broad and deep participation of the most vulnerable people.

One of the most innovative elements of ADPs in Vietnam is developing and working with "hamlet facilitators." These are local people, usually farmers, who receive training from the staff of WV or partners. The hamlet facilitators then share their knowledge with the community members who live around them. Currently, WVV has mobilized a network of 2,300 hamlet facilitators to implement community development work in the absence of outside resources.

WVV acknowledges that rural development will not be sustained unless powerful community-based agricultural and food security programs support it. Since poverty and food insecurity are mostly located in rural areas, growth in the agricultural sector has been a key mission for WVV. Recently, WVV agricultural projects focus on integrated pest management (IPM), rodent control, and participatory irrigation management (PIM), among others. It is also important to note that strong links between WV's agricultural thrust and other sectors such as disaster mitigation, nutrition, and business development services (BDS) have been established.

R-E interface and multistakeholder partnerships

WVV projects are based on a strong local support system that strengthens local ownership and capacity to reinforce new techniques. They also establish a hamlet facilitator network (composed of volunteers from the community), which is structured in a way in which knowledge flows through the facilitators to their adjacent households. Hamlet facilitators receive a number of technical training skills and acquire significant teaching and facilitation skills. With access to ADP training materials, hamlet facilitators are able to keep looking for opportunities to improve the living conditions of their hamlet even if the ADP has ended.

Lessons from ADP

1. Invest in grass-roots capacity and capability
   WVV ensures that the partners in the village, commune, and district have the capacity to sustain their work after transition. Substantial funding is allocated to staff and partner capacity building. Capacity-building activities focus on "learning by doing" and participatory tools such as participatory adaptive research are used in the work with ethnic minorities.
2. Integration
   Projects will not be implemented in isolation, but designed in such a way that outcomes in one project can be measured in other projects (e.g., the effects of early childhood education on nutrition).
3. Long-term results
   WVV believes that sustainable development in communities takes time. Therefore, WVV assesses and designs ADPs that are operational for a longer period of up to 15 years. Further, reducing dole-outs has been found to increase ownership and sustainability.

Source: Dzung NV. 2008. Area Development Program as a model for the dissemination of natural resource management. Paper presented at the IRRC-ICOP Workshop. Philippine Rice Research Institute, Maligaya, Nueva Ecija, Philippines, 6 February 2008.

munes from these projects, as compared with communes with no project interventions. Finally, we draw some lessons learned for the implementation of these projects.

Rodent control in rice-based farming systems

The overall goal of the project was to assist farmers in Bac Binh District, Binh Thuan Province, to protect rice crops from damage by rodents by using environmentally friendly methods, including a community trap-barrier system (CTBS) in lieu of chemical control methods. The project lasted from 2001 to 2005.

Project objectives:

- To test and upscale the use of CTBS over Bac Binh District, and later in Binh Thuan Province.
- To develop a user-friendly, field-based toolkit and leaflets for farmers and extensionists to enable sustainable use of the CTBS for rodent control (in lieu of existing chemical control methods).
- To disseminate CTBS methods across Vietnam through World Vision's Area Development Programs in Vietnam's 14 provinces.
- To distribute the toolkit through the network of plant protection agencies through the Plant Protection Department of the Ministry of Agriculture and Rural Development.

The Soil Fertility Improvement project

The overall goal of this project was to help farmers in Bac Binh District, especially those who live in remote, mountainous areas with less-favored soil, to improve their household food security by improving their crop yield through improved soil fertility. Specifically, the project aimed to help farmers improve their understanding of their soils, be able to classify soil types, assess current soil nutrient status, participate in on-farm trials, and experiment to find ways to improve soil fertility to maintain/increase crop yield. The project lasted from 2001 to 2005.

Short-term objectives

- Help farmers improve crop yield through adoption of appropriate trial-based fertilizer formulas (recommended by the National Institute of Soils and Fertilizers, NISF).
- Introduce new high-yielding varieties suitable to local conditions to increase household food security. These are tested with fertilizer formulas recommended by NISF before scaling-out.
- Encourage the use of organic fertilizers (manure) to improve soil health and the adoption of integrated pest management techniques as an integral part of soil conservation.

- Conduct farmer-to-farmer extension to diffuse best practices gained from successful trials.
- Establish extension clubs to encourage sharing of information and experiences from these participatory adaptive research and extension activities.

Long-term objectives

- Recommend new crop patterns to maintain soil health and increase crop yield.
- Provide district Department of Agriculture staff with a knowledge base of local soil properties.
- Introduce methods of soil testing (rate trials and omission trials) currently used to identify nutrient limitations in soil for a particular type of crop.
- Introduce GIS-based land appraisal technology, used to identify potential land areas for a particular type of crop, through pilot testing of a Land Suitability Map for Hoa Thang commune.
- Build a demonstration database of soil properties for future adoption by the district Department of Agriculture and encourage local use in formulating an agricultural development master plan.

It should be noted that the above two projects were integrated into an ongoing development program implemented by World Vision in Bac Binh called the Area Development Program. The ADP is a model community-based, demand-driven development program typically comprising intervention activities focusing on agriculture, public health, education, economic development (such as micro-enterprise), and natural disaster management, done under cross-cutting issues, including gender, monitoring and evaluation, and capacity building for local people. An ADP is normally designed for 10 to 15 years' operation with funding committed from a key support office from within World Vision Partnership. Both areas of intervention and time duration for an ADP are expected to allow time and opportunities for a community to make efforts to move out of poverty. As such, the above two projects are fed into this program for this reason and to make sure that the add-on projects are an innovative addition to the overall development program in an ADP. We noted that the existence of a multiyear development program like this Bac Binh ADP is extremely vital to the success of these two projects given the leveraging of the WV's staff, commitment, and existing partnership with local partners, including governments, technical support network, and beneficiary communities.

Participatory adaptive research model—roles of change agents and opinion leaders

The traditional innovation diffusion model

Traditional research on diffusion puts farmers at the center of the diffusion process. Goss (1979) argued that traditional systems tended to hold farmers responsible for their actions in adopting an innovation. This is called person-blame causal distribution bias. This assumption caused an ignorance of the consequences as a result of the diffusion process. Classic linear models of diffusion of innovation assumed that innovations are always good and farmers should adopt them (Fliegel 1993).

Rogers (2003) argued that this tendency is a *pro-innovation bias* and was one of the most serious assumptions that pervaded research tradition without a remedy, making these assumptions troublesome and potentially dangerous in terms of intellectual sense. This assumption resulted in diffusion researchers ignoring studying why there was an ignorance of innovation and why they underemphasized the rejection or discontinuance of innovations, and overlooked reinvention until the 1970s, when criticism of this assumption rose. Rogers (2003) pointed out two main reasons for this assumption: first, most diffusion research was funded by change agencies whose purpose was to promote the use of the innovations they wanted; second, rejected or discontinued innovation was less likely to be investigated by diffusion researchers. He suggested that pro-innovation bias could be overcome by considering the following points:

1. Investigate the diffusion of innovation while the process is underway to ensure collection of reliable data;
2. Be thoughtful in selecting an area of study—comparative analysis of both successful and unsuccessful cases of innovation diffusion is useful because such a wide range of innovations helps overcome pro-innovation bias;
3. Try to understand individuals' perceptions of innovation and their situation given that personal perception could lead to rejection, discontinuance, or reinvention of the innovation; and
4. Study the diffusion of innovation in a broader context.

Considering these factors, in Rogers' opinion, helps avoid possible pro-innovation bias. Finally, he recommended that attempts be made to understand users' motivations for adopting an innovation so as to avoid this type of bias.

The diffusion of innovation is complex and the success of diffusion could not be warranted unless the roles of stakeholders participating in this process are analyzed to ensure that stakeholders share and are committed to achieving the goal. In this review, we focus on the role of change agents and opinion leaders to see how these stakeholders interact to facilitate the success of a project. In the next section, we will outline our project collaborative research model. Then, we elaborate the roles that change agents and opinion leaders play in this model, which made the projects successful.

The project collaborative model

The commune administrative unit (rather than experimental site) is used in our review as the unit of analysis so as to assess the spillover effect of the results from project experiments. Experiments and demonstration sites were set up with the participation of selected farmers who monitor and manage the experimental sites under the supervision and support of WV's project team and research staff from research institutions. The schematic model below outlines the reciprocal relationship between stakeholders and the purposes of each relationship in this participatory adaptive research model.

A total of 42 experimental sites were set up under the rodent project and 28 sites under the soil fertility project over the course of 5 years for both experimental and demonstration purposes. All sites were managed by farmers, supported with weekly site visits by project staff and district extension staff for data collection, technical clarification, and problem solving. The experimental design and laboratory testing were supported by staff from relevant research institutions. At key times during the cropping seasons (experimental design, fertilizer application, establishment of a community trap-barrier system (CTBS) to catch rats, harvesting…), technical staff from participating institutes came to work closely with farmers and local staff (World Vision, extension centers, farmers, local governmental leaders) and provided training to farmers using the farmers' field school training approach.

Change agents (World Vision and participating research institutions)

World Vision Vietnam was assigned the responsibility of implementing the projects. The project team coordinates all project activities and works closely with experts from collaborating institutes and farmers at the project sites to set up experimentation and to conduct capacity-building activities for district and provincial extension staff. The WV's local team also aimed to share (within World Vision Vietnam) project training materials and organize training in other provinces where applicability of project technologies was appropriate. Participating research institutions acted as the principal technical advisors to the WV's project team. They were involved in field surveys, experimental design, data analysis, and on-farm training (to farmers and local extension staff). World Vision and researchers from participating institutions worked closely with each other to maximize the strength of each party while compensating for the disadvantages inherent to each so as to maximize the concerted support to local farmers and extension agencies.

Opinion leaders (innovative farmers and community leaders)

Opinion leaders of the projects included both innovative farmers and community leaders. Both parties played different roles but complemented each other in different ways to assure maximum participation of local stakeholders, while sustaining and disseminating project outcomes to other sites (both within and outside the province).

Farmers who were selected to manage the experimental or demonstration sites were those who are known locally as innovators (those who usually try new ideas/technologies) or are collaborators of national extension programs. They had to commit time, effort, and part of their farm plot for experiments. Typically, these innovators have good communication skills and a good reputation locally.

Within the project area, communes that have ongoing support from WV and a need for appropriate technology are typically selected because there is already a commitment from the communal authority to carry out the project activities. This status is very important in making sure that experiments are overseen by local leaders and successful activities can be promoted and adopted by beneficiaries of ongoing WV projects.

Project outcomes

When commitments were made by the project team and scientists from participating research institutions, and a measurable and achievable plan of adaptive research was in place (with participation from local farmers), this generated significant leverage of limited local extension resources (typically limited human and financial resources and technical expertise) and enhanced the likelihood of experimental success.

The concerted action and effort of change agents and opinion leaders led to the success of the project. Table 1 summarizes the key findings of our review of the two projects.

Lessons learned and conclusions

The main lessons we draw from the two reviewed projects are different in nature. While the rodent control project aimed to maintain expected crop yields by preventing losses from rodents, the soil fertility project aimed for increased crop yields. Nevertheless, the role of the stakeholders—the change agents and the opinion leaders—were equally important and instrumental to the success of the technology diffusion process. We particularly found that the high level of technical support and the continuous commitment from researchers from national and international institutions played an important role in providing a strong platform for change for the major end-users—local government officials, farmers, and other WV staff.

Scientists from research institutions provided different pathways for bringing effective and sustainable change to famer groups. They brought a high level of expertise to the area of research in question, particularly their knowledge and research methods. Developing field trials in a farmer participatory adaptive research framework made the knowledge more accessible to farmers. Also, their regular presence in the field provided farmers and local agricultural staff with opportunities to ask questions that perhaps they would not have been prepared to ask during a formal training course. Their presence in the field, planning experiments together with farmers and training them in their own fields, provided an encouraging atmosphere for farmers to adopt new attitudes, knowledge, and practices. The adaptive research confirmed farmers' understanding of problems they faced, and most importantly provided them with a way to address the problem through an evidence-based approach to new knowledge and improvement in their crop production.

World Vision (a nongovernmental organization) played a vital role in both projects. The implementation of the projects was integrated into its ADP program, with emphasis on (1) *capacity building*, which focuses on the "learning by doing" approach; (2) *integration*, which focuses on the idea of implementing the project in relation to other projects and with respect to the other aspects of community life such as health, education, economics, consumption, and livelihood, among others; and (3) *sustainability*, which involves capacity building of all the stakeholders, understanding that sustainable development communities take a long time, and building a sense of ownership among the people.

Table 1. Overview of the activities for the two projects established in target communes compared with normal farmer practices (nontarget communes), and their associated impacts. CTBS = community trap-barrier system.

<table>
<tr><th colspan="2">Rodent control in rice-based farming systems</th></tr>
<tr><td>Farmers in target communes</td><td>Farmers in nontarget communes</td></tr>
<tr><td>▪ After trying the CTBS, farmers from agricultural cooperatives started using it when rodents became abundant.
▪ There was a reduced reliance on chemical control methods, which can be harmful to both humans and domestic animals, including possible contamination of water sources.
▪ There was collaboration for consensus building and community action among farmers in habitats where rodents were abundant when the crop was fallow.
▪ Community action was conducted before rodent populations reached densities that cause significant economic losses.</td><td>▪ Farmers use potentially harmful chemicals to control rodents.
▪ Farmers work individually to control rodents in their own fields.
▪ Farmers tend to apply control too late, after damage has occurred to their crops.
▪ Control actions were less targeted with regard to refuge habitats.</td></tr>
<tr><td colspan="2">Project impact</td></tr>
<tr><td colspan="2">▪ CTBS technology is known now not only within the original target district (Bac Binh) but also in the whole province of Binh Thuan.
▪ The technology is now commanded by technical staff from district and provincial levels of this province.
▪ Rat abundance decreased significantly over three consecutive years following the introduction of the CTBS to the community in Bac Binh and in two other districts of the province.
▪ The technology was also replicated by the World Vision program across its 14 Area Development Programs (14 provinces) at that time.
▪ The success story and CTBS methods (built from lessons learned from Bac Binh) was documented in a toolkit that has been re-printed by World Vision and shared across Vietnam, World Vision International (as a case study), and the Plant Protection Department of the Ministry of Agriculture and Rural Development.
▪ The toolkit was also shared electronically on the Web site of mekonginfo.org and the Web site of World Vision in Vietnam. It was also shared by CARE International.</td></tr>
<tr><th colspan="2">Soil fertility in acidic uplands</th></tr>
<tr><td>Farmers in target communes</td><td>Farmers in nontarget communes</td></tr>
<tr><td>▪ Farmers know how to improve yield through the adoption of an appropriate fertilizer formula recommended by the National Institute of Soils and Fertilizers.
▪ Farmers were willing to conduct farmer-to-farmer extension to disseminate results and methods from successful trials to similar land areas through on-farm workshops.
▪ Farmers established extension clubs to enable sharing of information and experiences from farmer-based research activities.</td><td>▪ Farmers continued with traditional soil management practices.
▪ Farmers worked individually and relied on local agricultural extension services (to which they had limited access).</td></tr>
</table>

Table 1 continued.

DARD of Bac Binh District	Nontarget districts of Binh Thuan Province
▪ District Department of Agriculture and other subdepartments had a better understanding of soil properties. ▪ Understand methods of soil testing (rate trials and omission trials) that could be used to identify nutrient limitations in soil for a particular type of crop. ▪ Have a better understanding of GIS-based land appraisal technology, which helps identify areas suitable for particular types of crops. ▪ Have access to a "crop suitability" map (piloted for Hoa Thang commune), which is helpful for planning crop cultivation.	▪ Continuing to rely on soil maps that are not suitable to planning crop cultivation. ▪ Lack of knowledge on soil properties limited the effectiveness of agricultural extension activities and annual crop planning.
Project impact	
▪ Farmers are now aware of the important role of organic fertilizers. Therefore, cow manure, which is available in great quantity in the community, was retained for local use rather than being sold to farmers in other areas in the Mekong Delta. ▪ Farmers appreciated the role of on-farm experiments for their own learning process and considered this an important part of their effort toward improving the quality of soil health and crop yield. ▪ Staff at agricultural extension stations at the district and provincial level are more aware of the role of experiments in raising the awareness of farmers in improving soil quality. ▪ The World Vision project team was able to continue experiments after the project closed. This experimental mind-set created a learning community in the project area covered by World Vision. ▪ Relationships established with a national research institution (National Institute for Soils and Fertilizers) were continued in other aspects of agricultural research and extension under other World Vision programs. ▪ Knowledge gained from the project was extended to other World Vision teams as part of knowledge sharing in the area of soil amelioration.	

WV (the local team) maintained effective communication among stakeholders and provided an effective link between farmers and researchers, and the funding agency (Australian Centre for International Agricultural Research). WV staff ensured that local staff maintained a focus on project goals and that they became achievable within the project time frame. While scientists are not always at the site, WV acted in the role of clarifying technical issues and ensured effective communication between stakeholders, and that experiments were conducted properly (failure of one experiment in some cases is equivalent to the loss of one year since the failed experiment needs to be repeated in the same cropping season the next year). Their job was also to ensure that experiments were co-managed by farmers and extension technicians to ensure satisfactory completion of field trials and demonstrations.

Local governmental leaders were pivotal in both projects. Continuous support and monitoring of experimental activities and support for replication of experiments and request for concerted coordination between relevant local agencies (DARD, plant protection stations, agricultural extension station, farmers' association, women's association) were important to ensure that successful activities were shared across the project area. This was then fed back to the regular agricultural extension program of the government, indicating local government co-ownership of the projects.

Farmers are the end-users and they provided a clear measurement of whether the projects could add value to their current practices. They decide whether they adopt the technology as they validate it by evaluating its value in contributing to increasing their crop quality and yield. Despite the wealth of their indigenous knowledge, they know that their knowledge needs to be updated to cope with continuously changing conditions (soil, water, air, farming systems, market conditions, etc.) to maintain and increase their crop yield. In addition, given the context of climate change, an increasing need for improved crop quality, and the pressures of regional food security, effective cooperation between farmers, scientists, local government, and the business sector needs to be maintained. This collaborative model using adaptive research provided a good framework of partnership and an active learning alliance between these partners. Such success stories need to be scaled out, not only to leverage the limited financial and human resources on the part of the government but also to avoid possible traps in the innovation diffusion process. The two projects mentioned above are actually a dialogue between development organization, technical support institutions, and the beneficiary communities. When the commitment of these parties is sustained, this achieves the goal of innovation diffusion in agricultural extension.

References

Bohlen JM. 1964. The adoption and diffusion of ideas in agriculture. In: Copp JH, editor. Our changing rural society. Ames, Iowa (USA): Iowa State University Press. p 265-287.

Buttel FH, Larson OF, Gillespie GW, and Rural Sociological Society. 1990. The sociology of agriculture. New York (USA): Greenwood Press.

Fliegel FC. 1993. Diffusion research in rural sociology: the record and prospects for the future. Westport, Conn. (USA): Greenwood Press.

Goss KF. 1979. Consequences of diffusion of innovation. Rural Sociol. 44:754-772.
Rogers EM. 1995. Diffusion of innovation. 4th edn. New York: Free Press.
Rogers EM. 2003. Diffusion of innovation. 5th edn. New York: Free Press.
Sevcik P. 2004. Innovation diffusion. Bus. Comm. Rev. 34(9):8-11.

Notes

Authors' addresses: Le Anh Tuan, The World Bank in Vietnam, Ho Chi Minh City; Grant Singleton and Flor Palis, International Rice Research Institute, Los Baños, Philippines; Nguyen Viet Dzung, World Vision Vietnam, Hanoi; email: tle5@worldbank.org.

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SOLIDARITY's approach to rural development in northern Bangladesh: a case of *monga* mitigation

S.M. Harun-Or-Rashid Lal, M.A. Rahman, M. Sadequl Islam, S.A. Khair, and M.A. Mazid

Promoting people's capacity for food security is a strategy of the NGO SOLIDARITY to enable the poor and extreme poor in northern Bangladesh to cope with the difficulties pervading their communities. SOLIDARITY, with the help of the Bangladesh Rice Research Institute (BRRI) Regional Station, Rangpur, and Swiss Development Cooperation (SDC)-supported NGO Intercooperation (IC), undertook initiatives to disseminate a short-duration rice variety, BRRI dhan33, together with its component production technology to improve household food security.

During the wet season (aman season, June-November) of 2007, 4 hectares of land in a rural community in Kurigram District were sown with short-duration rice variety BRRI dhan33 as direct-seeded rice by using a drum seeder. At the same time, a group of farmers was encouraged to cultivate the same variety by transplanting and the rest of the farmers cultivated local varieties using local cultivation technologies. The directly sown BRRI dhan33 matured at 105 days, 10–15 days earlier than the transplanted variety, and 40 days earlier than the other local long-duration aman variety. This resulted in an extended harvesting period, thus creating employment opportunities for agricultural laborers, which enabled them to improve their livelihoods.

Keywords: food security, BRRI dhan33, *monga*, drum seeder, aman season

SOLIDARITY is a nongovernment and nonprofit local development organization in Kurigram District under Rajshahi Division in the northern part of Bangladesh. SOLIDARITY was established in 1992 to assist the disadvantaged and underprivileged people of Kurigram, Lalmonirhat, Rangpur, Dinajpur, and Joypurhat districts. Kurigram and Lalmonirhat are very prone to natural disasters, which disrupt the lives of many who already suffer many hardships. Sixteen large and small rivers flow across these areas. It is a common scenario for these areas to experience calamities such as floods, river erosion, extreme cold spells with thick fog, and drought, which all make life extremely difficult for the communities. Most of the people are resource-poor, landless, and jobless. *Monga* is the local term for the silent famine that occurs annually in the greater

Rangpur District area. It is associated with the lean period prior to the rice-cropping season, when employment opportunities for agricultural workers are scarce. Most of the poor and marginalized families suffer from starvation and malnutrition because of insufficient food. The people cope with *monga* by getting loans from local money lenders at high interest rates or by selling their assets. The *monga* period makes the poor people become more vulnerable to exploitation and risks. Many men migrate to large cities in search of jobs. SOLIDARITY is committed to work for these disadvantaged and neglected men, women, and children to improve their livelihood as well as empower them.

SOLIDARITY fosters effective coordination among the local administration: local government, community-based organizations (CBOs), and nongovernment organizations (NGOs). Further, the organization formulates a favorable sectoral policy environment, needs analysis, planning, management program, implementation, and development assessment. This strengthened its role and made networking more sustainable.

SOLIDARITY aims to build "grass-roots" organizations by engaging in activities to raise awareness and build the capacity of poor people. Some activities of SOLIDARITY include

1. Teaching people to generate more income from agriculture and livestock raising.
2. Developing plants and nurseries.
3. Providing safe drinking water.
4. Maintaining environmental sanitation by teaching people to practice and maintain good hygiene.
5. Educating adolescents on reproductive health.
6. Providing primary health care.
7. Campaigning for arsenic mitigation and testing water sources for arsenic contamination.
8. Conducting nonformal education.
9. Providing legal aid support for justice and good governance; promoting adherence to children's rights.
10. Implementing a disaster response program.
11. Initiating training on human resource development and overcoming disability.

Major areas of work

Agricultural development

SOLIDARITY has 15 years of experience in implementing an agricultural development program in rural areas and marginal communities such as *char* (sandy areas where cropping is difficult). Its program includes activities such as homestead gardening, establishment of learning plots, demonstration of improved crop varieties, developing new crops and technologies, crop diversification, integrated crop management (ICM) in vegetables and field crops, roadside vegetable cultivation for the extreme poor, and dike crop cultivation, among others. SOLIDARITY also has experience in providing support to rural communities in other sectors of agriculture such as poultry, livestock, fisheries, nursery development, tree crops, and plantations. With such development programs, SOLIDARITY was recognized and honored by the Department of Agriculture Extension (DAE) for effectively implementing and showcasing its activities in fields, at fairs, and on farmers' field days.

Group development

In the past 15 years, SOLIDARITY formed and developed more than 1,500 community-based organizations of different socioeconomic status, age, sex, and professions. Among them, 296 groups were formed with the rural poor—marginal and small farmers. These groups are taking an active part in community development by becoming involved in different income-generating activities (IGAs), new agricultural technologies, homestead gardening, and different social awareness-building activities. SOLIDARITY provided support to increase their organizational capacity to empower them to access different services from the respective departments and organizations.

SOLIDARITY provided support for human and institutional development by helping the CBOs/groups to identify and prioritize local problems and accordingly develop an annual plan of operations. It also provided support to identify local resources (physical, human, natural, and financial) so that they could implement their annual plan by using those resources. In this regard, SOLIDARITY provided the following capacity-building support to the CBOs/groups:

- Training on leadership and development of facilitation skills.
- Training on financial management (maintenance of a cash book, ledger book. savings register, credit management, etc.) and provision of complementary support during the initial years.
- Complementary support on maintaining important organizational tools such as a resolution book, notice book, etc.
- Assistance in developing an organizational constitution, by-laws; opening a bank account, etc.
- Organizing learning/exposure visits for community leaders and progressive farmers.
- Support for establishing linkage with different government and nongovernment organizations.

SOLIDARITY also organized different types of awareness-building events on different issues. These included a campaign against dowry, early marriage, and polygamy. SOLIDARITY helped the communities to develop a local committee or platform in collaboration with the local government in order to protect women and children against all sorts of violence. SOLIDARITY took initiative to help more than 70,000 illiterate rural people become literate. In recognition of these outstanding activities, SOLIDARITY received a national award from the Ministry of Mass and Primary Education through the Directorate of Nonformal Education.

Agricultural credit

Micro-finance is being used as a tool to fight poverty and it is one of the main vehicles to serve impoverished people. SOLIDARITY has been operating a micro-credit program since 1992. SOLIDARITY is registered with the Palli Karma Sahayak Foundation (PKSF), an autonomous institute that lends micro-credit funds to local NGOs, which in turn loan them to the poor beneficiaries. SOLIDARITY has tried to help more than 7,000 members by promoting income-generating activities and other agricultural projects in both rural and urban areas in order to help people become self-reliant and independent. It now has more than 400 groups in the micro-credit program.

As SOLIDARITY mainly works in structured groups, the members are organized in groups and centers were established to facilitate regular meetings. Certain rules and regulations are established for the disbursement of loans to members to promote group dynamism and to maintain a proper monitoring system. As SOLIDARITY follows structured program planning, it implements a loan ceiling for each loan. But, in special cases, borrowers can obtain a larger amount based on justifiable grounds and on the financial requirement of a project undertaken by the borrower. In 2005 to 2006, SOLIDARITY disbursed a total of Tk. 2.0 million (approx. US$300,000) as loans. The recovery rate was above 97%.

SOLIDARITY follows the PKSF approach with a blend of some other appropriate features for managing the program. After attaining membership in the organization, members need to regularly attend meetings and make a savings deposit of a predetermined amount fixed by the group. A member gets his or her first loan at least three months after enrollment. The rate of savings by the hardcore poor is much more flexible.

These groups are structured in the sense that the members have to strictly comply with the following rules and regulations:

1. Members must be organized in groups.
2. Members have to attend group meetings regularly.
3. Members have to save a predetermined amount on a weekly basis, but this is flexible for the hardcore poor.
4. Members have to ensure the repayment of the loan amount in equal installments paid during the group meetings.

Research and extension interface and multistakeholder partnerships—the example of *monga* mitigation

Networking and partnership development

To help address *monga*, SOLIDARITY sought help from Intercooperation (IC), an international development organization working on development issues in the northern area of Bangladesh already linked to BRRI, to develop and extend options for early harvests to improve household food security. A collaborative project was developed and implemented to promote a short-duration crop of BRRI dhan33, a short-maturing rice variety, and its corresponding production technology to reduce the crisis period.

SOLIDARITY then carried out a capacity-building program for the CBOs and local-level implementers to help implement the project in the field.

The roles of different implementing partners

The Bangladesh Rice Research Institute is a national research organization of Bangladesh that focuses on rice research, particularly on developing and releasing new varieties appropriate for the different rice-growing environments of the country. It also develops suitable crop management technologies for high-yielding yet sustainable rice production. BRRI trains NGOs and CBOs to promote new varieties of early-maturing crops as well as crop diversification.

BRRI has close links with the International Rice Research Institute (IRRI) and the Irrigated Rice Research Consortium (IRRC) and, through these linkages, a number of options had been developed for early harvests (*monga* mitigation) (see Mazid and Johnson, this volume). *Monga* mitigation options that include the cultivation of a short-duration rice variety (BRRI dhan33), adjustment of time of seeding/planting, establishment methods (direct-seeded rice [DSR] versus transplanted rice [TPR]), and crop diversification (rice-potato-maize, rice-potato-mungbean, rice-wheat-mungbean, rice-vegetable, rice-potato-boro, etc.) were demonstrated for employment opportunity, food security for agricultural day laborers and marginal farmers, and livelihood improvement.

The major role of BRRI was to partner with NGOs such as Intercooperation and it provided training of trainers (ToT) to IC and partner NGOs (PNGOs) such as SOLIDARITY at Kurigram, ZIBIKA at Lalmonirhat, BRIF and SERF at Nilphamari, and UDDYOG at Gaibhandha through BRRI-IRRI (IRRC-LPWG) collaboration. The staff also extended refresher training to officers, staff, and local service providers of SOLIDARITY; conducted joint visits to farmers' fields; did monitoring; and attended field days and review meetings.

Dr. M.A. Mazid, principal agronomist and head of the BRRI Regional Station in Rangpur and principal investigator of LPWG-IRRC, developed the *monga* mitigation model, worked as a resource person of ToT, and coordinated with partner NGOs through BRRI-IRRI collaboration.

Intercooperation is an international NGO implementing SDC-suggested issues, and it has been working for 25 years in Bangladesh. IC helps to implement the promotion of BRRI dhan33 in collaboration with BRRI-IRRI and SOLIDARITY.

A three-tier approach for technology dissemination

SOLIDARITY followed a three-tier approach for technology dissemination in implementing this project:

Level 1: upazilla/union *parishad* level

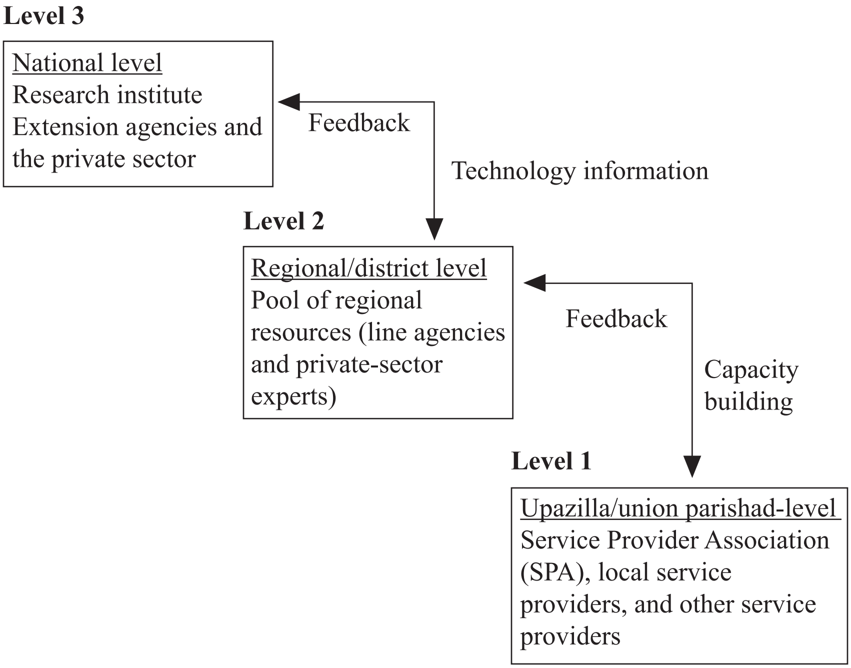
This tier is composed of a local-level NGO (SOLIDARITY), local service providers, the Service Provider Association (SPA), CBOs, cluster platforms, and local government and other government line agencies at the upazilla level. These institutions and groups provided support in implementing the project. Regular meetings, attended by the coordination forum, network members, and staff from the Agricultural Training Center (ATC) and Upazilla Agricultural Extension Coordination Committee (UAECC), were organized by local government bodies and line agencies to plan, monitor, and evaluate the implementation of the project.

Level 2: regional/district level

Partners at the district and regional level shared tasks and pooled resources, thus expanding impact (increased outreach with less expenditure). Formal agreements were forged among institutions to share in the costs of implementing the project. Experts coming from regional-level research organizations, the private sector, and district-level line agencies, etc., composed this tier.

Level 3: National level

To leverage more funds to expand project outreach, activities were also begun at the national level. Using different thematic platforms for possible scaling up and scaling out of the project, forums and workshops were conducted to consolidate partnerships, and to learn and exchange approaches and practices with different development organizations and donors. At this level, institutions involved included national research institutions, the private sector, universities, ministries, and other government offices involved in implementing development programs as well as in crafting policies.



How the technology was found

SOLIDARITY learned about the technology (BRRI dhan33) during a planning workshop in early 2007. The technology was shared with the SOLIDARITY management and this group decided to demonstrate it. SOLIDARITY shared the technology with two potential CBOs (Sobhondho and Kendra) in their regular meetings and these groups decided to demonstrate the technology.

SOLIDARITY is implementing a livelihood program called LEAF (Livelihoods, Empowerment, and Agro Forestry) funded by SDC and managed by Intercooperation Bangladesh, with a view to improving the livelihood of the poor and extreme poor through capacity building. Figure 1 demonstrates how the different players interact and the process of working with farmer groups in a collaborative project such as promoting BRRI dhan33. Farmers get technology support and knowledge from BRRI via the NGOs that are partners of Intercooperation. The local service providers group, market actors, and other stakeholders play a pivotal role of introducing new technology to the farmers.

Strategies followed

SOLIDARITY disseminated the rice technologies by following these strategies:

1. Participatory planning among donors, development partners, and grass-roots-level stakeholders through problem analysis and action plan preparation at the field level.
2. Strengthening local service providers. SOLIDARITY trained people to provide service in the locality (with a low fee) and to enhance their skills in disseminating the technology in a manner well understood and properly implemented by the local beneficiaries.
3. Strengthening the CBOs so that they jointly implement the project.

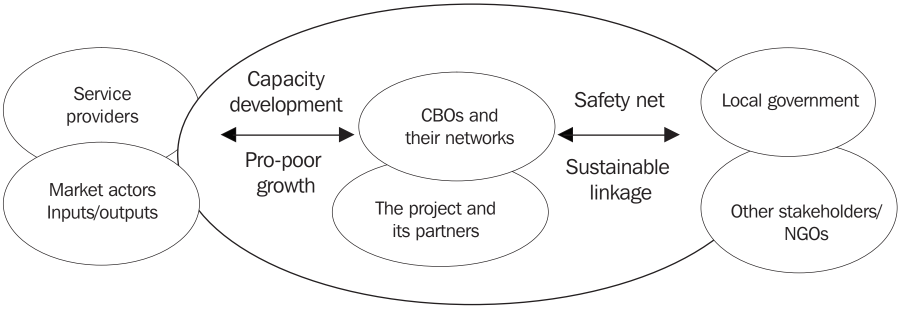


Fig. 1. Linking farmers in community-based organizations (CBOs) with government, NGOs, and the private sector.

Selection of farmers

The CBOs selected a total of 20 farmers to demonstrate the technology. Among these, 10 were selected to demonstrate the direct-sowing method using a drum seeder and another 10 were selected for the transplanting method of cultivation of BRRI dhan33. The selection criteria for farmers were

- Having at least 0.04 hectare of land.
- Willing to take care of the crop as recommended
- Agreeing to provide inputs for the land with the guidance of SOLIDARITY technical staff.
- Willing to save the yield as seeds for the next season.

Capacity building of farmers

Officers of SOLIDARITY underwent a ToT conducted by BRRI and IRRC and with financial support from IC management. BRRI also provided a three-day skills training to selected local service providers (LSPs) on facilitating and using new rice production technologies, especially crop establishment methods, crop diversification, and *monga* mitigation. The selected farmers were then trained by the LSPs with the assistance of BRRI and SOLIDARITY on the following technologies to enhance their skills in rice production and increase their confidence:

- How to use a drum seeder
- How to use the leaf color chart (LCC)
- How to save seeds of BRRI dhan33
- Cultivation techniques of BRRI dhan33 by using the direct-sowing method through a drum seeder
- Cultivation techniques of BRRI dhan33 by using the transplanting method

SOLIDARITY provided follow-up and technical support during the cropping season to help farmers solve rice production problems.

Demonstrating the technologies

During the aman season of 2007, all 20 selected farmers prepared their seed for germination on the same day. Ten farmers sowed the germinated seedlings in the rice fields by using a drum seeder and the other ten farmers sowed the seeds in a seedbed.

Cultural management of rice

All farmers maintained the same cultural management practices learned from the training except for weed management. The farmers who used the direct-sowing method used herbicide for controlling weeds while the other group used manual methods for weeding.

Farmers' field days

The CBOs organized FFDs in order to disseminate the technologies to other farmers and the community. In the FFDs, BRRI-IRRI researchers, experts from the Agricultural Extension Department, high officials from the government administration, other GO and NGO officials, electronic and print media personnel, and a huge number of farmers participated. Media covered the harvest ceremony and made a broadcast on local cable television. The success of the field days was also featured in local print media. BRRI also provided handouts and leaflets on cultivation techniques and *monga* mitigation for distribution.

Results

The following results were observed from the demonstration:

- BRRI dhan33 sown directly using a drum seeder matured at 105 days after sowing, 40 days earlier than the other local long-duration varieties.
- Transplanted BRRI dhan33 matured within 115 days, 30 days earlier than the other locally used long-duration varieties.
- The yield obtained irrespective of method was 24 kg per decimal (5.93 t ha^{-1} dry weight), similar to the yields of other local varieties used in the community.
- A total of 68 extremely poor agricultural laborers got employment for 30 days for rice and 15 days for potato during the *monga* period.
- A total of 56 neighbors shared the rice from the selected farmers when they faced a food crisis.
- Three crops were planted over the year in the plots where the direct-sowing method was used.

Limitations faced and the remedies

- The direct-sowing method needs herbicide for effective weed control, which was new for the community and not available in the local market. The CBOs can buy the herbicide from a distant market and distribute it among the farmers.
- A drum seeder was also not available in the local market. The CBOs can purchase the seeder and rent it to the farmers, thus creating an opportunity for the CBOs to raise funds.
- This method requires well-leveled land. This can be overcome by diligently following the technology in the next two to three years.

Adoption and evidence of impact

SOLIDARITY implemented the project at the local level with the different CBOs through their cluster platforms and the union network. Members of the local community selected the local service providers to facilitate the identification, prioritization, and finding solutions to pressing development issues. The local CBOs prepared their annual plan of operation and found some problems that were not possible to solve at the local level.

Responding to the issues raised by the CBO, SOLIDARITY initiated linkage with IC and BRRI to conceptualize and implement a project that can help mitigate *monga* in northern Bangladesh. Hence, BRRI dhan33 was adapted and demonstrated in collaboration with two CBOs. Farmers and local service providers were trained prior to the implementation of the demonstration. Field days were also conducted to showcase the technology to other farmers and show how it can provide employment to agricultural workers during the *monga* season. The field days were like rural festivals in the community because the harvesting time of the rice occurred during the *monga* period.

It is expected that short-duration varieties will become popular among farmers and planted on a wider area in the coming seasons. As a result, *monga* would be reduced toward zero and, we hope, this will be a sustainable strategy for mitigating *monga*.

Lessons learned

The following lessons were learned from the project implemented:

1. The rice was harvested during the lean period. As a result, this created work opportunities for marginalized laborers.
2. The early crop can mitigate *monga* because of its early harvesting time.
3. The government of Bangladesh has taken initiative to disseminate the technologies of BRRI dhan33 in the northern region of Bangladesh.
4. Other agencies already introduced different short-duration varieties of rice.
5. Different government and nongovernment research institutes already started a large number of action research programs.
6. Farmers are spontaneously planting the early varieties of the crop, and relay crops for food and fodder for cattle.
7. Farmers on their own initiative are now planting BRRI dhan33 three to four times in a year in a region, an example for other farmers to follow.
8. The number of cross-learning visits of farmers and researchers is increasing at home as well as abroad.
9. Farmer field days are being organized by different organizations during growing, flowering, and harvesting periods.

Future prospects

Our experiences showed considerable potential for expanding the area of implementation of *monga* mitigation options. With the strengthened partnership of people's organizations with institutions such as BRRI and SOLIDARITY, it is expected that 30% of the farmers in the locality will be involved in cultivating early-maturing varieties. A minimum of 25% of the geographical area surrounding the villages where testing of the *monga* mitigation strategies was done will be covered for the scaling-out activities in collaboration with the government and other partners. As a result, 40% of the day laborers will have an opportunity to work in the locality during the lean months and thus contribute to reducing the number of people that suffer from hardship during the *monga* period.

On the other hand, we will continue to work well and further strengthen our partnership with BRRI, IC, other local NGOs, farmers' groups, and the national government to promote *monga* mitigation strategies. We hope that research institutions will find more solutions to the pervading problems associated with *monga*.

Further reading

Mazid MA. 2008. BRRI dhan33 and *monga* mitigation in local language (Bengali) published in Krishikota, AIS, DAE, Farmgate. Dhaka, Bangladesh.

Mazid MA, Khamarker B, Mortimer AM, Riches CR. 2008. Developments in direct seeding of rainfed rice in the High Barind Tract. In: Riches C, Harris D, Johnson DE, Hardy B, editors. Improving agricultural productivity in rice-based systems of the High Barind Tract of Bangladesh. Los Baños (Philippines): International Rice Research Institute. p 33-46.

Mazid MA, Riches CR, Mortimer AM, Wade LJ, Johnson DE. 2006. Improving rice-based cropping systems in north-west Bangladesh. 15th Australian Weeds Conference Proceedings. p 331-334.

Mazid MA, Johnson DE, Mortimer AM, Riches CR. 2005. Wet, direct seeding and weed control options for dry season rice in the north-west of Bangladesh. In: Proceedings of the 20th Asian-Pacific Weed Science Society Conference held during 7-11 November 2005 in Ho Chi Minh City, Vietnam.

SOLIDARITY. 2006. Annual report. New Town, Kurigram (Bangladesh): SOLIDARITY. p 8-9.

SOLIDARITY. 2005. The final report of South Asia Program for fiscal year-2005: promotion of people's capacity on food security (PPCFS) of Kurigram's *monga* Project. p 3, 4, 7, 13, 20, & 21.

Notes

Authors' addresses: S.M. Harun-Or-Rashid Lal, M.A. Rahman, M. Sadequi Islam, and S. Khair, SOLIDARITY, Kurigram; M.A. Mazid, BRRI Regional Station, Rangpur, Bangladesh. Email: solidarity_bd@yahoo.com.

Part III

Assessment of Impacts

Adoption of crop management technology and cost-efficiency impacts: the case of Three Reductions, Three Gains in the Mekong River Delta of Vietnam

Zenaida M. Huelgas and Deborah J. Templeton

"Three Reductions, Three Gains" is a crop management technology designed by the International Rice Research Institute to reduce production costs, improve farmers' health, and protect the environment in irrigated rice production in southern Vietnam through the reduced use of seeds, nitrogen fertilizer, and pesticides. It was vigorously introduced to farmers by the Ministry of Agriculture and Rural Development in early 2000 through traditional extension work and mass media. Probit adoption analysis of farm survey data provided evidence that extension education is the main determinant of adoption. Stochastic frontier cost analysis showed that adopters were more cost–efficient. Adoption improved per capita incomes, albeit marginally.

Keywords: crop management technology, probit adoption model, stochastic frontier unit cost model

The importance of rice in the Asian diet, life, and socio-political economy cannot be overemphasized. Most Asians,[1] especially the rural and urban poor, normally have three meals of rice daily; thus, per capita annual consumption ranges from 90 to 200 kg or about 50–80% of caloric intake. Rice farming is a part of Asian heritage in which tilling small parcels of land is more often than not passed from one generation to the next regardless of tenancy or ownership of lands. For some of these farmers, rice farming is the only way to secure food for their families. The rural and urban poor, comprising about 70% of the Asian population, spend at least a third of their income on rice.

Keeping rice prices low on the one hand and the soaring prices of farm inputs (such as petroleum-based fertilizer, fuel, and labor) on the other limited poses a challenge to researchers and governments to develop technologies and economically sound programs that boost yield and/or minimize production costs. These technologies and programs are common requisites to achieving local, national, and global food

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[1] Some exceptions include those living in northern China, northern India, Pakistan, and Bhutan.

security[2] and alleviating poverty. Although research into rice varietal improvement is still paramount, there has been increased attention toward improving crop management strategies. Broadly speaking, these crop management strategies can be categorized as (1) those aimed at increasing yield while largely maintaining input use, and (2) those aimed at reducing input requirements without sacrificing yield. The technology of interest here, which is commonly referred to as "Three Reductions, Three Gains" (3R3G), falls into the second broad category. In essence, it is a knowledge-based crop management technology aimed at lowering the cost of growing rice in irrigated systems (through reduced quantities of seeds, nitrogen fertilizer, and pesticides) while maintaining yield, and improving farmers' health and better protecting the environment (through a reduced reliance on agrochemicals[3]).

The 3R3G project evolved from an integrated pest management (IPM) project in which the concept of not spraying for pests in rice fields the first 40 days after sowing was developed. This concept was based on research findings that showed that early spraying was unnecessary as any damage from leaf-feeding insects (the prime cause of early spraying) did not affect yield (Heong et al 1994). Given the strength of the research findings, a "No Early Spraying" (NES) media campaign was funded and reached around 92% of the 2.3 million farmer households in the Mekong Delta in Vietnam. As a result, the number of insecticide sprays per season dropped by 70% from 3.4 to 1.0 (Huan et al 1999). This was a remarkable change as farmers responded positively to the challenge posed by the media campaign.

The success of the NES experiments, combined with the knowledge that farmers in the Mekong Delta were applying high seeding rates (200–300 kg ha^{-1}) and nitrogen applications of around 150–300 kg ha^{-1}, motivated the Irrigated Rice Research Consortium (IRRC), with funding support from the Swiss Agency for Development and Cooperation (SDC), to conduct on-farm research in the province of Can Tho in 2001 to determine the amount by which seed and fertilizer use could be reduced. In the following year, the Plant Protection Division (PPD) under Vietnam's Ministry of Agriculture and Rural Development (MARD) validated the results of the experiments in 11 provinces with matching funds from the Danish International Development Agency (DANIDA). This study, involving 951 farmers, showed that seeds, fertilizers, and insecticides can be reduced by 40%, 13%, and 50%, respectively, resulting in marginal yield increases and increased profits of US$44–58 ha^{-1} (corrected figures from Huan et al 2005). As a result, the pesticide management practice of NES was packaged with lower seed rates and lower nitrogen use and became known locally as *Ba Giảm, Ba Tăng* (3R3G). (See Table 1 for information on 2002 data on farmers' practices and the scientist-based recommended target rates.) By February 2005, a national committee was established by MARD to develop plans to scale up implementation of 3R3G. In 2006, MARD allocated about $230,000 to 64 provinces, specifically for *Ba Giảm, Ba Tăng* implementation.

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[2] In some instances, a nation is food-secure but still has pockets of severe food insecurity.

[3] Concerns about the environmental and health consequences of the injudicious use of agrochemicals are extensively discussed in the literature. See, for example, Nguyen and Tran (1997).

Table 1. Three Reductions, Three Gains (3R3G) technology targets seed, fertilizer, and pesticide use rates.[a]

Item	Farmers' practice in 2002[b]	Target for dry season (winter-spring)	Target for wet season (summer-autumn)
Seed (kg ha^{-1})	200–350	70–100	100–120
Fertilizer	150–300	120	100
Nitrogen (kg ha^{-1})	No data available	30	30
Phosphorus (kg ha^{-1})	No data available	30	50
Potassium (kg ha^{-1})			
Insecticide	Spray 10–15 days after planting	NES first 40 days after planting	
Fungicide	"Calendar" spraying	Use fungicide when blast symptoms are visible at booting stage (at 60 days after planting)	

[a]These are scientist-based recommended rates. The Ministry of Agriculture and Rural Development was aware that achieving these rates will take a few years so that annual targets were adjusted accordingly. [b]Elicited from Plant Protection Division provincial, district, and village directors during key informant interviews in June 2006 and March 2007.

The national program used standard extension activities combined with a quite elaborate and creative mass media campaign. Through a multistakeholder participatory planning process, a campaign package was developed to reach and motivate large numbers of rice farmers in the Mekong Delta (Huan et al 2005). It consisted of communication media (TV, radio, print, and demonstrations) and materials (soap operas, leaflets, pamphlets, and farmer field days) geared toward increasing farmers' ability and motivation to modify their resource management practices by adopting the relatively knowledge-intensive technology. The strategy was to change farmers' attitude toward input use from one of "more is better" to one of "less is more sensible" through a number of information-delivery systems. In particular, these included billboards along main roads, soap operas aired on national radio and television stations,[4] and public amplifiers installed along village roadsides that replayed radio broadcasts at daybreak as farmers walked from home to their rice fields. It became nearly impossible for a farmer not to hear about 3R3G.

The principal IRRI scientists[5] from the 3R3G project received recognitions and awards from the Vietnamese government and the SDC, suggesting that the technology

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[4] Funding support for various radio and television soap operas came from the Rockefeller Foundation and the World Bank ($131,800), with IRRI as project proponent. One specific radio program is "Chuyen Que Minh" or "My Homeland," which is well described by Escalada and Heong (2007).

[5] The principal IRRI scientists of 3R3G, Drs. K.L. Heong and M. Escalada, received three awards—2003 golden rice award by the MARD of Vietnam, 2005 best innovation award by Can Tho city government of Vietnam, and second prize in the 2005 success stories competition of the SDC.

succeeded in making a difference in terms of farmers' (and environmental) well-being. A farm-level impact survey was then begun to provide credible evidence of technology adoption and economic impact. The specific objectives of this chapter are to

(a) estimate the adoption rate of 3R3G and analyze determinants of adoption;
(b) compare farm-level performance of adopters and nonadopters with respect to input use, yield, cost, and income; and
(c) analyze the difference in cost efficiencies that could be attributed to 3R3G adoption.

The study area and sample households

Mekong River Delta

A turning point in Vietnam's rice history occurred in 1989 when the country was transformed from an importer to an exporter of rice. In 2004, Vietnam's rice area of more than 7 million ha covered 75% of the country's cultivated land and produced 36 million tons of rough rice. Production exceeded domestic demand and 4 million tons of milled rice were exported in the same year. Vietnam became a leading rice-exporting country by the mid-1990s.

Vietnam's Mekong River Delta is at the end of the world's 12th longest river. Arising from the Himalayas, the Mekong River supplies the tropical wetlands of Vietnam with rich alluvial deposits, making the soil sufficiently fertile that the area is home to 15 million people. The intense green of cultivated rice paddies can be seen across the river, threaded through by an intricate web of irrigation and drainage canals.[6] The Mekong River Delta has 13 provinces that altogether accounted for about 52% of total national rice output of 36 million tons in 2005. Generally, two rice crops are grown per year. The national average yield in 2005 was 4.89 tons ha^{-1}.

Vietnamese households

Household surveys were completed in the provinces of An Giang and Can Tho in August 2006 and in Soc Trang in May 2007. For each province, as many as three districts and three villages per district were selected. Sample sizes at each geographical level were proportionate to rice area. Farmers interviewed were chosen at random in each village. Thus, a stratified simple random sampling procedure was used to select 200 farmers in each province (Table 2). The questionnaire used was well structured and designed to collect input-output data and information on the knowledge and perceptions of farmers with regard to 3R3G in particular and to rice farming in general. The data were collected for two seasons—the dry season (winter-spring, from December 2005 to April 2006) and the wet season (summer-autumn, from May to July 2006)—by the staff of the Faculty of Economics at An Giang University, An Giang Province, Vietnam.

Vietnamese farming households covered in the survey were typically Asian—for one, averaging 5 in the number of members. Heads of households were middle aged,

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[6] Source: European space agency accessible at http://earth.esa.int/cgi–bin/satimgsql.pl?pf=473.

Table 2. Sample distribution, demographic profile, and farm characteristics of selected provinces of the Mekong River Delta, crop years 2005-07.[a]

Item	An Giang	Can Tho	Soc Trang	All
Sample distribution				
Dry season 2005-06	166	169		
Wet season 2006	166	169	172	507
Dry season 2006-07			172	
Demographic profile				
Ave. age (years)	46	48	46	47
Ave. education (years)	6	7	6	6
Ave. farm experience (years)	21	24	23	23
Ave. household size (number)	5	5	5	5
Farm characteristics				
Farm size (ha)	2.16	2.18	1.76	2.03
Tenure (number)				
Owner	163	161	170	500
Lessee	3	2	2	7

[a] Two hundred farmers were interviewed in each province. Transplanted farms and those with incomplete information were deleted from the analysis.

engaged in rice farming most of their adult years, and, although their seven years of formal schooling may not get them white-collar jobs, they were adequately educated to comprehend and follow simple written or oral instructions (Table 2). Farm sizes were rather small, averaging 2 ha and mostly owned.

The farm survey was complemented by farmers' focus group discussions (FGD), key informant interviews (KII) of seed growers, and collection of price data from agricultural chemical retail shops in all the provinces.

Analytical framework

Pathway to higher farm profits

The 3R3G technology is not a physical good (such as in the case of a new high-yielding rice variety) but rather a package of input management recommendations that farmers can use in their profit-maximizing or input use and decision-making process (Fig. 1). The 3R3G technology capitalizes on the synergistic effects of reducing three inputs together without sacrificing yield, that is, if seed rates are lowered, less fertilizer is required, which, individually and jointly, makes the crop less attractive to pests, thus reducing the need for insecticides for the whole cropping season. Further, the adoption of NES also discourages pest population buildup because not only is early spraying unnecessary in terms of yield benefits (as stated above) but, by destroying pest preda-

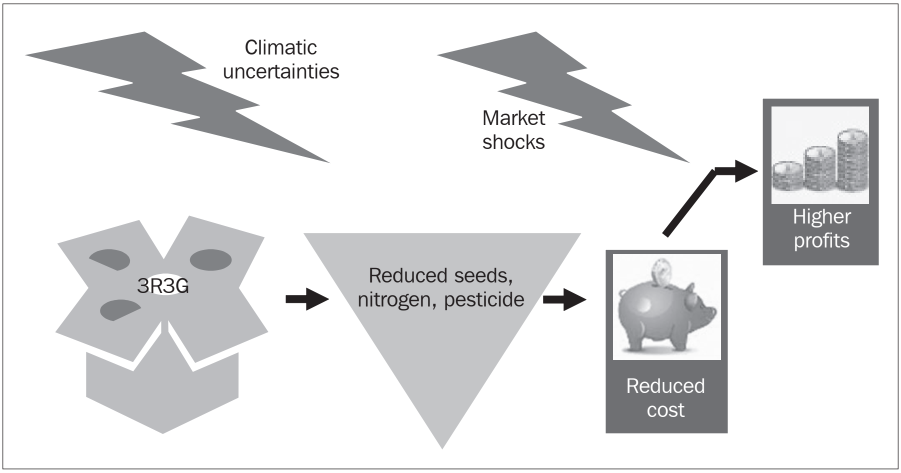

Fig. 1. Pathway to higher farm profits for "Three Reductions, Three Gains" technology.

tors, it can lead to pest resurgence problems. In other words, the more a farmer sprays, the more a farmer may need to spray. As such, the benefits of the 3R3G technology package should be manifested in reduced input use intensities without yield loss and, therefore, reduced costs and higher profits.

Uptake of 3R3G by the Vietnamese MARD first occurred at the provincial level and then at the national level. Perhaps part of the reason of the ministry's interest in 3R3G was that it complemented other (much larger) R&D programs aimed at increasing the use of seeders and certified (good) seeds. As the proceeding discussion will show, seed reduction was the component that contributed most to overall gains from 3R3G.

In addition to the development and promotion of other technologies, the adoption of one or more of the components of 3R3G was influenced by a range of biotic and abiotic stresses. For example, the marked resurgence of an insect called brown planthopper in the Mekong Delta in crop year 2005 could have had a significant negative impact on farmers' willingness to reduce insecticide use. In addition, farmers will react to changes in the price of inputs or output in terms of increased or reduced input use.

Definition of adopters and nonadopters

A requisite for measuring impact is being able to establish "with and without" technology scenarios. In this case, it is done by establishing and comparing two groups of farmers who have similar characteristics, except with respect to their uptake of 3R3G. The two groups are the "adopters" and "nonadopters." Since 3R3G is basically a suite of crop management technologies containing three components, it is possible for some farmers to fully adopt all three components and others to partially adopt one or a paired combination of the components. The analyses done in this study do not differentiate partial from full adopters; they are merged into one group—adopters.

The **nonadopters** group is composed of farmers who did not practice any of the recommendations because they

(a) have never heard about 3R3G,
(b) have heard about 3R3G but do not believe in the principal recommendations, or
(c) have heard about and believed in the principles of 3R3G but were not willing to take the risk and therefore did not change their farming practices according to the 3R3G recommendations.

The **adopters** group is composed of farmers who have stated that they

(a) have heard about 3R3G,
(b) believed in the principal recommendations, and
(c) were willing to take the risk and took up one or more of the 3R3G recommendations and lowered their use of (1) seed, (2) nitrogen, and/or (3) pesticides.

Determinants of adoption

To establish the success or failure of 3R3G promotion in the region, adoption rates need to be measured and factors influencing adoption identified. Of particular interest is the extent by which mass media and traditional extension work influenced adoption and how adoption may have varied among provinces in the Mekong Delta. Based on the interviews of key MARD personnel from the provincial to village level, the provinces in the region were motivated by a common 3R3G goal but differed in the manner of resource allocation and intensity or coverage of extension work among others.

A probit analysis for a binary choice model for adoption was used to determine farmer/farm characteristics and technology transfer strategies that best influenced adoption. Two statistical packages[7] that can be used to estimate the parameters of the model using survey data are LimDep 8.0 and Stata 9.2. Both packages give exactly the same results, including the option to compute for marginal effects. The marginal effect measures how the probability of adoption is increased or decreased with an incremental increase in the explanatory variables or, in the case of a dummy, a discrete change from 0 to 1. The estimating equation for the binary choice adoption model specified in probit form is

$$\begin{aligned} \Pr(D_{3R3G} = 1) = {} & \acute{\alpha} + \beta_1 Ext + \beta_2 TvRad + \beta_3 Exp + \beta_4 School + {} \\ & \beta_5 F_S + \beta_6 D_{p1} + \beta_7 D_{p2} + \varepsilon \end{aligned}$$

where the dependent variables (left-hand side) and explanatory variables (right-hand side) of the above equation correspond to

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[7] It is not necessary to use both Stata and LimDep; either one should be sufficient. However, this study benefited from the exercise of running the model using both because it allowed identifying and correcting errors in transferring data from Excel (original setup) to Stata and LimDep when the results differed. This turned out to be a good practice.

D_{3R3G} = 3R3G adoption dummy
(1 if adopter, 0 otherwise)
Ext = received education regarding 3R3G from extension workers
(1 if yes, 0 otherwise)
TvRad = received education regarding 3R3G from TV and/or radio
(1 if yes, 0 otherwise)
Exp = experience in rice farming (years)
School = formal schooling (years)
F_s = farm size (ha)
D_{p1}, D_{p2} = province dummies for An Giang and Can Tho, respectively
$\acute{\alpha}$, B_i = parameter to be estimated for the ith regressor (where i = 1, ..., 7)
ε = random error

Comparison of input rates, yield, costs, and income

The first step in finding evidence of economic impact is to look at farm-level data and examine changes in practices (input use) and performance (yield, costs, and income). An independent t-test on the mean difference to compare adopters and nonadopters was done using SPSS software.

Unit cost function

The 3R3G is an input-reducing technological innovation that directly reduces variable cost per fixed factor[8] and variable cost per unit of output (unit cost). Better information or increased know-how set the adopters apart so they would have the predisposition to use inputs judiciously and more efficiently. This can be modeled in two ways, by specifying an 3R3G adoption dummy in an average unit cost function (model 1) and estimating the coefficients via ordinary least squares (OLS) using SPSS.

Model 1: Average unit cost function with adoption dummy via OLS

$$C = \acute{\alpha} + \beta_1 Y + \beta_2 Y^2 + \beta_3 D_a + \beta_4 D_{p1} + \beta_5 D_{p2} + \beta_5 F_s + \varepsilon$$

Or, a frontier cost function can be specified without the adoption dummy (model 2), coefficients estimated via maximum likelihood estimation (MLE) using FRONTIER 4.1,[9] efficiency scores (automatically generated as an output) established, scores sorted by adoption, and an independent t-test done on mean difference using SPSS. The cost (in)efficiency scores are to establish whether the adopters indeed perform better than the nonadopters.

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[8] Gabre-Madhin et al (2003) argued that this type of innovation when adopted ”on a wide scale” affects the aggregate supply curve by shifting it to the right as producers offer more for sale at any price. Further, in the study of firm behavior in the manufacturing industry, Olive (2002) proved the validity of average variable cost as a proxy for short-run marginal cost.

[9] Frontier 4.1 is a computer program written specifically to estimate stochastic frontier functions. A free download is available at www.uq.edu.au/economics/cepa/frontier.htm, including an electronic copy of the manual or guide, which discusses the mathematical specification and estimation procedure.

Model 2: Stochastic frontier unit cost function without adoption dummy via MLE

$$C = \acute{\alpha} + \beta_1 Y + \beta_2 Y^2 + \beta_3 D_{p1} + \beta_4 D_{p2} + \beta_5 F_s + (v + u)$$

where
C = per unit cost (total cost/rice output, US$/t)
Y = yield (t/ha)
Y^2 = square of yield
D_a = 3R3G adoption dummy (0, 1)
D_{p1}, D_{p2} = province dummies for An Giang and Can Tho (0, 1)
F_s = farm size (ha)
$\acute{\alpha}$, β_i = parameter to be estimated for the ith regressor (where $i = 1, \ldots, 5$)
u = one-sided error representing inefficiency
v = random error term

In both models, the unit cost function is convex and quadratic in yield—the expected signs of the coefficients are negative ($\beta_1<0$) for the yield term and positive ($\beta_2>0$) for the squared term.

Results

All farms considered in the analyses were direct seeded; the few transplanted farms were dropped from the analysis. Also excluded from the analysis in the wet season were farms with incomplete output information because interviews were done prior to harvesting. The following discussion refers to Tables 3 to 10.

Awareness and adoption

An entertainment-education (E-E) media format and traditional extension work promoting 3R3G succeeded in creating more than 80% awareness regarding the teachings and benefits of reducing the three key inputs—seed, fertilizer, and pesticides (Table 3). Even those who have not participated in farmers' training and demonstration trials were able to enumerate the reduction teachings heard or seen repeatedly over the radio, TV, village amplifiers, and billboards. The E-E approach, which delivered the reductions message through scripted talk shows and countryside drama, was both educational and entertaining. It was also effectively used for its precursor, integrated pest management (IPM) (Heong et al 2008). The media campaign was an effective tool in creating an attitudinal change from "more is better" to "less is more sensible" among farmers. During focus group discussions, farmers demonstrated open mindedness and expressed willingness to reduce seed rate in a little plot and then "wait and see" whether it worked. For most, it was still "to see is to believe."

However, it takes more than awareness to affect practices. It is necessary that farmers acquire the minimum know-how and skills to apply them. Equally important is that they should be sufficiently convinced that such a change will work to their advantage—this is where "hard-core" extension work through direct, personal, and

Table 3. Awareness and adoption rates (%) of 3R3G as reported by farmers, selected provinces of Mekong River Delta, crop years 2005-07.[a]

Item	An Giang	Can Tho	Soc Trang	ALL
Awareness	86	84	95	89
Practice change				
• Reduced seeds	48	34	56	46
• Reduced nitrogen/fertilizer	35	25	40	33
• Reduced insecticide/pesticide	40	26	40	35
Adoption level				
I: "One reduction"	6	8	13	9
II: "Two reductions" (any two-combination)	13	7	14	11
III: "Three reductions"	30	21	32	28
Adopters (one, two, and three reductions)	49	36	59	48
Nonadopters	51	64	41	52
Total number of respondents	166	169	172	507

[a] Percent was based on total number of respondents.

frequent interaction of agricultural technicians with farmers plays an important role. The media campaign, however, made it easier for the technicians to convince farmers to assume risks of yield loss associated with input reductions. Farmers were encouraged to reduce inputs gradually, season after season, until the optimum targets were reached. This eventually led to adoption. Other important considerations for adoption are farmers' assessment of risks imposed by the vagaries of weather, incidence of migratory pests, and fluctuations in input/output prices. It can be expected that, all else being equal, natural disasters causing floods, pest migration into the area, and unstable prices singularly, or in combination, discourage farmers from reducing seed, fertilizer, and pesticides.

Adopters and nonadopters were almost equally represented on the sample farms covered in the survey. More than half of the adopters are actually full adopters. Of the three reductions, reducing seed had the highest adoption rate. This is a positive outcome because if farmers are able to reduce seed rates, then adoption of the other two components may ensue naturally as there is less pest pressure and fertilizer requirements decline (Heong 2006). The success of the seed component was likely to have been due to the complementary programs of the MARD, namely, the provision of a reliable supply of affordable, good-quality seeds and the promotion of mechanical seeders. The adoption rate of lower seed application was highest in Soc Trang (56%), followed by An Giang (48%) and Can Tho (34%). Interprovincial differences possibly reflect variation in the assessment of the size of risks of yield loss as seed rates are reduced. Another probable reason that needs further investigation is the limitation

Table 4. Multiple sources of information regarding 3R3G, selected provinces of the Mekong River Delta, crop years 2005-07.

Province	Agric. technician	Radio and TV	Others[a]	No response	Number reporting
	Row percentage, %				
An Giang					
Adopters	49	43	7	–	81
Nonadopters	14	51	8	27	85
Both	31	47	8	14	166
Can Tho					
Adopters	43	54	2	2	61
Nonadopters	18	56	1	25	108
Both	27	56	1	17	169
Soc Trang					
Adopters	40	36	20	5	101
Nonadopters	20	48	21	11	71
Both	31	41	20	8	172
All					
Adopters	44	43	11	2	243
Nonadopters	17	53	9	22	261
Both	30	48	10	13	507

[a] Includes co-farmers, relatives, and input suppliers.

imposed by access to certified, registered, or commercial seeds at “affordable” prices, which are of higher quality than seeds harvested by farmers in the preceding season. Indeed, the farmers indicated that they will continue to reduce seed rates as cheaper quality seeds and mechanical seeders become increasingly available. In other words, indications are that uptake of the seed component of the 3R3G crop management package is enhanced by the outputs of the complementary MARD programs.

Determinants of adoption

The process of adoption may follow a complicated path; for simplicity, the decision to adopt is defined earlier to be a binary choice that allows the specification of a probit adoption model. From the enormous data collected, the items of interest are narrowed to only those hypothesized to influence a farmer’s decision to adopt and these are the main source of 3R3G information (extension and mass media, which are mutually exclusive sources), length of experience in rice farming, formal schooling, and farm size. The location effect represented by province dummies was included in the model to statistically validate differences in the overall effectiveness of implementing the 3R3G

Table 5. Probit regression: determinants of 3R3G adoption, selected provinces of the Mekong River Delta, crop years 2005-07.

Item	Coefficient	z/χ^2 value	Level of significance	Mean	Marginal effect*
Intercept	–0.862	–3.780	0.000		
Sources of 3R3G information					
Extension education[a]	0.822	6.890	0.000	0.491	0.319
Radio and TV[a]	0.151	1.100	0.271	0.732	0.060
Demographic characteristics					
Farm experience	0.007	1.260	0.209	22.558	0.003
Formal schooling	0.059	3.080	0.002	6.355	0.023
Farm size	0.000	0.020	0.988	2.032	0.000
Location effects					
An Giang[a]	–0.220	–1.510	0.131	0.327	–0.087
Can Tho[a]	–0.527	–3.600	0.000	0.333	–0.206
Log-likelihood, χ^2 (df = 7)	–308.867	84.250	0.000		
Pseudo R^2 (McFadden)	0.120				
Number of observations	507				

[a]These were estimated using Stata 9.2 and LimDep 8.0, which yielded the same results. Marginal effects were evaluated at the mean for continuous variables and at discrete change from 0 to 1 for dummies (*).

program across provinces. Using LimDep 8.0 and Stata 9.2, the results of maximum likelihood estimation and computed marginal effects are presented in Table 5.

Pervasive awareness regarding the technology was made possible by radio and television programs in an education-entertainment format as well as talk shows. Awareness preconditioned farmers for adoption. Conceivably, mental appreciation of the merits of the technology as they are entertained altered risk preference to the extent that farmers were more willing to take small lots of risk associated with yield loss when seed rates, fertilizers, and pesticides were reduced by a small proportion at a time.[10] As a stand-alone, however, it did not prove statistically significant in the final decision to adopt. Traditional extension education through individual or one-on-one visits, group meetings called by agricultural technicians, and participation in training/field trials proved more effective in influencing adoption. Probit analysis shows a 32% increase in the probability of adoption for farmers who received 3R3G education via extension work.

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[10] The various works of Escalada and Heong (2004) and Heong et al (2008) pointed out the success of mass media campaigns and the significance of the education-entertainment process in creating favorable attitudes and changing rice farmers' practices on the use of insecticides, seeds, and fertilizers in Vietnam.

Of the three demographics specified in the model, only formal schooling positively and significantly increased probability of adoption, although by a small margin of 2%. The logic behind lower fertilizer requirements and lower insect pest pressure following a seed rate reduction is arguably more appealing to more educated farmers, all other things being equal.

Of special note are the apparent counterintuitive results for location effects. Can Tho is the center of rice breeding research, education, and training in southern Vietnam as it houses the Cuu Long Rice Research Institute (www.clrri.org/en/function.htm). Moreover, most of the newer production management technologies in rice such as 3R3G in 2001 are pilot-tested in this province. Yet, rates of awareness and adoption were below those in the other two surveyed provinces (see Table 3). These results suggest that the promotion of 3R3G in Can Tho was not as successful as it was in An Giang or Soc Trang. The succeeding discussion on economic payoff provides some insights into the lower awareness and adoption rates.

Changes in input use and yield

The following discussion compares input use between adopters and nonadopters found in Tables 6A (dry season) and 6B (wet season). Reference is also made to the target recommendations in Table 1.

Results from the household surveys reveal that farmers have two equally important goals—to maximize yield and to maximize net income. Unlike formal businesses in which the entrepreneur usually conducts a feasibility study and keeps business records, farmers base their decision on recall of past seasons' yields and incomes plus some erstwhile unorganized records of costs incurred for the season. In making decisions regarding input use, they first consider the recommended rates provided by technicians and sales representatives from pesticide and fertilizer companies. Then, depending on current input prices and their cash and credit position, they will determine how closely they can follow the recommended rates. Often, long experience in farming provides a cognitive evaluation of economic optima that will maximize net income. Furthermore, there are compelling natural events and noneconomic considerations in input-use decisions. The interplay of these events and considerations compromises the integrity of *changes in input use* as an indicator of impact unless one can isolate changes that are purely attributable to 3R3G.

Seeds. On average, adopters in An Giang reported the lowest seed rate (151 kg ha^{-1}) during the dry season of 2005-06, whereas the highest seed rate (220 kg ha^{-1}) was reported by farmers in Can Tho in the wet season (Tables 6A, 6B). These rates are both well above the science-based recommendation of 100 kg ha^{-1} (Table 1). Most of these adopters indicated that they would continue reducing seed rate in increments of about 10–20 kg ha^{-1} every season conditional on favorable weather or climatic conditions and for as long as there would be no indication of a forthcoming significant yield loss. This is consistent with the overall MARD strategy of allowing farmers to slowly achieve a seed rate target year-by-year. As such, the continued fall in seed cost over time needs to be considered in an analysis of a temporal flow of benefits from the adoption of 3R3G recommendations.

Table 6A. Average per hectare input use, yield, cost, and income comparisons, adopters vs. nonadopters of 3R3G, selected provinces of the Mekong River Delta, dry season.[a]

Item	Adopter (A)	Non-adopter (B)	Input/cost reductions (A – B)	Level of statistical significance	Adopter (A)	Non-adopter (B)	Input/cost reductions (A – B)	Level of statistical significance
	An Giang, 2006				Can Tho, 2006			
Number of cases	81	85			61	108		
Seed rate (kg ha^{-1})	150.58	185.58	–35.00	0.000	196.39	213.25	–16.86	0.002
Elemental nitrogen (kg ha^{-1})	105.32	116.24	–10.92	0.024	100.48	98.65	1.83	0.755
Elemental phosphorus (kg ha^{-1})	29.66	31.59	–1.93	0.336	26.96	27.94	–0.98	0.667
Elemental potassium (kg ha^{-1})	54.49	47.98	6.50	0.093	40.08	38.84	1.24	0.750
Herbicide cost (US$ ha^{-1})	14.93	14.93	0.00	1.000	12.93	13.81	–0.88	0.490
Insecticide cost ($ ha^{-1})	19.32	28.21	–8.89	0.019	16.42	29.03	–12.60	0.047
Fungicide cost ($ ha^{-1})	45.04	46.74	–1.70	0.746	31.02	40.74	–9.72	0.010
Molluscicide cost ($ ha^{-1})	11.35	12.10	–0.75	0.721	9.83	11.56	–1.73	0.311
Yield (t ha^{-1})	7.71	7.55	0.16	0.186	7.65	8.00	–0.34	0.043
Cost: labor ($ ha^{-1})	179.85	184.66	–4.80	0.487	161.49	172.51	–11.02	0.099
Cost: materials ($ ha^{-1})	298.94	331.41	–32.47	0.004	256.39	289.91	–33.52	0.010
Cost: total ($ ha^{-1})	478.80	516.07	–37.27	0.005	417.88	462.42	–44.54	0.005
Cost: per unit ($)	62.65	68.84	–6.19	0.001	55.09	58.48	–3.39	0.108
Income: gross ($ ha^{-1})	1,169.27	1,101.55	67.72	0.001	1,163.89	1,244.81	–80.93	0.007
Income: net ($ ha^{-1})	690.47	585.48	104.99	0.000	746.01	782.39	–36.39	0.207

Continued on next page

Table 6A continued.

Item	Adopter (A)	Non-adopter (B)	Input/cost reductions (A – B)	Level of statistical significance	Adopter (A)	Non-adopter (B)	Input/cost reductions (A – B)	Level of statistical significance
	Soc Trang, 2007				All			
Number of cases	101	71						
Seed rate (kg ha^{-1})	182.18	208.07	–25.90	0.000	175.21	202.95	–27.74	0.000
Elemental nitrogen (kg ha^{-1})	85.00	99.28	–14.28	0.004	95.66	104.48	–8.82	0.004
Elemental phosphorus (kg ha^{-1})	19.96	21.43	–1.46	0.414	24.95	27.36	–2.41	0.045
Elemental potassium (kg ha^{-1})	27.97	23.39	4.58	0.080	39.85	37.63	2.22	0.308
Herbicide cost ($ ha^{-1})	15.07	18.68	–3.61	0.111	14.48	15.48	–0.99	0.321
Insecticide cost ($ ha^{-1})	21.52	28.34	–6.83	0.024	19.50	28.58	–9.08	0.000
Fungicide cost ($ ha^{-1})	31.39	27.95	3.45	0.331	35.85	39.23	–3.38	0.172
Molluscicide cost ($ ha^{-1})	4.42	4.37	0.05	0.954	8.09	9.80	–1.71	0.076
Yield (t ha^{-1})	6.05	6.01	0.04	0.805	7.01	7.32	–0.31	0.008
Cost: labor ($ ha^{-1})	134.01	141.16	–7.15	0.113	156.19	167.99	–11.80	0.002
Cost: materials ($ ha^{-1})	227.88	257.53	–29.65	0.003	258.72	294.56	–35.84	0.000
Cost: total ($ ha^{-1})	361.89	398.69	–36.80	0.002	414.91	462.55	–47.64	0.000
Cost: per unit ($)	61.08	68.52	–7.45	0.001	60.10	64.51	–4.42	0.000
Income: gross ($ ha^{-1})	889.91	885.82	4.09	0.886	1,051.81	1,102.14	–50.34	0.010
Income: net ($ ha)	528.02	487.13	40.89	0.122	636.89	639.59	–2.70	0.879

[a] All monetary values are in 2006 prices.

Table 6B. Average per hectare input use, yield, cost, and income comparisons, adopters vs. nonadopters of 3R3G, selected provinces of Mekong River Delta, wet season.[a]

Item	Adopter	Non-adopter	Input/cost reductions	Level of statistical significance	Adopter	Nonadopter	Input/cost reductions	Level of statistical significance
	(A)	(B)	(A – B)		(A)	(B)	(A – B)	
	An Giang, 2006				Can Tho, 2006			
Number of cases	81	85			61	108		
Seed rate (kg ha^{-1})	153.49	193.37	–39.88	0.000	202.23	219.83	–17.60	0.002
Elemental nitrogen (kg ha^{-1})	107.74	118.63	–10.89	0.045	108.17	102.63	5.54	0.354
Elemental phosphorus (kg ha^{-1})	30.14	31.06	–0.93	0.659	29.11	30.35	–1.24	0.615
Elemental potassium (kg ha^{-1})	55.49	49.02	6.48	0.101	44.72	45.26	–0.53	0.895
Herbicide cost ($ ha^{-1})	15.37	15.48	–0.10	0.951	12.72	14.59	–1.87	0.136
Insecticide cost ($ ha^{-1})	21.56	25.51	–3.95	0.349	17.74	27.46	–9.71	0.005
Fungicide cost ($ ha^{-1})	42.77	51.44	–8.67	0.137	30.94	40.91	–9.96	0.008
Molluscicide cost ($ ha^{-1})	8.47	9.61	–1.14	0.502	7.60	14.42	–6.81	0.007
Yield (t ha^{-1})	5.86	5.60	0.25	0.106	4.78	5.25	–0.47	0.002
Cost: labor ($ ha^{-1})	211.72	230.43	–18.71	0.067	167.88	183.66	–15.79	0.014
Cost: materials ($ ha^{-1})	293.71	328.66	–34.95	0.002	267.01	296.89	–29.88	0.013
Cost: total ($ ha^{-1})	505.43	559.09	–53.66	0.001	434.89	480.55	–45.66	0.002
Cost: per unit (US$/t)	89.28	104.18	–14.90	0.002	93.30	94.05	–0.75	0.835
Income: gross ($ ha^{-1})	910.31	849.75	60.56	0.015	709.77	788.60	–78.83	0.001
Income: net ($ ha^{-1})	404.88	290.66	114.22	0.000	274.89	308.05	–33.16	0.178

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Table 6B continued.[a]

Item	Adopter (A)	Non-adopter (B)	Input/cost reductions (A – B)	Level of statistical significance	Adopter (A)	Nonadopter (B)	Input/cost reductions (A – B)	Level of statistical significance
	Soc Trang, 2006				All			
Number of cases	101	71			243	264		
Seed rate (kg ha^{-1})	187.20	213.36	–26.16	0.000	179.74	209.57	–29.84	0.000
Elemental nitrogen (kg ha^{-1})	81.35	92.35	–11.00	0.016	96.88	105.02	–8.14	0.011
Elemental phosphorus (kg ha^{-1})	18.42	19.43	–1.00	0.487	25.01	27.64	–2.63	0.034
Elemental potassium (kg ha^{-1})	25.62	21.04	4.58	0.080	40.37	39.96	0.42	0.856
Herbicide cost ($ ha^{-1})	14.06	16.69	–2.63	0.221	14.16	15.44	–1.28	0.195
Insecticide cost ($ ha^{-1})	13.24	17.67	–4.43	0.028	17.15	24.20	–7.05	0.000
Fungicide cost ($ ha^{-1})	28.61	26.38	2.23	0.469	33.91	40.39	–6.48	0.012
Molluscicide cost ($ ha^{-1})	4.53	4.53	0.00	1.000	6.61	10.21	–3.59	0.001
Yield (t ha^{-1})	5.69	5.42	0.28	0.099	5.52	5.41	0.11	0.247
Cost: labor ($ ha^{-1})	127.73	129.38	–1.65	0.664	165.80	184.12	–18.32	0.001
Cost: materials ($ ha^{-1})	199.65	219.17	–19.52	0.039	247.91	286.22	–38.30	0.000
Cost: total ($ ha^{-1})	327.38	348.55	–21.17	0.060	413.72	470.34	–56.62	0.000
Cost: per unit (US$/t)	58.63	66.69	–8.06	0.001	77.55	89.96	–12.41	0.000
Income: gross (US$/ha)	685.55	669.74	15.81	0.536	766.55	776.32	–9.77	0.539
Income: net ($ ha^{-1})	358.17	321.19	36.98	0.131	352.83	305.98	46.85	0.002

[a] All monetary values are in 2006 prices.

Fertilizer. Nutrient management in rice evolved from blanket recommendations of prescheduled and predetermined N-P-K (nitrogen-phosphorus-potassium) rates into a regimen that is site-specific and need-based.[11] Being site-specific, the rates (theoretically) vary with the inherent nutrient-supplying capacity of the soil and crop demand. These rates presume biological optima for all other inputs (including seeds) corresponding to a maximum yield level such that beyond these rates there will be no significant yield gains. Crop demand for these macro-nutrients is directly influenced by seed rate or plant density. Farmers in the Mekong historically sowed an excessive quantity of seeds, perhaps to mitigate the risk of losing seedlings to snails and losing yield to diseased seeds, weed competition, and flood—or due to a lack of awareness. High seed rates and high plant density led to high crop demand for nutrients or synthetic fertilizers. When seed rates are reduced, crop demand for these nutrients naturally diminishes, leading to lower rates of application, lower costs, and improved profits. Note that, for as long as fertilizer is not costless, the economic optimum rate is lower than the biological (production-maximizing) optimum rate. Furthermore, as fertilizer prices rise, all other things being equal, it is economically rational to reduce application rates. Hence, observed reductions in fertilizer could come from reduced crop demand resulting from reduced seed rates, or increases in fertilizer prices.

Fertilizer rates were invariant between seasons despite the seasonally different recommended rates for nitrogen and potassium. However, variations occurred across locations (provinces): farmers' fertilizer rates in Soc Trang were usually lower than the recommended rates, whereas, in An Giang and Can Tho, fertilizer rates were either marginally below or marginally above the same recommendations. Between adopters and nonadopters, significant differences were most evident for nitrogen.

Adopters generally used less nitrogen than nonadopters except in Can Tho, where adopters applied more. The mean values for elemental nitrogen (85–116 kg ha^{-1}) were within the range of recommended rates (100–120 kg ha^{-1}).

For elemental phosphorus, adopters' rates in An Giang and Can Tho were not significantly different from those of nonadopters; the rates were, in fact, quite close to the science-based recommendations of 30 kg ha^{-1}. Soc Trang farmers, however, applied 10 kg below the recommended rate.

Although the recommended rates for potassium differ between seasons (30 kg ha^{-1} in the dry and 50 kg ha^{-1} in the wet), farmers' application rates were quite invariant. Dry-season averages for the provinces of An Giang and Can Tho exceeded the recommended rates by about 10–25 kg while in Soc Trang the rates were short by 2–7 kg. Wet-season averages for An Giang and Can Tho were close to the recommendations while in Soc Trang the rates were short by 25–30 kg.

Pesticides. Adopters of 3R3G spent less than nonadopters on pesticides, particularly insecticides. As mentioned earlier, 3R3G had its roots in NES. However, rather than promoting NES per se, the message delivered in the media campaign was one of a general reduction in the use of all pesticides, which further simplified the NES

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[11] This is well described on the IRRI Web site at www.irri.org/ssnm (accessed September 2008).

message, which was to refrain from applying insecticides within the first 45 days after planting.

Further discussions with farmers and district technicians revealed an active IPM program in the region prior to 3R3G. IPM taught farmers to assess pest situations, to use pesticides judiciously, and later to follow the NES rule. Since 3R3G can be regarded to have only reinforced the IPM teaching, then the benefit of a reduction in pesticide use cannot be fully attributed to 3R3G. However, any difference between the amounts spent between adopters and nonadopters can be largely attributed to 3R3G, as they were both exposed to IPM.

Changes in the three inputs targeted in the 3R3G campaign also affected, directly or indirectly, the use of other inputs, especially labor, although the aggregate effect is quite ambiguous. For example, sowing less seed will not likely alter the sowing labor requirement, while using less fertilizer and reducing the frequency of pesticide sprays could lessen labor usage. However, in the case of snail control, hand picking of snails was a common substitute for molluscicide application.

Yield. The national yield average for Vietnam in 2005 was 4.89 t ha^{-1}. Yields are higher in irrigated (favorable) areas than in rainfed (less favorable) areas. Southern Vietnam is a prime rice-growing area because of high alluvial deposits feeding the paddy soils along the trail and tail end of the Mekong River. The provinces along the river have fertile soils resulting in high yields. Between seasons, yields are much higher in the dry season because of greater solar radiation that results in more and heavier grains. This is supported by the survey data, which show that, in the dry season, average yields were 6–8 t ha^{-1}, whereas, in the wet season, average yields were 5–6 t ha^{-1}. Nevertheless, the wet-season yields were still higher than the national average.

As mentioned previously, 3R3G aims to reduce the use of seed, nitrogen fertilizer, and insecticides without sacrificing yield. Hence, it can be hypothesized that adopters' yield should not be statistically less than the yield obtained by nonadopters despite the input reductions. Effects of 3R3G on yields are inconclusive—no change for An Giang, a loss for Can Tho, and a gain for Soc Trang. Yield is therefore a poor partial indicator of 3R3G impact.

Economic payoff of adoption—cost and income comparisons

Rational business choices, even in rice farming, are often made based on a rule that says, "a cost saved is profit gained." Faced with ever-changing product and input prices and new crop management options, farmers change the mix of inputs with only one goal in mind—improve incomes and, in the case of three reductions, lower costs. This section examines the economic payoff of adoption by looking at overall farm performance using costs and incomes.

When costs are aggregated into two components—labor and materials—the resulting proportion of labor to material cost is 40–60. Labor cost consists of paid-out labor costs (including meals) plus imputed unpaid labor costs for which family/exchange labor is judged to be nonsupervisory and can be substituted with hired labor. Material costs include seed, fertilizer, pesticides, fuel, and oil. Roughly, seed, fertilizer, and pesticides account for about 8%, 30%, and 18% of total costs, respectively, quite invariant with respect to location (province), adoption, and season. Although the proportion of the three-reduction inputs put together is quite large (56% of total cost), the input/cost reductions were not large enough to affect the cost proportions (or cost structure).

A more insightful indicator of overall cost performance is in terms of unit cost, especially when this is compared with paddy (rough rice) price, for which the difference measures profit margins. The unit cost is equal to the total cost divided by total production. Adopters are hypothesized to exhibit a lower average unit cost; in fact, they do except in the case of Can Tho. Across provinces, mean differences between adopters and nonadopters were statistically significant—US\$4.42 t^{-1} in the dry season and \$12.41 t^{-1} in the wet season. Although the additional profit margin for individual farms is minimal, when extrapolated to all adopting farms, then aggregate benefits are significant.

On the basis of the unit cost, results suggest that it is more expensive to grow rice in the wet season than in the dry season because yields are lower in the wet season, whereas per hectare costs are relatively consistent. As such, the benefits of cost savings are amplified in the wet season when yields are low.

The economic payoff of adoption proved by the unit cost analysis did not come through the per hectare net income comparisons probably because the cost reductions were masked by lower farm-gate prices received by adopters. Farm-gate prices are sensitive to the timing of harvest. In general, rough rice sold either early or very late in the season receives higher prices. The expected higher per hectare income results, however, were evident only in An Giang for both seasons. Thus, unit cost stood out as the best indicator of 3R3G impact and a consistent measure of economic payoff.

Rice income and its implications for poverty reduction

Annual income from rice was computed by adding the two-season net incomes for the actual farm size of each household (Table 7). Adopters of 3R3G in An Giang and Soc Trang reaped statistically significant income gains. Adopters in Can Tho suffered some income losses (mainly because of lower yields) although these were not statistically significant.

To assess the ***possible*** impact of adoption on poverty reduction, per capita incomes were computed and compared to the poverty line—an estimate of the per person cost of procuring the 2,100 calories a day deemed necessary for human health. The World Bank \$1 per day[12] poverty line means that each person should have a disposable income of at least \$365 per year to buy enough food for a healthy living. Using survey data on net income from rice and average farm size and household size, annual per capita incomes were computed for each province (see footnote b of Table 7). This reveals the amount of money that can be drawn out of rice earnings to defray the cost of living of a household member. Per capita rice incomes computed for the three provinces surveyed in the region fall within the range of the poverty

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[12] The Asian Development Bank recently raised the poverty line from \$1 per day to \$1.35 per day while the World Bank raised it to \$1.25 per day.

Table 7. Annual income comparisons, adopters vs. nonadopters of 3R3G, selected provinces of the Mekong River Delta, crop year 2005-06–2006-07.

Item	Adopter (A)	Non-adopter (B)	Mean difference (A – B)	Level of statistical significance	Adopter (A)	Non-adopter (B)	Mean difference (A – B)	Level of statistical significance
			An Giang				Can Tho	
Number of cases	81	85			61	108		
Income: gross ($ ha^{-1})	2,079.58	1,951.30	128.28	0.001	1,873.66	2,033.42	–159.75	0.001
Cost: labor ($ ha^{-1})	391.57	415.09	–23.51	0.120	329.37	356.18	–26.81	0.021
Cost: materials ($ ha^{-1})	592.65	660.07	–67.42	0.001	523.40	586.79	–63.40	0.007
Cost: total ($ ha^{-1})	984.23	1,075.16	–90.93	0.001	852.77	942.97	–90.20	0.002
Income: net ($ ha^{-1})	1,095.35	876.14	219.21	0.000	1,020.89	1,090.44	–69.55	0.140
Average farm size (ha)	2.53	1.80	0.73	0.006	2.08	2.24	–0.16	0.737
Average household size	4.91	4.73	0.18	0.393	4.62	4.93	–0.30	0.173
Income: per capita ($)	594.48	384.34	210.14	0.002	497.22	561.21	–63.98	0.620
			Soc Trang				All	
Number of cases	101	71			243	264		
Income: gross ($ ha^{-1})	1,575.46	1,555.56	19.90	0.658	1,818.36	1,878.46	–60.11	0.052
Cost: labor ($ ha^{-1})	261.74	270.54	–8.80	0.258	322.00	352.11	–30.12	0.000
Cost: materials ($ ha^{-1})	427.53	476.70	–49.17	0.007	506.64	580.78	–74.14	0.000
Cost: total ($ ha^{-1})	689.27	747.24	–57.97	0.008	828.63	932.89	–104.26	0.000
Income: net ($ ha^{-1})	886.19	808.32	77.87	0.057	989.72	945.57	44.15	0.100
Average farm size (ha)	1.83	1.66	0.17	0.401	2.13	1.94	0.18	0.335
Average household size	4.74	4.93	–0.19	0.377	4.77	4.86	–0.09	0.442
Income: per capita ($)[b]	360.05	282.58	77.47	0.071	472.63	429.33	43.30	0.382

[a] All monetary values are in 2006 prices. [b] Income: per capita is [Income:net] multiplied by [average farm size] divided by [average household size].

Table 8. Average unit-cost function (via OLS) results by season.

Item	Dry season		Wet season	
	Coefficient	Level of significance	Coefficient	Level of significance
Intercept	147.171	0.000	260.240	0.000
Yield	–18.469	0.000	–56.469	0.000
Square of yield	0.862	0.000	3.770	0.000
Adoption dummy	–5.385	0.000	–6.836	0.000
An Giang Province dummy	12.625	0.000	37.137	0.000
Can Tho Province dummy	4.228	0.009	23.384	0.000
Farm size	–0.531	0.031	–0.559	0.145
R^2	0.328		0.614	
Adjusted R^2	0.320		0.609	
F-value	40.761	0.000	132.556	0.000
Number of observations	507		507	

line. With an increase in per capita income of $77-210, adoption of three reductions had a positive influence on the well-being of households in An Giang and Soc Trang (statistically speaking). Whereas, in Can Tho, the per capita income of adopters was lower on average by $63, suggesting that the survey data and analysis employed failed to show any economic payoff of 3R3G adoption to farmers in this province.

From a livelihood perspective, rice farmers in the Mekong region have other sources of income such as livestock, fisheries, and off-farm employment so that incomes from rice account for about 20–40% of total household income (Hossain et al 2006, Ut et al 2000) and could even be less with rising employment opportunities from the burgeoning industrial/manufacturing and service sectors. Given rice income to buy enough food and the 60–80% of income from nonrice sources, it follows that rice farmers in the region live well above poverty.[13]

Cost efficiency

Results supporting the cost-reducing effect of 3R3G are quite robust based on the estimated coefficients of the two unit-cost models presented in Tables 8–10. All variables hypothesized to affect unit cost have coefficients bearing the expected signs

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[13] It can be further said that the total and incremental changes in rice incomes due to 3R3G or any crop management technology for that matter are rather small to have a substantial poverty impact on households that experience growing income opportunities in the industrial, manufacturing, and service sectors. Also, poverty impacts, especially in this particular situation, are better assessed in the context of overall livelihood opportunities rather than improvements in rice incomes alone.

Table 9. Stochastic frontier cost function (via MLE) results by season.[a]

Item	Dry season		Wet season	
	Coefficient	Level of significance	Coefficient	Level of significance
Intercept	136.992	0.000	200.410	0.000
Yield	–20.428	0.000	–43.890	0.000
Square of yield	1.013	0.000	2.787	0.000
An Giang Province dummy	13.703	0.000	34.309	0.000
Can Tho Province dummy	5.571	0.000	23.767	0.000
Farm size	–0.633	0.027	–0.983	0.026
Sigma-squared, σ^2	310.536	0.000	737.833	0.000
Gamma, λ	0.877	0.000	0.901	0.000
Log likelihood function	–1,949.496		–2,154.210	
LR[b] test of the one–sided error	47.666		76.014	
Number of observations	507		507	

[a] Mu (μ) and eta (η) were restricted to zero. [b] LR = likelihood ratio.

Table 10. T-test on mean difference of cost efficiency (CE) scores.

Item	Adopter ave. score (A)	Nonadopter ave. score (B)	Mean difference (A – B)	Level of statistical significance
Dry season				
An Giang	1.212	1.266	–0.054	0.020
Can Tho	1.243	1.331	–0.088	0.016
Soc Trang	1.235	1.326	–0.092	0.002
All	1.229	1.309	–0.080	0.000
Wet season				
An Giang	1.229	1.319	–0.090	0.004
Can Tho	1.222	1.333	–0.111	0.005
Soc Trang	1.455	1.491	–0.036	0.470
All	1.321	1.371	–0.050	0.043

and are significant at least at the 5% level. Consistent with economic theory, unit cost is quadratic and convex.

In the first model, the effect of adoption was determined by specifying an adoption dummy to explain average variations in the unit cost. The OLS estimate (Table 8) shows that, on average, adoption reduced unit cost by \$5.39 t^{-1}, all other things being equal. Further, differences occur in the unit cost across provinces, which likely reflect differences in wages paid. Wage rates were highest in An Giang, which has more employment opportunities, followed by Can Tho and Soc Trang. Relatively larger farms have a lower per unit cost, which suggests economies of scale. In fact, as the province progresses, labor becomes increasingly scarce and more expensive, thus setting the stage for mechanization. Since investing in machinery makes more sense if farms are larger, some farmers interviewed reported having grouped to consolidate their lands with respect to farm operations to justify the acquisition of bigger tractors, large-capacity dryers, and threshers. Substituting machines for labor lowers unit cost.

The second model takes the cost-efficiency concept in a more intuitively appealing framework—the stochastic frontier approach. The model is re-specified by taking out the adoption dummy. The approach involves connecting the points of the most efficient farms to define a frontier cost curve. The next step involves assessing the inefficiency of the rest of the farms by calculating the distance of the less efficient farms from the frontier called "efficiency score." A computer algorithm makes this otherwise complex (maximum likelihood) procedure computationally possible and tractable. Efficient farms have scores closer to 1 whereas inefficient farms have scores much higher than 1. Finally, the mean efficiency scores of adopters and nonadopters are compared statistically.

In Table 9, the results of Model 2 (stochastic frontier unit cost) reinforce the results of Model 1 (average unit cost) discussed earlier except for a slight variation in the magnitude and improved level of significance of the coefficients. Gamma (γ) coefficients in both the dry and wet seasons are significantly different from zero, which means that inefficiencies exist (Coelli 1996). Average cost-efficiency scores in Table 10 indicate inefficiencies for both although the inefficiencies were greater for nonadopters. Finally, a t-test on the mean difference of cost-efficiency scores supports the OLS results that adoption improved cost efficiency.[14]

Conclusions

Three-reductions technology is a knowledge-based crop management innovation aimed at solving the excessive seeding rate and overuse of fertilizers and pesticides in southern Vietnam. IRRI used SDC funds and invested in on-farm research in the province of Can Tho in 2001, which the MARD of southern Vietnam quickly adopted

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[14] Although it is tempting to conclude that the incidence of inefficiency for adopters indicates room for improving the technical content or delivery of 3R3G, given that only about 30% of the variation in the average unit cost is explained by the independent variables in the OLS model, it cannot be categorically stated that this is the case. The authors believe that the scores are best interpreted for their relative rather than absolute values. Besides, there will always be some inefficiency.

in its agricultural programs by replicating the research in other provinces, promoting the three reductions on the radio and television in an entertainment format, and organizing small farmers' meetings with local government technicians for the mechanics of the three-reductions technology. Radio and television promoted awareness, but the extension work of local technicians remains the most significant determinant of farmers' decision to adopt. Contrary to expectations, Can Tho showed the lowest awareness and adoption rates. The low adoption could also be because of the lack of economic payoff to adoption in this province resulting from the yield loss associated with adoption.

Adoption of three reductions, partial or full, most significantly lowered seed rates, which were likely to have been made possible by the increased availability of certified and good seeds in addition to soft loans that enabled farmers to acquire mechanical seeders as part of the overall rice program in the region. Effects of three reductions on yield and net incomes are quite inconclusive; therefore, these are poor indicators of impacts. Unit cost is the most consistent and, hence, the best indicator of 3R3G impact—adopters showed lower unit costs. When the frontier approach was used, adopters were proved to be more cost efficient than nonadopters. Unit costs were also lower for larger farms, suggesting the presence of economies of scale. Finally, rice incomes were sufficient for households to purchase food to be healthy. Other sources of income such as nonrice ventures or off-farm employment are important in ensuring that these rice households remain a leap away from poverty.

Lessons learned

Facilitative nature of the E-E approach in technology dissemination

In promoting awareness and adoption of technologies, it was learned that mass media using the E-E approach facilitated the work of traditional person-to-person extension in as much as this prepared farmers mentally and psychologically in understanding, appreciating, and evaluating the pros and cons of 3R3G. Imagine how advertisements raise the curiosity, wants, and desires of consumers for products so neatly and alluringly presented in colorful images and sounds. E-E and mass media, similar to product advertisements, drive farmers to curiosity and want—at least they want to experiment to see whether the technology works. Extension workers can build on this "conditioning" and effectively motivate farmers to experiment and adopt. An in-depth investigation of these two would be most helpful for guiding technology diffusion programs in the future.

Establishing counterfactuals and attribution

In ex post impact analysis, the most challenging part methodologically is the establishment of a counterfactual or causal relationship between intervention and impact. It must address the general question, "What could have happened had there been no intervention?" In this study, the question is, "What could have happened to input use, yield, production costs, and farm income had IRRI not introduced 3R3G?" To answer this, the study surveyed a random sample of farmers in order to create comparable groups of adopters and nonadopters wherein the observed differences in their input use, costs, and incomes were equated to measures of impacts of the intervention.

However, just when the data had been analyzed and a report written, the authors learned that the random sampling procedure deployed does not ensure random assignment of "treatment" so there exists the possibility of *self-selection into treatment ... or adoption decision ... relevant to the process determining the outcome* (Faltermeier and Abdulai 2009). In other words, the adopters may be systematically different from nonadopters in that they may be more knowledgeable and innovative, less capital-constrained, less risk averse, and consequently have adopted superior technologies apart from 3R3G. When this happens, there is an upward bias in our impact measures as they also capture the benefits from other technologies the adopters were using concurrently. This is an example of an attribution problem, which is often referred to as the central problem in impact evaluations (Leeuw and Vaessen 2009).

Solutions to the problem of attribution and creating counterfactuals are becoming commonplace in economic literature as they continue to evolve. But, the econometric procedure is usually difficult to follow and not readily applicable to the specific cases at hand. An impact evaluator therefore needs to keep abreast of the methodological evolution and learn to adapt such to specific impact studies.

References

Coelli TJ. 1996. A guide to FRONTIER Version 4.1: a computer program for stochastic frontier production and cost function estimation. Centre for Efficiency and Productivity Analysis Working Papers No. 7/96. University of New England, Armidale, Australia. Free download of software and this article is available at www.uq.edu.au/economics/cepa/frontier.htm (accessed 24 Jul 2009).

Escalada MM, Heong KL. 2004. The case of using mass media: communication and behavior change in resource management. In: New directions for a diverse planet. Proceedings of the 4th International Crop Science Congress, 26 Sep.-1 Oct. 2004, Brisbane, Australia. Available at www.cropscience.org.au/icsc2004/symposia/4/2/356_escaladam.htm (accessed September 2008).

Escalada MM, Heong KL. 2007. Environmental radio soap opera for rural Vietnam. Paper presented at Radio Asia 2007, 19-22 June 2007, Singapore. Available at http://devcompage.files.wordpress.com/2007/12/mescaladaheong-asia-radio-paper.pdf.

Faltermeier L, Abdulai A. 2009. The impact of water conservation and intensification technologies: empirical evidence for rice farmers in Ghana. Agric. Econ. 40:365-379.

Gabre-Madhin E, Barrett CB, Dorosh P. 2003. Technological change and price effects in agriculture: conceptual and comparative perspectives. Discussion paper no. 62. Markets, Trade and Institutions Division, International Food Policy Research Institute, Washington, D.C. Available at www.ifpri.org/divs/mtid/dp/papers/mtidp62.pdf (accessed in August 2008).

Heong KL, Escalada MM, Huan NH, Ky Ba VH, Quynh PV, Thiet LV, Chien HV. 2008. Entertainment-education and rice pest management: a radio soap opera in Vietnam. Crop Prot. 27:1392-1397.

Heong KL. 2006. Transforming research to benefit millions: the case of the 3R3G program in Vietnam. Division Seminar, Social Sciences Division, 23 June 2006, International Rice Research Institute, Los Baños, Philippines.

Heong KL, Escalada MM, Mai V. 1994. An analysis of insecticide use in rice: case studies in the Philippines and Vietnam. Int. J. Pest Manage. 40:173-178.

Hossain M, TT Ut, ML Bose. 2006. Livelihood systems and dynamics of poverty in a coastal province of Vietnam. In: Hoanh CT, Tuong TP, Gowing JW, Hardy B, editors. Environment and livelihoods in tropical coastal zones. Manila (Philippines): International Rice Research Institute and Penang (Malaysia): International Water Management Institute: CAB International. p 30-47.

Huan NH, Mai V, Escalada MM, Heong KL. 1999. Changes in rice farmers' pest management in the Mekong Delta, Vietnam. Crop Prot. 18:557-563.

Huan NH, Thiet LV, Chien HV, Heong KL. 2005. Farmers' evaluation of reducing pesticides, fertilizers and seed rates in rice farming through participatory research in the Mekong Delta, Vietnam. Crop Prot. 24:457-464.

Leew F, Vaessen J. 2009. Impact evaluations and development: NONIE guidance on impact evaluation. Washington, D.C. (USA): World Bank. Available at http://siteresources.worldbank.org/EXTOED/Resources/nonie_guidance.pdf (accessed 28 May 2010).

Nguyen HD, Tran TTD. 1997. Economic and health consequences of pesticide use in paddy production in the Mekong Delta, Vietnam. Ottawa (Canada): International Development Research Centre. Available at www.idrc.ca/uploads/user–S/10536137480ACF124.pdf (accessed September 2008).

Olive M. 2002. Is average variable cost a good proxy for short-run marginal cost and why is it important? Sydney: Macquarie University, Department of Economics. Available at www.econ.mq.edu.au/research/2002/8–2002Olive.PDF (accessed September 2008).

Ut TT, Hossain M, Janaiah A. 2000. Modern farm technology and infrastructure in Vietnam. Econ. Polit. Weekly 35:52(25-42).

Notes

Authors' addresses: Zenaida M. Huelgas, Social Sciences Division, International Rice Research Institute, Los Baños, Laguna, Philippines, email: z.huelgas@cgiar.org; Deborah J. Templeton, Livestock Production Systems Program, Australian Centre for International Agricultural Research, Canberra ACT, Australia, email: Templeton@aciar.gov.au.

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Development and impact of site-specific nutrient management in the Red River Delta of Vietnam

N.T.D. Nga, D.G. Rodriguez, T.T. Son, and R.J. Buresh

Site-specific nutrient management (SSNM) for a more effective use of fertilizers in rice production was developed and validated in the Red River Delta (RRD) of northern Vietnam through a partnership of the Soils and Fertilizers Research Institute (SFRI) and the International Rice Research Institute (IRRI) beginning in 1997. The subsequent dissemination of validated SSNM practices involved collaboration of SFRI and IRRI with the extension system and Plant Protection Division (PPD). We review the development of SSNM in the RRD and estimate the impact of SSNM adoption at the farm level through a survey in 2007 of adopters and nonadopters of SSNM in Ha Nam and Ha Tay provinces. SSNM improved farmers' rice yield by 0.2 t ha^{-1} in Ha Nam and by 0.34 t ha^{-1} in Ha Tay in the spring season. SSNM adopters appeared to have improved fertilizer management. SSNM increased net annual income by US\$57 ha^{-1} in Ha Tay and by \$78 ha^{-1} in Ha Nam. Simple projections for the wide application of SSNM throughout the RRD indicate potential annual gains of 228,000 tons of additional unmilled rice. Based on frontier production functions, adopters achieved a slightly higher index of technical efficiency in rice production. SSNM improved farmers' knowledge, attitudes, and skills in rice farming.

Keywords: site-specific nutrient management (SSNM), rice, nitrogen, frontier production function, Red River Delta

Rice production in the Red River Delta (RRD) accounts for about 20% of total rice output in Vietnam. Rice production has intensified in the region since 1990, with the number of rice crops per year increasing from 1.61 to 1.88 in 2003 (Dai et al 2005). This intensification coupled with the introduction of new hybrid varieties with an adoption rate in the RRD of 19% in 2006, based on Ministry of Agriculture and Rural Development (MARD) statistics, and decreasing unmilled rice-to-fertilizer price ratio (UNEP 2005) contributed to substantial increases in the application of fertilizer to rice.

During the period 1990-2003, total cultivated area in Vietnam increased 1.4 times, while urea applied per ha increased 2.97 times, phosphate applied per ha increased 4.76 times, and potassium increased 14.3 times (Hien 2005). Unbalanced and excessive use of chemical fertilizers, especially N, in the RRD were reported in various studies (Dung et al 2003, Hien 2005, UNEP 2005). Inappropriate rates and timing of fertilizer applied to rice might result in economic loss and negative environmental impacts.

Site-specific nutrient management (SSNM), a fertilizer application scheme taking into account site and season variations in both attainable rice yield with fertilization and the indigenous nutrient-supplying capacity of soil, has been developed for rice in Asia from research begun in the mid-1990s (IRRI 2010). SSNM promotes the optimal use of existing indigenous nutrients from soil, plant residues, manure, and irrigation water combined with the timely application of fertilizers at appropriate rates to match crop needs during the cropping season. The underlying premise of SSNM is that indigenous and applied nutrients will be used more effectively by the crop when they are applied when and as needed. As a result, it is believed that wider farmer adoption of SSNM will minimize overfertilization of rice, increase profitability, and decrease fertilizer-related pollution in the environment.

In Vietnam, on-farm development and evaluation of SSNM were conducted in five provinces in the RRD through collaboration between IRRI and the Soils and Fertilizers Research Institute (SFRI) during 1997-2004. In 2005, wider-scale evaluation and promotion of SSNM expanded to 11 provinces across northern Vietnam. In 2007, we evaluated the SSNM project in two provinces. This paper aims to review SSNM development in the RRD of Vietnam, assess the likely impact of SSNM practices on rice production and income of farm households, and summarize lessons learned for future SSNM development in northern Vietnam.

Site characteristics

The RRD in northern Vietnam covers 10 provinces, including the Hanoi capital area. The population was 18.4 million in 2007, with a density of 1,238 persons per km^2. Total agricultural land is 756,300 ha, accounting for 51% of the total land area of the region in 2007. There is a distinct cool, dry winter and a hot, humid summer. Rainfalls and storms occur mostly from May to September.

The RRD is the second-largest rice area in Vietnam after the Mekong River Delta, and it is considered the rice bowl for northern Vietnam. There are two rice crop seasons per year. The winter-spring season, hereafter referred to as the spring season, lasts from February to June. The summer-autumn season, hereafter referred to as the summer season, lasts from June to September. Rice yield is usually lower in the summer season than the spring season because of less favorable climate conditions, including heavy rainfall. Some 549 ha of rice land in the RRD are the alluvial soil type, accounting for 84% of total rice land (Dai et al 2005). Land topography is quite favorable for rice farming, with about 90% of the rice land suitable for irrigation. Rice area in the RRD increased slightly from 1986 to 2000, and then since 2000 it has tended to decline (Fig. 1). In 2007, the total annual rice-cropping area in the RRD was 1.11 million ha, which was less area than in 1986 (Fig. 1). This decline in rice cultivated area indicates that increased intensity of rice cropping did not offset

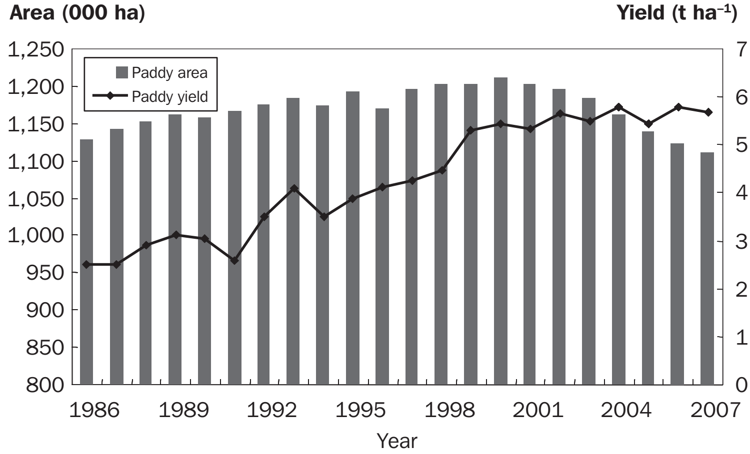


Fig. 1. Trend in rice area and yield in the Red River Delta, Vietnam, 1986-2007.

the rice area transferred to nonagricultural purposes. Rice productivity in the RRD improved considerably from 2.5 t ha^{-1} in 1986 to 5.67 t ha^{-1} during 1986-2007 (Fig. 1). Therefore, the RRD has been able to annually produce more than 6 million tons of unmilled rice, maintaining a share of about 18% to 20% of total rice production in the country and serving as a supplier of rice for nearby rice-deficit regions in northern Vietnam. Rice yield in the RRD, however, grew at a slow rate of 0.3% annually during 2000-07, which was much lower than the annual rate of 5.7% during the previous period (Fig. 1).

Methodology

Data collection

Primary data were obtained from SSNM farmer-adopters and non-SSNM farmer-adopters in Ha Nam and Ha Tay provinces, with a total sample size of 372 farmers. Random samples of SSNM farmer-adopters were chosen to represent the "with" group and a random sample of non-SSNM farmer-adopters was chosen to represent the "without" or control group. Some 61% of the respondents were classified as adopters and 39% as nonadopters.

Data analysis

The impact of SSNM practices was assessed through the comparison of "with" and "without" groups. Fertilizer and pesticide application, cost of production, rice yield, and income from rice were compared between the groups of adopters and nonadopters. Partial budget analysis for farm income is done to analyze the impact of SSNM on income from rice. Means were compared using t-tests. A frontier production function was used to evaluate the technical efficiency achieved by the adopters and nonadopters. The model is in log form, as follows:

$$\mathrm{Ln(YIELD)} = \alpha_0 + \alpha_1\mathrm{Ln(PC)} + \alpha_2\mathrm{Ln(L)} + \alpha_3\mathrm{ADOPT} + \\ \alpha_4\mathrm{Ln(N)} + \alpha_5\mathrm{Ln(P)} + \alpha_6\mathrm{Ln(K)} + u,$$

where YIELD is rice yield in t ha^{-1}, PC is pesticide cost in Vietnamese dong (VND) ha^{-1}, L is labor in person-days ha^{-1}, N is the amount of N fertilizer applied in kg ha^{-1}, P is the amount of P fertilizer applied in kg ha^{-1}, K is the amount of K fertilizer applied in kg ha^{-1}, and ADOPT is a dummy variable that equals 1 if the farmer adopts SSNM and 0 if the farmer does not adopt SSNM.

Results and discussion

SSNM development in the RRD

SSNM initiation. The implementation of SSNM involves establishing a target grain yield, effectively using the existing indigenous supply of nutrients, determining NPK fertilizer rates, and dynamic N management including use of the leaf color chart (LCC) to match the addition of N with crop needs (IRRI 2010). The nutrient omission plot technique can be used as an alternative to soil tests to determine the nutrient-supplying capacity of soils and to validate and fine-tune recommendations for P and K fertilizers. The nutrient addition plot technique can be used to make appropriate decisions on micronutrient management. IRRI researchers collaborated with SFRI starting in 1997 to develop SSNM recommendations tailored to types of soil and seasons for rice in the RRD.

The development of SSNM in the RRD started through a partnership of IRRI and SFRI in the Reversing Trends in Declining Productivity (RTDP) project from 1997 to 2000, which focused on on-farm research to establish preliminary recommendations for nutrient management for alluvial and degraded soils and to demonstrate results to farmers. Project sites were at Ha Tay and Vinh Phuc.

The second phase was from 2001 to 2004 through the Reaching Toward Optimum Productivity (RTOP) project, which focused on developing and validating SSNM technology for intensive rice systems at more sites and integrating SSNM with integrated pest management (IPM) in collaboration with the Plant Protection Division (PPD) to establish integrated crop management (ICM) practices. Project sites were located in five provinces of the RRD, namely, Nam Dinh, Ha Nam, Ha Tay, Vinh Phuc, and Hai Phong. From 2003 to 2004, additional provinces, including Ha Giang, Dien Bien, and Ha Tinh, got involved in the project.

The methodology for SSNM validation and dissemination in the RRD included on-farm research, pilot trials, training of trainers (ToT), farmer field schools (FFS), and demonstrations with field days. Activities of the SFRI on the dissemination of SSNM were primarily implemented through partnerships with either PPD through the national IPM program or the extension network through provincial extension centers

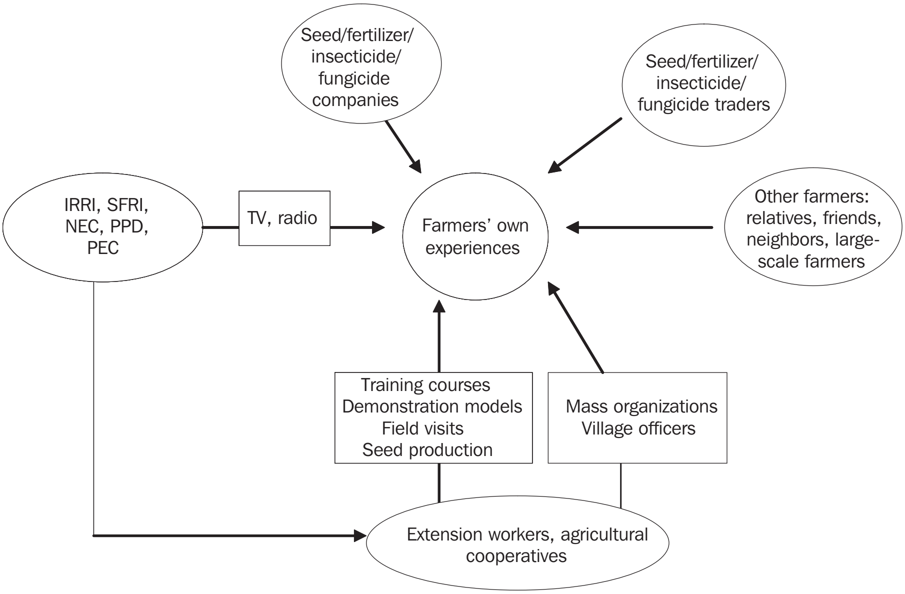


Fig. 2. Sources of information to rice farmers, Red River Delta, Vietnam.

(PEC). A training manual for farmers was developed and revised in four consecutive crop seasons in 2003-04.

SSNM dissemination. SSNM was disseminated to farmers on a wider scale when the recommendations were validated through pilot trials during the RTOP project. Steps in the dissemination of SSNM were to organize ToT with participants from extension departments of provinces and districts and leaders from some agricultural cooperatives and to organize FFS with participants, including extension workers from communes and representatives from local organizations such as women's groups, farmers' groups, and active farmers. The participants of ToT became lecturers for FFS. SSNM was eventually transferred to farmers by participants from both FFS and ToT.

In ToT and FFS, lectures and demonstrations were combined. Each course lasted for a rice crop season, enabling participants to learn and practice SSNM for all growth stages of rice in experimental fields. For the FFS organized and supported by PPD, all participants were given funds to develop trials in their own fields. This provided participants with a good understanding of how to implement SSNM practices and with firsthand experience on the benefits of SSNM. Results from experimental fields provided visible and convincing examples for nearby farmers.

Sources of information to farmers. In the RRD, there are several ways a technology related to crop farming can be transferred to farmers. As illustrated in Figure 2, a farm household can get information on rice farming from five major sources: NARES at the provincial or central level; extension workers and agricultural cooperatives; other farmers, including relatives and friends; traders of inputs, including seed and fertilizer; and companies providing seed, fertilizer, and plant protection chemicals.

The national extension center (NEC) and PPD provide extension information directly to farmers through mass media such as TV, radio, and publications. PEC and sub-PPDs also broadcast information on provincial TV channels and provide information through their publications. Extension workers at both district and communal levels organize training courses, develop demonstrations, and organize workshops and field visits for farmers using funds from the government budget allocated through higher-level organizations such as PPD and NEC.

Mass media are an important means of transferring information in communes and villages. Collective actions of a community are very important in many farming activities in the RRD because rice fields are composed of many small plots of farmers. Agricultural cooperatives, through the village head, inform farmers about crop schedules, such as nursery establishment, transplanting, crop insects, and diseases. Some specific programs targeting the development of rice, such as high-quality rice production and hybrid seed production, usually require cooperatives to train farmers.

Organizations such as women's groups and farmers' groups at the grass-roots level in a village can play an important role in helping farmers borrow from banks. Key persons, such as the chairperson in these organizations and the village's head, usually participate in training courses in extension; hence, they are involved in disseminating information from extension worker at various levels to farmers in their village through meetings. This happens in most communes where the budget is not enough to organize training courses for all farmers.

Input traders supply seed, fertilizer, and pesticides to farmers and give farmers recommendations for application, especially for new brands of inputs or new varieties. Seed, fertilizer, and plant protection chemical companies also organize training courses or demonstrations for farmers to introduce their products. Because of limited funds from government, some communes seek funds from these companies to organize training courses and conduct demonstrations.

Extension information from a higher level of extension and the PPD is channeled to farmers through mass media such as TV and radio. Some farmers, such as relatives, neighbors, and friends, are sources of technical advice for farmers. Large-scale farmers also require hired laborers to practice technology they have adopted. Once benefits are realized by the hired laborers, they become more inclined to adopt the technology for their own fields.

SSNM dissemination to farmers. PECs and sub-PPDs broadcast information on SSNM for rice via TV and radio, mostly limited to the provincial level, at project sites. Extension workers and agricultural cooperatives at project sites were involved in SSNM dissemination as trainers for farmers. This, however, is not sustainable when funds from a project stopped or in areas where SSNM was developed through PEC. The main reason for this lack of sustained support is that SSNM had not been approved as an "advanced technology" by the Scientific Committee of MARD. As long as a new technology is not approved by this committee, it is not considered a technology that can be officially disseminated through the wide network of the extension system. Hence, no funds from extension were provided for SSNM diffusion.

Recommendations on fertilizer application, like information on crop schedule, were announced through a loudspeaker in communes and villages. In some communes, SSNM was required in seed production, and seed growers applied SSNM to rice production in their field. SSNM recommendations were also given in meetings of villages and mass organizations.

Farmers observed and learned from each other how to practice SSNM. The uptake of SSNM by hired laborers for large-scale farms adopting SSNM was a source of technology diffusion. A few NGOs, such as World Vision, were involved and helped to spread SSNM in other regions, such as the northwest (Dien Bien and Ha Giang provinces) and the northcentral coast (Ha Tinh Province).

Seed, fertilizer, and plant protection chemical companies and input traders were not involved with the public sector in disseminating SSNM technology. Their blanket fertilizer recommendations were mostly inconsistent with SSNM.

The spread of SSNM by 2007 was mostly concentrated among farmers and communes at project sites. There were no close linkages among provincial technical teams such as extension and the PPD to share and promote the technology. SSNM by itself in 2007 had not gained much attention from donors, development institutions, and policymakers. A key factor limiting SSNM dissemination was the lack of its approval by the Scientific Committee. Hence, the scaling up of SSNM in the impact pathway (Fig. 3) was very limited.

Key issues in SSNM dissemination to farmers. The weak capability of extension workers and other trainers is a constraint. Grass-roots extension workers directly disseminating SSNM to farmers often have limited capability for a number of reasons, including (1) a lack of knowledge and experiences arising from little chance to update themselves with new knowledge and practices, (2) a lack of incentive because extension workers have much work in communes and low payment, and (3) the involvement of extension workers in other businesses such as input traders because of low pay. In some communes, village leaders, farmer groups, and agricultural cooperatives are active in providing farmers with inputs, mostly fertilizers and plant protection chemicals. Blanket fertilizer recommendations, delivered by the public and private sector, are simpler for farmers to understand than SSNM, which can vary among fields and presents a bigger challenge for extension workers to understand and explain. The weak capability of trainers can prevent them from exactly describing SSNM principles and guiding farmers. Confusion, misunderstanding, and failure in the application of new technology can frustrate farmers.

Another issue was that farmers often receive different recommendations from different sources. Both public- and private-sector organizations provide farmers with farming techniques and information. The extension system recommends technology developed by NARES and/or approved by the Scientific Committee. Private seed and fertilizer companies and input traders, on the other hand, provide farmers with recommendations for their specific products. Farmers with limited education and a lack of information can become confused from the contrasting information they receive. In some cases, companies provide farmers with incentives such as cash or a lower

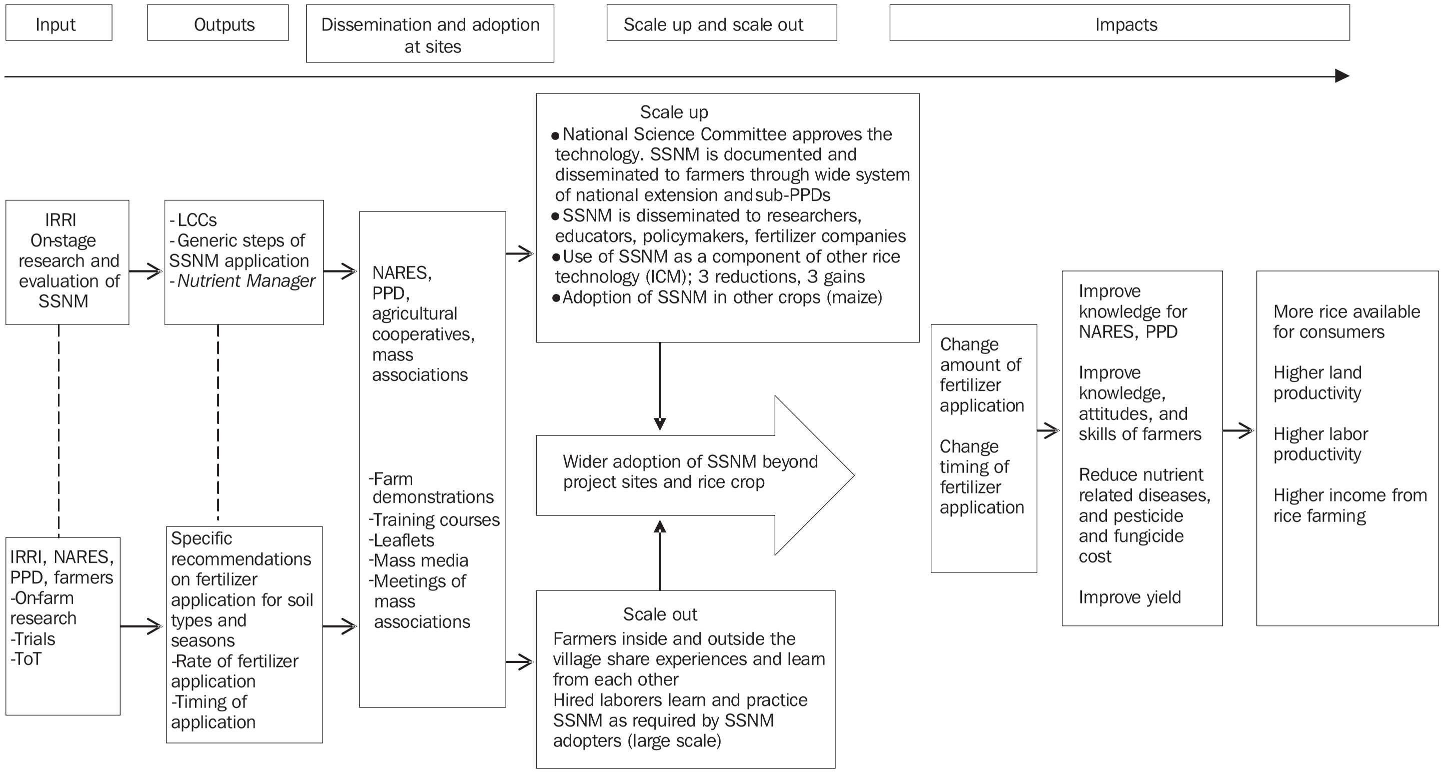


Fig. 3. Impact pathway of SSNM in Vietnam.

price, which can induce farmers to adopt the specific products and technology of the company.

The availability and quality of inputs are important to farmers' adoption of technology. It is easiest for adopters to calculate the required amounts of fertilizer from N, P, and K recommendations when single-element fertilizers such as urea and single superphosphate are used. Fertilizers, however, are currently marketed with various brand names, proportions of nutrient, and quality, and farmers are not always able to buy fertilizer sources that can give them the exact proportions of N, P, and K recommended for their field.

Another concern is fertilizer quality. In some places in Vietnam, the actual content of nutrients in fertilizer is less than indicated from the label on the fertilizer bag. The use of bad-quality fertilizer leading to poor performance of SSNM can frustrate farmers and discourage their adoption of SSNM.

Differences in fertilizer use and application

Farmers in the RRD currently apply both organic materials and chemical fertilizers to rice. SSNM has focused mainly on the application of chemical fertilizer; therefore, it was expected that adopters and nonadopters would differ more in patterns of applying chemical fertilizer than organic materials.

Farmyard manure (FYM) application. FYM was applied once, mostly ranging from 1 to 10 days before transplanting in Ha Nam and Ha Tay provinces in both seasons. The timing of FYM application was not different between adopters and nonadopters. About 78% of the farmers applied FYM, sourced mostly from home animal raising (95%), for rice in both summer and spring seasons. Approximately 40% of the FYM was composed of straw and crop residues before application. Adopters in Ha Tay applied FYM at average rates of 4.4 t ha^{-1} in the spring season and 4.1 t ha^{-1} in the summer season, which was significantly less than for nonadopters (Table 1). No significant difference in FYM use was found between adopters and nonadopters in Ha Nam.

Chemical fertilizer use. The number of applications of fertilizer was significantly different between adopters and nonadopters (Table 1). Adopters applied fertilizer in more splits than nonadopters. The nonadopter group showed more variation in number of times of fertilizer application, ranging from 2 to 5. Some farmers applied urea whenever they saw that leaves were not as green as they wanted, but they did not apply urea after early heading.

The adopters applied fertilizer with timing recommended by extension workers. All P was applied preplanting, and total N was split into 3–4 applications depending on variety and leaf color. About 20% of the total fertilizer N was applied from preplant to 2–3 weeks after transplanting, 50% N was applied at tillering stage, and the remainder was applied based on leaf color. Total K was divided equally into two applications, one at tillering and the other at panicle initiation.

Timing of fertilizer application varied among the nonadopter group. In general, nonadopters applied more than the SSNM recommendation for N within 20 days after transplanting when plant growth was still relatively slow and roots did not absorb much

Table 1. Quantity of selected inputs used in rice production based on 2007 survey data in Ha Nam and Ha Tay provinces, Vietnam.

Province and parameter	Unit	Spring season			Summer season		
		Adopters	Nonadopters	Difference[a]	Adopters	Nonadopters	Difference
Ha Nam Province							
Fertilizer N	kg ha^{-1}	78	93	–15**	79	90	–11**
Fertilizer P	kg ha^{-1}	23	24	–0.8 n.s.	23	24	–0.8 n.s.
Fertilizer K	kg ha^{-1}	69	72	–2.7 n.s.	69	69	–0.2 n.s.
FYM	t ha^{-1}	6.1	6.3	–0.17 n.s.	7.7	6.6	1.1 n.s.
Fertilizer N applications	no. season^{-1}	3.1	2.8	0.29**	3.1	2.8	0.29**
Pesticide cost	US$ ha^{-1}	18.30	19.30	–1.00 n.s.	20.40	20.40	0.02 n.s.
Ha Tay Province							
Fertilizer N	kg ha^{-1}	81	71	10**	75	79	–4.2 n.s.
Fertilizer P	kg ha^{-1}	21	14	7.6**	18	13	5.1**
Fertilizer K	kg ha^{-1}	47	57	–10**	48	58	–9.9 n.s.
FYM	t ha^{-1}	4.4	9.0	–4.6**	4.1	10.5	–6.5**
Fertilizer N applications	no. season^{-1}	3.4	3.0	0.42**	3.3	2.9	0.45**
Pesticide cost	US$ ha^{-1}	8.90	15.70	–6.70**	12.90	19.00	–6.10**

[a] ** = significant at 1%, n.s. = not significant.

N. Nonadopters at Ha Nam applied more N than adopters, and nonadopters tended to apply N across a wider range in crop growth stages to achieve "green" leaf color.

In the spring season, adopters in Ha Nam applied 78 kg N ha^{-1} while nonadopters used 93 kg N ha^{-1} (Table 1). This corresponded to a use of 15 kg ha^{-1} less N by SSNM adopters in the spring season, which matches closely with the 11 kg ha^{-1} less N used by adopters in the summer season at Ha Nam. The differences in P and K rates between adopters and nonadopters were small and nonsignificant in both seasons.

At Ha Tay, adopters used 10 kg N ha^{-1} more in the spring season (Table 1). Adopters applied 7.6 kg ha^{-1} more P in the spring season and 5.1 kg ha^{-1} more P in the summer season. Adopters applied 10 kg ha^{-1} less K than nonadopters in the spring season. About 10% of the respondents commented that the level of fertilizer used in their area was too much.

Farmers often used compound NPK-containing fertilizers that did not have P and K ratios well matched to the ratios of P and K recommended by SSNM. Farmers were exposed to a number of fertilizer brands with different contents of nutrients and to input traders providing fertilizer recommendations not well matched with the SSNM recommendation. Farmers were not always able to buy fertilizers that they could mix to obtain the right amount of required N, P, and K.

Use of the LCC. About one-third of the respondents reported that they had seen LCCs. Less than 20% of the adopters had owned an LCC. Almost no farmer was using an LCC at the time of the survey in 2007. Some farmers indicated they were able to observe leaf color and decide how much N to apply and when to apply N without the LCC. In other cases, village leaders and extension workers took LCC readings in rice fields for farmers and provided farmers with a recommendation for fertilizer application through a loudspeaker system. In other cases, farmers simply had no LCC. A number of farmers reported that they were given LCCs but they were not given sufficient training on how to use the LCC, and hence those LCCs were now left somewhere else.

Impact of SSNM

Impact on farmers' knowledge, attitudes, and skills (KAS). Almost 100% of the respondents had an understanding about the role of fertilizers, such as K for better filled grain and P for neutralization on acid soil. Adopters reported that, before learning SSNM, they had not been much aware about nutrient needs for rice at different growth stages and the relationships among nutrients, pests, diseases, and rice yield. They had thought that green leaves were always good and they tried to apply urea to maintain green leaves. SSNM, especially combined with IPM, had improved their knowledge.

SSNM adoption also changed farmers' attitude to rice farming. Farmers stated that before they simply believed rice plants needed to be fed in fixed schedules. Some modified blanket recommendations, but did not spend much time to understand the nutrient needs of rice plants. With SSNM, they really became a "scientist" in their own fields, spending time to observe rice plants in different growth stages and paying more attention to crop health as related to nutrient supply. During the research and validating periods, farmers had much interest in on-farm experimentation and trials.

Table 2. Estimate results from a frontier production model computed on the basis of 2007 survey data in Ha Nam and Ha Tay provinces, Vietnam.

Variable	Parameter	Coefficient[a]
Constant	α^0	8.573**
PC	α^1	0.002 n.s
L	α^2	–0.023 n.s.
ADOPT	α^3	0.042*
N	. α^4	0.027 n.s.
P	α^5	0.015**
K	α^6	0.024**
Variance parameters	σ^2	0.245**
	λ	2.439**
Log likelihood function		153.3
Number of observations, n		372

[a]**, * = significant at 1% and 10%, respectively; n.s. = not significant.

SSNM changed farmers' skills in rice farming, mostly in determining the timing and rate for urea fertilizer application. Some adopters used LCCs for only two seasons, and then they could observe leaf color and know whether to apply N. In areas where SSNM was combined with IPM, farmers learned to observe and know when to apply insecticide or fungicide and at what rate.

Impact on technical efficiency in rice production. SSNM is expected to enable rice farmers to reach an attainable yield and hence improve technical efficiency in rice production. To estimate a technical efficiency index for adopter and nonadopter groups, a frontier production function was developed (Table 2). This function indicated that P and K had a positive impact on rice yield, though the effect was very small. A 1% increase in applied P resulted in a 0.015% improvement of rice yield when other factors remained constant. A 1% increase in applied K resulted in a 0.024% improvement of rice yield. Coefficients of pesticide cost, labor, and N were insignificant, indicating that these inputs were no longer constraints to rice yield. The coefficient of ADOPT was statistically significant at 1%, indicating that on average SSNM adoption improved rice yield 0.04% over nonadoption when other factors remained constant.

The average index of technical efficiency was estimated at 84.3% for the whole sample, indicating that the average farm produced 84.3% of the maximum attainable output for a given level of input. Adopters achieved higher technical efficiency, with an index of 84.7%, while nonadopters reached a technical efficiency index of 83.7%, 1% lower than that of the adopter group.

Impact on pesticide use. Balanced application of fertilizer for rice plants improved crop health, leading to reduced damage from insects and diseases, especially those related to nutrient management such as blast, bacterial blight, and brown plant-

Table 3. Yield of unmilled rice attained by adopters and nonadopters of SSNM based on 2007 survey data in Ha Nam and Ha Tay provinces, Vietnam.

Province and season	Actual yield (t ha^{-1})		Difference[a]	
	Adopters	Nonadopters	t ha^{-1}	%
Ha Nam Province				
Spring	5.8	5.6	0.20**	3.4
Summer	5.27	5.23	0.04 n.s.	0.8
Year total	11.1	10.9	0.24	2.2
Ha Tay Province				
Spring	5.1	4.8	0.34**	6.6
Summer	4.6	4.8	–0.17 n.s.	–3.7
Year total	9.8	9.6	0.17	1.7

[a]** = significant at 1%, n.s. = not significant.

hopper (Son 2006). SSNM is expected to reduce insect and fungi incidence, thereby saving costs from the application of insecticide and fungicide.

Pesticide cost was not significantly different between adopters and nonadopters in Ha Nam in both seasons (Table 1). In Ha Tay, pesticide cost was significantly less for adopters by about US\$6 ha^{-1} in both seasons. The difference between Ha Nam and Ha Tay was likely the result of promotion of IPM with SSNM through the support of the PPD in Ha Tay, whereas IPM was not promoted with SSNM at the survey sites in Ha Nam. This highlights the merit of training farmers on both SSNM and IPM.

Impact on rice yield. Yield of unmilled rice was higher for adopters than for nonadopters in both Ha Nam and Ha Tay in the spring season. Yield was 0.2 t ha^{-1} (3.4%) higher for adopters in Ha Nam and 0.34 t ha^{-1} (6.6%) higher for adopters in Ha Tay (Table 3). There was no significant difference in the rice yield between adopters and nonadopters during the summer season in both provinces. Unfavorable climatic conditions such as drought in the summer of 2006 might have contributed to the lack of differences between adopters and nonadopters in the summer season. The use of FYM might have also been a contributing factor because nonadopters used much more FYM than adopters in Ha Tay in both seasons (Table 1).

A simple projection for potential impact of SSNM on rice output in the RRD was generated from the average yield gain for adopters. Assuming that the benefit of SSNM on rice yield for the RRD is the yield gain of 0.2 t ha^{-1} for adopters averaged for the two seasons for Ha Nam and Ha Tay, then the adoption of SSNM throughout the RRD would result in an annual addition of 228,000 tons of unmilled rice.

Net impact on income. Partial budget analysis shows that the positive effects brought by SSNM adoption, comprising additional income and reduced cost, were estimated to be \$2,679 ha^{-1} for farmers in Ha Nam and \$2,340 ha^{-1} for farmers in Ha Tay (Table 4). Adopting SSNM instead of traditional practices also caused negative

Table 4. Impact of SSNM adoption on annual income from rice farming based on 2007 survey data in Ha Nam and Ha Tay provinces, Vietnam.

Budget components	Amount ($US\$\ ha^{-1}\ y^{-1}$)	
	Ha Nam	Ha Tay
Positive effects		
Additional income	2,399	2,116
Reduced cost	280	224
Total additional income and reduced cost	2,679	2,340
Negative effects		
Reduced income	2,345	2,070
Additional cost	256	213
Total reduced income and additional cost	2,601	2,283
Change in net income	78	57

impacts, amounting to \$2,601 ha^{-1} for farmers in Ha Nam and \$2,283 ha^{-1} for farmers in Ha Tay. The adoption of SSNM brought an average additional annual net income of \$78 ha^{-1} for farmers in Ha Nam and \$57 ha^{-1} in Ha Tay. The difference in FYM cost was not included because SSNM in 2007 had not focused on either changing FYM use or adjusting chemical fertilizer rates for FYM application. The adjustment of chemical fertilizer rates for FYM application should be taken into consideration in the future development of SSNM-based practices.

Impact of SSNM research and development on social net welfare. In a study on the impact of R&D in agriculture (Rodriguez et al 2008), an economic surplus model (DREAM—Dynamic Research Evaluation for Management) was implemented to estimate the level and distribution of the economic benefits of SSNM research in the RRD. The economic benefits were estimated over the period 1997-2026 (30 years) and the research benefits and costs were discounted using a 5% discount rate. The net present value (NPV) of SSNM was forecast to be \$13.6 million in Ha Nam, \$24.7 million in Ha Tay, and \$117.7 million for the rest of the RRD rice-growing region. The corresponding benefit-cost ratios were estimated to be 134:1, 243:1, and 72:1, respectively. The internal rates of return are 120%, 147%, and 95%, respectively. Research and development of SSNM in the RRD created net gains in social welfare for the region.

Lessons learned

By 2005, after eight years of research on validating and disseminating SSNM in Vietnam, the technology had been introduced in 11 provinces in northern Vietnam, some of them beyond the RRD. Although proven to bring benefits to rice farmers and appreciated by the adopters, SSNM has not been diffused widely in many areas in northern Vietnam. Key lessons for the development of SSNM in the RRD, which were drawn from the 2007 survey, include

- The factors contributing to success in developing SSNM through on-farm research were a good matching of trials with farmers' skills, simplified trial design, and good facilitation by researchers during the process. Conducting on-farm research simultaneously through pilot trials and FFS at a number of sites shortened the time to achieve and consolidate results.
- Feedback from farmers was important to SSNM development because the technology is applied flexibly to different farming conditions.
- The dissemination of SSNM with other related technology such as IPM contributed to a wider spread of the technology, brought more benefits to farmers than with only one technology, and reduced research cost per amount of benefit for farmers.
- A wide network of partnership with the extension system was important to the diffusion of the technology. However, weak capabilities of extension staff, especially at the grass-roots level, and lack of incentives for extension were constraints to a wider adoption of SSNM.
- Publications on SSNM are critical for wider awareness of farmers, policy-makers, development institutions, and other stakeholders, thereby helping to scale out and scale up the technology.
- Approval by the Scientific Committee of MARD is a key factor for the wide-scale dissemination of SSNM because this approval is necessary to facilitate its dissemination through the wide network of the extension system in the country.
- Different recommendations on nutrient management obtained by farmers from other sources could change farmers' decision to adopt SSNM technology.
- The private sector played an important role through the availability and quality of agricultural inputs with accompanying recommendations to influence farmers' decision on technology adoption.
- The active involvement of NGOs in transferring the technology to farmers was important in terms of their capability to reach farmers, especially in remote and poor areas. However, very few NGOs were involved with the SSNM initiative in northern Vietnam.
- The agricultural education system should be involved in SSNM development and dissemination, but its participation was very limited in the RRD.
- Different views on nutrient management for rice among researchers, scientists, and key leaders limited the dissemination of SSNM and reaching farmers with consistent information.
- The provision of LCCs must be accompanied with training for farmers on their use and on SSNM.

Conclusions and future outlook

At the time of this survey in 2007, after almost a decade since SSNM was first introduced in the RRD, the technology had spread in 11 provinces in northern Vietnam and gained farmers' appreciation. The attractiveness of SSNM was in its principles for farmers, which enable them to increase yield and profit.

SSNM was verified and disseminated through collaboration among IRRI, SFRI, the extension system, and PPD. The key factors for success were (1) good strategies in research and adaptation encompassing on-farm research and trials to validate results, (2) active involvement of multidisciplinary institutions (SFRI, extension centers, PPD, and NGOs), (3) a good strategy for dissemination with IPM technology, and (4) active involvement by extension, PPD staff, agricultural cooperatives, farmer groups, commune and village leaders, and representative farmers.

The major constraints for the dissemination of SSNM were (1) no approval and endorsement from the Scientific Committee of MARD, which prevented SSNM from being disseminated widely through the extension network; (2) weak capability of extension staff, especially at the grass-roots level; (3) many sources of information with contrary recommendations on nutrient management for rice, which influence farmers' decision; (4) the different availability and quality of fertilizer for farmers in villages; and (5) different views on SSNM among scientists and key leaders. The development of SSNM concentrated on its scaling out. Scaling up should be promoted because the chances of influencing higher officials increase as change spreads further geographically. Likewise, as technology goes to higher institutional levels, the chances for horizontal spread increase.

As of 2007, the Scientific Committee of MARD had recently approved the integrated crop management (ICM) innovation. ICM was developed based on several crop management practices such as SSNM, IPM, integrated water management, variety choice, and seed health management. ICM can, however, be complex to practice on a wide scale, and the principles of SSNM—an important component of ICM—need to be well understood for the successful wide-scale dissemination of ICM.

Strong support from MARD is a key factor for scaling up SSNM. With approval from the Scientific Committee, SSNM could be disseminated through the wide network of the extension system using various tools such as training courses, demonstrations, and publications funded by the government.

A challenge ahead remains the limited capability of local extension staff. The implementation of SSNM can be relatively knowledge-intensive because fertilizer management is tailored to field-specific conditions based on crop yield, crop residue management, the use of organic materials, rice variety, and rice establishment method. Country-specific, computer-based decision tools called *Nutrient Manager for Rice* are now being developed to enable extension workers to use SSNM principles to rapidly develop locally adapted best nutrient management practices for specific fields and rice-growing conditions. With *Nutrient Manager for Rice*, extension workers can use the response of farmers to 10 to 15 easy-to-answer questions about their rice field and cultivation practices to develop, within 15 minutes, a field-specific recommendation for farmers (IRRI 2010). Fertilizer recommendations developed with *Nutrient Manager for Rice* take into account the indigenous supply of nutrients from soil, applied farmyard manure, crop residues, and irrigation water. Successful dissemination of SSNM through such a decision tool will require enhanced skills of extension workers with computers and information technology. Feedback from farmers and follow-up with them will be crucial for verification of the decision tool and its effective use with farmers.

Harmonization among institutions, scientists, and key leaders is important for the scaling up of SSNM. Different views on SSNM might have prevented its spread beyond the project sites in the past. Scaling out and scaling up of SSNM should be facilitated by using benchmark sites as training sites for local government leaders and farmers, and for sensitizing policymakers.

All stakeholders, including the public sector, private sector, and NGOs, should be involved in technology development and dissemination. This will help harmonize the sources of information channeled to farmers by different organizations. Better linkage and synergy among programs related to crop farming developed in rural areas should be further pursued in terms of efficient use of resources and wider adoption and diffusion of technology. SSNM should be integrated into IPM and ICM.

Agricultural education systems should be involved in the research to improve SSNM and in its dissemination to various audiences through education programs. A technical team with strong knowledge on SSNM and crop management practices should be built with members from various institutions representing the private and public sector. The team should be responsible for dealing with problems related to the technology that could not be solved at the local level. The team should also facilitate linkages between provinces and regions to ensure that farmers from different places benefit from the technology.

References

Dai Do Dinh, Nguyen Thi Ha, Vu Xuan Thanh. 2005. Vấn đề an ninh lương thực và sử dụng hợp lý quỹ đất lúa ở Việt nam. In: Khoa học công nghệ nông nghiệp và Phát triển nông thôn, 20 năm đổi mới. Vol. 3. Vietnam National Political Publisher. p 147-167.

Dung Nguyen Huu, Tran Chi Thien, Nguyen Van Hong, Nguyen Thi Loc, Dang Van Minh, Trinh Dinh Thau, Huynh Thi Le Nguyen, Nguyen Tan Phong, Thai Thanh Son. 2003. Impact of agro-chemical use on productivity and health in Vietnam. EEPSEA research report. www.idrc.ca/uploads/user-S/10536112540ACF122.pdf.

Hien Bui Huy. 2005. Kết quả nghiên cứu dinh dưỡng cây trồng, sử dụng có hiệu quả phân bón trong thời kỳ đổi mới và kế hoạch hoạt động giai đoạn 2006-2010. In: Khoa học công nghệ nông nghiệp và Phát triển nông thôn, 20 năm đổi mới. Vol. 3. Vietnam National Political Publisher. p 245-264.

IRRI (International Rice Research Institute). 2010. Site-specific nutrient management. www.irri.org/ssnm. Accessed 2 August 2010.

Son Tran Thuc. 2006. Kết hợp quản lý dinh dưỡng với phòng trừ dịch hại tổng hợp là chìa khóa để giảm mức đầu tư phân bón, thuốc trừ sâu, làm tăng năng suất, phẩm chất và tăng thu nhập cho người trồng lúa. Paper presented at the workshop "Three reductions, three gains in rice." Vinh Phuc Province.

UNEP (United Nations Environment Programme). 2005. Integrated assessment of the impact of trade liberalization: a country study on the Vietnam rice sector.

Notes

Authors' addresses: N.T.D. Nga, lecturer, Faculty of Economics and Rural Development, Hanoi University of Agriculture, Hanoi, Vietnam; D.G. Rodriguez, consultant, Irrigated Rice Research Consortium, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines; T.T. Son, former vice director, Soils and Fertilizers Research Institute, Dong Ngac, Tu Liem District, Hanoi; R.J. Buresh, principal scientist, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines. Email: ngantd@gmail.com.

Adoption and impact of aerobic rice in North Anhui

Shijun Ding, Haitao Wu, B.A.M. Bouman, Huaqi Wang, Shaobing Peng, and Yuping Chen

With scarcity of water resources and a shortage in labor supply, pressure has been increasing on lowland rice production in China. Aerobic rice has undergone experiments since the 1980s in China. Farmers in northern China have been increasingly adopting aerobic rice. However, little is known about farmers' understanding of aerobic rice and the impact of adoption on farmers' livelihoods. This paper aims to obtain an inventory of the number of rice farmers and area of aerobic rice production in the study area, and to investigate the pattern of changes and driving forces in aerobic rice adoption.

The proportion of farmers growing aerobic rice was 25%, with a high of 73% in one county. The proportion of aerobic rice area was 7%, with a high of 20% in one county. Yield averaged 2.9 t ha^{-1}, with a high of 4.9 t ha^{-1} in one county. Aerobic rice can be more profitable than other summer crops under an environment of alternately occurring drought and flood. The relatively high and stable yield and gross margin in one county implies that aerobic rice has great potential. Aerobic rice was perceived as being water-saving and labor-saving and having simple management, whereas weeds and unstable yield are the top constraints. Farmers participated less in aerobic rice technology development. The main channel in aerobic rice diffusion was through private companies and dealers. The establishment of a public-private partnership has yet to be investigated and established for delivering aerobic rice in the study area.

Keywords: Aerobic rice, adoption, impact, North Anhui

Despite the increase in food production during the past decades in China, with its large and rapidly growing population, food security is still a crucial issue. This is especially true for the large number of rural people living in marginalized resource-poor rural areas. Rice remains the single largest cultivated food crop in China, occupying about 28% of food-crop sown area, and it accounted for 37% of total grain outputs in 2005. Drought is one of the major constraints to rice production in China (Dey and Updahyaya1996, Lin and Shen 1996, Ding et al 2004). Water resources are increasingly becoming scarce in the North China Plain, which contains a quarter of

China's cultivated land and population (Geng et al 2001) and supplies a large share of national grain production.

Breeders developed rice varieties that are more drought-tolerant with relatively stable yield in the North China Plain. Rice farmers, on the other hand, have developed various strategies to cope with water shortage, while at the same time rice production systems have been undergoing transitions toward more commercialization. However, the magnitude and extent of the drought-tolerant rice varieties adopted and the patterns of change in drought-tolerant rice production and their likely consequences for households' income generation and their livelihoods are currently poorly understood. It is important that suitable policy and technological interventions, based on in-depth understanding of the socioeconomic nature of farmers adopting improved rice varieties, be developed to deal with any negative consequences on household-level food security and income generation.

Aerobic rice, as a new concept and way of cultivating rice, has been defined as a production system in which especially developed, input-responsive rice varieties with "aerobic adaptation" are grown in well-drained, nonpuddled, and nonsaturated soils without ponded water, with a management system aiming at yield of 4–6 t ha^{-1} (Bouman 2001, 2007). In China, breeders have been developing special rice varieties (known as "Han Dao") for aerobic conditions since the mid-1980s (Wang et al 2002). New elite varieties from China Agricultural University (CAU), such as Han Dao 277, Han Dao 297, and Han Dao 502, have been continuously released since the 1990s. The diffusion of aerobic rice has been facilitated by the availability of other improved technologies, such as herbicides and seed coating. Aerobic rice has been increasingly adopted by rice farmers in northern China. As estimated by the China National Aerobic Rice Network in 2000, aerobic rice varieties are grown on some 80,000 ha in the North China Plain (Wang et al 2002).

Since 2001, CAU and IRRI have been conducting exploratory experiments on water use and yield performance of aerobic rice varieties, and CAU has been conducting experiments on using mulch in aerobic rice, as part of the Ground Cover Rice Production System Project. In 2001 and 2002, pilot sites were established for farmer participatory research and development on aerobic rice in villages in the Yellow River Basin. In 2004, CAU was invited to participate in the CPWF's PN16 project, in which sustainable aerobic rice systems for water-scarce irrigated and rainfed environments were to be developed, and four major activities (variety selection and improvement, field trials, participatory development, and target domain identification) were to be carried out. The project selected sites in northern China to experiment and diffuse its aerobic rice varieties.

Adopting aerobic rice has been hypothesized to increase water productivity in terms of both rice yield and net economic returns on water use, and to free up labor to obtain off-farm employment. To document the success and experience of aerobic rice diffusion in northern China, a socioeconomic study was carried out in 2007. This paper, based on the study, takes aerobic rice in North Anhui as the focus to investigate the impact of aerobic rice, the patterns of technology adoption, and the driving forces in the context of agricultural and economic transition.

This study aims to investigate patterns of aerobic rice adoption and driving forces behind the changes during agricultural and economic transition, so that more effective interventions for the development of aerobic rice technologies and production can be made. The objectives include (1) obtaining an inventory of the number of rice farmers and areas of aerobic rice in three counties in North Anhui; (2) investigating the patterns of change and driving forces in farm households' adoption of aerobic rice in the same locations, and suggesting options for technological interventions.

The study, using a case study approach, was based on microeconomic analysis of aerobic rice production mainly using household-level data. Information was gathered mainly through a household questionnaire survey. Interviews with various local authorities, agricultural technicians, and other key informants were supplemented.

Three counties in North Anhui were selected as fieldwork sites: Fengtai, Yingshang, and Funan of North Anhui in the North China Plain, representing different patterns of aerobic rice adoption. In each of the three counties, two or three townships where aerobic rice production was or is one of the major agricultural activities were selected. Two or three villages from each township were selected, and 20 households in each village were selected. Some 428 households and 854 cultivated plots were surveyed in 2007. Several sets of questions were asked in the questionnaire: (1) household characteristics: demographic, education, employment, source of income; (2) land use and cropping patterns; (3) crop activities and inputs and outputs for aerobic rice, lowland rice, and maize; and (4) farmers' adoption and perceptions on aerobic rice and conventional rice. The households surveyed were separated into households with aerobic rice and households without aerobic rice.

General characteristics of the study area and sample households

General information on the study area

North China can be defined geographically as the area lying to the north of the Qinling Mountains and Huaihe River. Socioeconomic indicators of the study counties in 2006 are listed in Table 1. The majority of the population engages in agricultural activities. GDP per capita, income per capita, and land area per capita are all lower than nationally. Cultivated lands are mostly for food-crop production.

The study area lying in the Huang-Huai-Hai Plain is short of water resources. Average annual rainfall in Fengtai, for example, was 948 mm during 2004 to 2006. For the three study counties as a whole, during the summer crop growing season from May to October, rainfall is 710 mm, of which over 60% occurs in June and July. The highest rainfall is in July (around 350 mm) and the lowest in October (10 mm).

Basic socioeconomic indicators of the sample households

Table 2 presents the general indicators of households. Some 13% of sample households are poor as perceived by villagers. An average household consists of 4.7 persons. Laborers include those aged 16 to 65+ years, and are 3.4 persons per household. The average dependency ratio is 37.5%. Male laborers account for 53.4% of the total laborers. Some 26.2% of household laborers go out either for a long time or a short time

Table 1. Socioeconomic indicators of the study counties in 2006.

Item	Fengtai	Yingshang	Funan	China
Population (000 persons)	60	161	155	131,448
Share of population in agriculture (%)	85	89	89	56
GDP per capita (US$)	1,714	463	387	2,124
Share of agricultural GDP (%)	11	29	43	12
Net income per capita (US$)	443	298	246	478
Land area per capita (ha)	0.09	0.07	0.06	0.17
Crop index[a]	1.41	1.97	1.81	1.26
Share of food crop sown area (%)	88	88	71	68

[a] Crop index, also cropping intensity index, is a time-weighted land-use index that evaluates the fraction of the total hectare-years available to farmers that is used for crop production.

Table 2. General indicators of sample households at study sites.

Item	Fengtai	Yingshang	Funan	Total
No. of households	186	122	120	428
Household size	4.76	4.57	4.71	4.69
Age of household head	50.2	48.8	52.0	50.3
Education level[a] of household head	5.3	5.4	4.7	5.2
No of laborers per household	3.38	3.48	3.38	3.41
Dependency ratio[b]	28.99	23.85	28.24	27.29
Share of male laborers (%)	55.32	51.85	51.98	53.40
No. of out-laborers per household	27.31	22.54	28.24	26.23

[a] Education level: number of years in school. Elementary education is from 1 to 6 years, i.e., grades 1–6. [b] Dependency ratio: refers to the proportion of number of persons aged 0–15 and 65+ to number of persons aged 15–64.

Table 3. Land endowments and soil quality (% of various types of land).

Item	Fengtai	Yingshang	Funan	Total
Farm size per capita (ha)	0.12	0.11	0.13	0.12
Rice land (%)	51.2	43.0	51.4	48.5
Nonrice land (%)	48.8	57.0	48.6	51.5
Number of plots	740	383	391	1,514
Rice land (%)	47.3	34.5	42.7	42.9
Nonrice land (%)	52.3	65.3	57.3	56.9
Soil quality				
Good (%)	32.2	44.4	30.4	34.9
Average (%)	49.7	42.3	54.2	49.0
Poor (%)	18.2	13.3	15.4	16.2

for nonfarm work. Educational attainment of a sample household head is 4.5 years.

Land endowment and soil quality. The rural reforms started in the 1980s in China altered the organization of agricultural production from a collective to a family-based farming system. Although land ownership rights were vested with the "collective," which is usually taken to mean the village, land was typically allocated to households for cultivation in a fairly egalitarian way on the basis of family size, demographic composition, and labor supply (Gaynor and Putterman 1993, Nyberg and Rozelle 1999).

Land can be categorized into different types regarding rice production. A popular categorization at the household level is land for rice production (rice land, hereafter) and land for nonrice production (nonrice land, hereafter). Rice land is normally located at places where water resources are available and rice can be grown in the summer, while nonrice land is for nonrice crops due to a lack of water resources or its hilly terrain. These two types of land, however, may be switched over as water availability may change over time. A typical rice farmer normally has both types of land for the sake of equity in the village. As soil quality differs and the distances from water sources also vary within the village, land is separated into many different parts (plots, hereafter). Households are usually allocated several plots with different soil quality and distances from water sources. A description of rice land and nonrice land appears in Table 3.

Cropping patterns and the rice production system

In the study area, lowland rice, aerobic rice, maize, and soybean are the main crops grown in summer, and wheat in winter. A wheat-rice rotation is the predominant cropping pattern. Summer crops are normally planted during March to June and

Table 4. Cropping patterns in the study counties.

Crop	SID[a]	Crops	% of crop area over total area
Winter crop in 2005	0.06	Wheat	97
Summer crop in 2006	0.76	Aerobic rice/maize/soybean/lowland rice	25/22/6/34
Winter crop in 2006	0.10	Wheat	95
Summer crop in 2007	0.73	Aerobic rice/maize/soybean/lowland rice	18/22/6/43

[a]SID $= 1 - \sum P_i^2$ where P_i is the proportionate area of the ith crop activity or enterprise or value in the gross cropped area or total value of output. The index scales are in the range of 0 to 1 with the degree of crop diversification in the respective geographical domain.

Table 5. Income per capita by source in study counties.

Item	Fengtai	Yingshan	Funan	Average
Net income (US$)	511	502	409	480
From crop production (%)	38.6	16.7	20.1	27.7
From livestock (%)	5.2	8.5	7.8	6.8
From nonfarm activities (%)	56.2	74.8	72.2	65.6

harvested during August to November, while winter crops are planted during September to November and harvested in the next May and June.

Two indices, including the crop diversification index and the proportion of crop area over total area, are used to describe cropping pattern and rice production in the study area, and the results are shown in Table 4. The crop diversification index is based on the Simpson Index of Diversity (SID). It is low for winter crops but high for summer crops. The proportions of crop area over total area vary depending on the crops concerned. The proportions for maize and soybean are relatively stable, whereas they varied greatly for lowland rice and aerobic rice that occupy 60% of the total sown area.

Major sources of income

Sources of household income in rural China can be generally classified into farm income and nonfarm income. Farm income derives from crop cultivation as well as animal husbandry, while nonfarm income comes mainly from migrant labor work and other nonfarm activities. Household income is separated into (1) income from crop production (summation of remainders of production value of each crop after deducting input costs; family labor inputs are not included); (2) income from animal husbandry (summation of the value of livestock sold after subtracting input costs); (3) nonfarm income (summation of income from wages, transfers, property, and other).

Table 5 shows household income and its structure by sources in 2006. An average household has per capita income of US$480 (roughly equal to the national level,

$478). Income from nonfarm activities accounts for 65.6%, while income from crop production accounts for 27.7%. Average income per capita in Fengtai is the highest, followed by Yingshan and Funan. It is important to note that the income share from crop production in Fengtai is significantly higher than in the other two counties.

Benefits of aerobic rice production

In investigating the impact of aerobic rice adoption precisely, profits from the same parcel with aerobic rice production and with nonaerobic rice production can be compared. However, this requires time-series data on the same parcel before and after aerobic rice production. With cross-sectional data in this paper, it is impossible. The structure of data does not allow us to use econometric approaches (for example, propensity score matching or instrumental variable) to deal with this issue either. A simple but still convincing approach is the comparison of neighboring parcels, which may provide better insight into the impact of aerobic rice. In this paper, the neighboring parcel is taken as a control because aerobic rice can also be cultivated in that parcel, and the aerobic rice parcel is matched with the neighboring parcel under different crops (maize and lowland rice). Information on the production of aerobic rice, lowland rice, and maize was gathered in the fieldwork stage, including input and output data at the cultivated plot level. The economic benefits of aerobic rice and other summer crops in the neighboring parcels are analyzed and compared in this section.

Yield and production value

Yield difference. Yield statistics of summer crops appear in Table 6. Crops have an obvious yield difference, with lowland rice (6.5 t ha^{-1}) the highest, followed by maize (3.6 t ha^{-1}) and aerobic rice (2.9 t ha^{-1}). Although yields of lowland rice and maize do not fluctuate much, the yield of aerobic rice does show great fluctuation (with the highest yield in Funan, being 4.86 t ha^{-1}). The fluctuation can be further confirmed by the differences in the coefficients of variation (CVs) among crops over counties. Although the CV of yield is relatively low for lowland rice (0.25), it is higher for aerobic rice (0.77), with the highest CV in Yingshang (1.49). It is worth noting that the CVs for aerobic rice and lowland rice in Funan are similar and both lower.

Interviews with local informants provide some help in explaining yield differences and fluctuations. Although variety degradation and lack of management technologies are acknowledged as main constraints for yield variation in Fengtai and Yingshang, farmers with a relatively long history of aerobic rice planting in Funan have accumulated experience and obtained high yield.

Price difference. Prices of summer crops at the household level were gathered during the fieldwork. Table 7 gives detailed information on prices. The price of aerobic rice is the highest, followed by lowland rice and maize. Interestingly, the price of aerobic rice is on average higher than that of lowland rice, perhaps because aerobic rice was sold as seed to neighbors and local seed dealers, and further interviews confirm that the price of aerobic rice sold for food grain ($0.15–0.20 kg^{-1}) is much less than that for seeds ($0.40–0.50 kg^{-1}).

Table 6. Gross margins of summer crop production in study counties.[a]

Item	Fengtai			Yingshang			Funan			Average		
	Aerobic rice	Lowland rice	Maize	Aerobic rice	Lowland rice	Maize	Aerobic rice	Lowland rice	Maize	Aerobic rice	Lowland rice	Maize
Yield (t ha^{-1})	3.13	6.61	3.92	0.74	6.3	4.04	4.86	6.29	2.99	2.93	6.46	3.7
(CV)	(0.60)	(0.32)	(0.53)	(1.49)	(0.25)	(0.54)	(0.32)	(0.25)	(0.65)	(0.77)	(0.25)	(0.58)
Production value (US$ ha^{-1})	807	1,628	669	206	1,237	738	920	1,084	518	644	1,316	642
(CV)	(0.75)	(0.32)	(0.55)	(2.01)	(0.31)	(0.56)	(0.30)	(0.34)	(0.67)	(0.84)	(0.37)	(0.67)
Labor (person-days ha^{-1})	76.1	94.7	118.8	100.5	89.6	148.9	89.2	112.3	113.7	88.6	98.9	127.1
Input cost ($ ha^{-1})												
Cash cost	513.70	615.60	316.50	526.30	650.40	331.30	535.60	632.80	350.40	525.20	633.00	332.70
(CV)	(0.31)	(0.81)	(0.48)	(0.32)	(0.37)	(0.53)	(0.33)	(0.26)	(0.50)	(0.33)	(0.61)	(0.51)
Seed	90.90	68.60	56.30	108.40	81.80	58.10	67.80	80.40	65.0	89.00	76.90	59.80
Pesticide	90.60	106.80	47.20	87.60	110.0	38.70	97.70	125.40	43.20	92.00	114.10	43.00
Fertilizer	190.90	225.10	165.90	193.10	234.30	170.20	198.0	230.20	174.0	194.00	229.90	170.00
Fuel and oil	55.80	37.90	37.20	38.40	33.10	16.10	50.0	55.10	27.40	48.10	42.00	26.90
Rent	85.50	177.30	9.90	98.80	191.10	48.20	122.1	141.70	40.80	102.10	170.00	33.00
Labor cost	205.50	255.70	320.80	271.40	241.90	402.0	240.8	303.20	307.0	239.20	266.90	343.30
Gross margin ($ ha^{-1})	87.80	756.70	31.80	−591.70	344.70	4.60	143.5	148.0	−139.40	−120.10	416.50	−34.30
(CV)	(4.15)	(0.7)	(0.7)	(−0.7)	(1.3)	(5.73)	(1.5)	(1.9)	(−0.15)	(−1.98)	(1.0)	(−0.7)

[a] The differences in yield and gross margin among study crops are all statistically significant at 1%, and t values are not presented.

Table 7. Prices of summer crops in study counties (US\$ kg^{-1}).

Crop	Fengtai	Yingshang	Funan	Average
Aerobic rice	0.26	0.28	0.19	0.22
Lowland rice	0.25	0.20	0.17	0.21
Maize	0.17	0.18	0.17	0.18

Difference in production value. Production values calculated per hectare at the plot level take the following formula, and the results appear in Table 6:

*Production value = yield * price*

Among the investigated crops, the production value per hectare of lowland rice is twice that of other crops, followed by aerobic rice and maize. The CV of the production value reflects its relative riskiness. On average, the relative riskiness of the production value for aerobic rice is highest in Fengtai and Yingshan and lowest in Funan.

Labor input

Labor uses in crops appear in Table 8. Maize costs more, followed by lowland rice, and aerobic rice requires less labor. For crop seeding and transplanting, lowland rice uses much more labor than other crops. For labor use in irrigation, lowland rice costs more. For labor in harvesting and other postharvest activities, aerobic rice and lowland rice need less, while maize requires a high labor input for manual harvest. Hand weeding uses the most labor for aerobic rice.

Cash costs

Cash costs for crop production mainly include cash payment for seed, pesticide, fertilizer, fuel, and rent. Table 6 shows cost items and the total cost for each crop studied. On average, the cash cost of lowland rice is the highest, followed by aerobic rice and maize. The costs of lowland rice and aerobic rice are mainly for the use of fertilizer and rent, and that of maize for fertilizer. Rent costs are higher for lowland rice because of the high payment for irrigation.

Gross margins of crop production

The gross margin of crops can be estimated using the following formula:

Gross margin = production value – total cost

where *Production value = yield * price,* and

Total cost = labor + seed + pesticide + fertilizer + fuel + rent

The gross margins of the crops studied are listed in Table 6. Labor has become increasingly expensive in China, and this is true for agricultural production as laborers previously involved in agriculture have been continuously migrating to urban areas for nonfarm work during the economic transition. In consideration of the opportunity cost,

Table 8. Labor use (person-days ha^{-1}) of summer crop production in study counties.

Item	Fengtai			Yingshang			Funan			Average		
	Aerobic rice	Lowland rice	Maize	Aerobic rice	Lowland rice	Maize	Aerobic rice	Lowland rice	Maize	Aerobic rice	Lowland rice	Maize
Land preparation	6.8	11.0	8.7	6.5	11.0	9.2	5.0	10.6	5.6	6.2	10.9	7.9
Seeding and transplanting	1.2	33.2	7.4	1.6	30.5	11.9	1.0	24.8	5.7	1.2	29.5	8.4
Hand weeding	40.3	10.3	28.6	55.4	10.5	31.2	42.7	12.8	34.4	45.2	11.2	31.4
Fertilizing	2.1	3.0	4.2	2.5	3.4	8.1	2.7	3.6	4.5	2.4	3.3	5.6
Spraying pesticide	8.0	6.9	6.7	8.1	10.0	9.6	9.1	12.0	5.9	8.4	9.6	7.4
Irrigation	7.5	24.3	0.6	10.1	24.4	3.2	18.8	38.8	0.4	11.4	29.2	1.4
Reaping	5.3	3.8	35.3	12.1	4.9	30.2	6.5	5.5	35.7	7.6	4.7	33.7
Transporting	2.9	2.5	6.0	2.0	2.3	7.0	2.1	3.1	7.0	2.4	2.6	6.7
Threshing	2.0	1.0	21.3	2.2	0.4	35.3	0.9	1.7	13.9	1.7	1.0	23.5
Other	0.0	0.7	0.0	0.0	0.0	3.1	0.5	0.2	0.7	0.1	0.3	1.3
Total labor use (CV)	76.1 (1.0)	96.6 (0.5)	118.8 (0.9)	100.5 (0.7)	97.5 (0.5)	148.9 (0.9)	89.2 (0.8)	113.1 (0.5)	113.7 (0.7)	86.7 (0.9)	102.4 (0.5)	127.1 (0.8)

labor cost is estimated using number of days times average wage rate at the village level, for which local agricultural labor is reported at US$2.70 per day.

When labor cost is considered, the gross margin for lowland rice is positive and considerably higher, whereas for aerobic rice it is negative mainly because of the failure of aerobic rice production in Yingshang. Although lowland rice has a higher gross margin in Fengtai and Yingshang, aerobic rice and lowland rice have similarly higher gross margins in Funan. In terms of relative riskiness, the CV of gross margin for aerobic rice is higher in Fengtai and Yingshang and lower in Funan.

Gross margin against cash inputs (not imputing family labor cost) becomes positive for three crops. Farmers can then see the cash balance, and this may be an important consideration for households using their own labor in the absence of alternative employment opportunities.

Other benefits of aerobic rice production

Environmental aspects. The contribution of aerobic rice to environment mainly involves protecting water resources by saving water during the course of planting. Generally, farmers irrigate 2–3 times during the growth duration of aerobic rice, while lowland rice must be irrigated 6–7 times to keep soil saturated. In irrigating, water depth of 2–5 cm is sufficient for aerobic rice growth, while usually 8–12 cm for lowland rice is required. Farmers reported that aerobic rice may save 50–70% water vis-à-vis lowland rice.

Labor savings and migrant workers. As a labor-saving technology, the planting of aerobic rice saves labor use, which promotes farmers working outside as nonfarm labor. It can be observed that with more aerobic rice planted, the share of labor migrating out for nonfarm work is higher. For example, aerobic rice production is more prevalent in Funan, whose share of labor migrating out is the highest (28.1%), while the share is the lowest (22.6%) in Yingshang, where aerobic rice is rarely planted.

Food self-sufficiency. Food self-sufficiency is of great importance for rice farmers to become involved in other economic activities. In places where water resources are scarce, the growing of aerobic rice is important for farmers' food self-sufficiency. An example is Shangtang Village in Fengtai, where lowland rice had been previously planted as a staple food crop. Prior to 2002, water was sufficient for lowland rice production because the village was near a water project that secured lowland rice production. However, as the groundwater level declined over years, the water project had to be moved to another location in 2003. Since then, water resources cannot meet the requirement for lowland rice growing. To meet their food needs, farmers have to buy food from the market, which led to a cash deficit for many households. The introduction of aerobic rice helps them in securing food production again.

The agricultural research and extension system in China

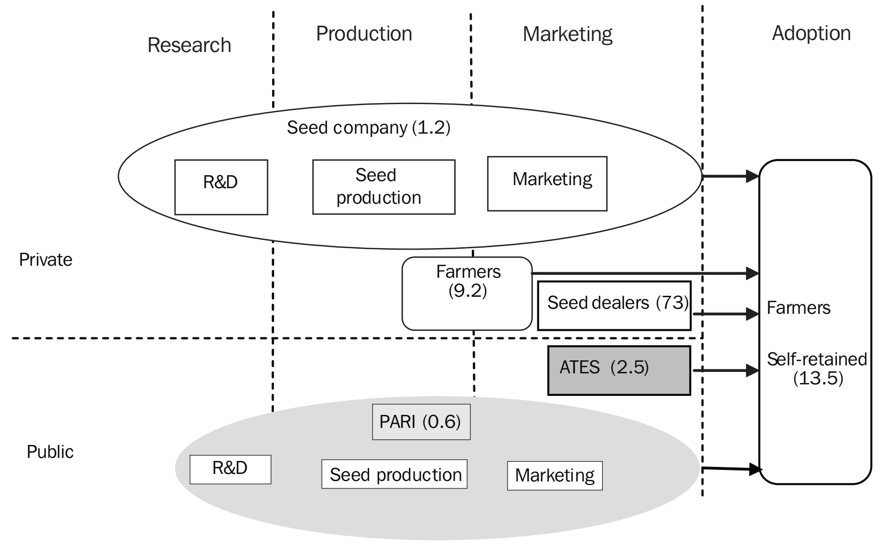
Technological change has been seen as the primary engine of agricultural growth in China. Agricultural R&D contributed to the changes. In extending technologies to farmers, researchers and policymakers have developed and designed many theories and practical methods and measures. An integrated national agricultural research and extension system (NARES), for example, is in place in many countries.

The agricultural research system was established in the 1950s, with its funding sources mainly from the government budget. The Chinese Academy of Agricultural Sciences (CAAS) is a leading national center in agricultural research, and has a strategic task of serving nationwide agricultural and rural development and empowering farmers with science and technology. Its major mandates focus on strategic and applied research solving key scientific problems that are of national or regional importance. Each of the country's 31 provinces has a provincial academy of agricultural sciences, mainly working in applied research, while agricultural institutes were also established at the prefecture and county level. In addition, several public agricultural universities at the national level and more than 30 public agricultural universities at the provincial level work on agricultural research and development.

Agricultural technologies had been almost entirely developed through such a public system until the 1980s. Crop breeding programs have been at the center of agricultural technology development, and are mainly carried out at central and provincial levels. With the economic reform since the 1980s, poor incentives at these public institutes have been an issue and the agricultural research system faced great challenges. Agricultural research investment, almost totally publicly funded, was declining, and funding was being allocated in ways that did not always reward excellence. A reform attempting to increase research productivity by shifting funding from institutional support to competitive grants and encouraging applied institutes to support themselves by selling the technology they produced started in the late 1980s. The private sector was allowed to invest in agricultural research, while foreign investors were also allowed to establish joint ventures in the agricultural sector.

Investment in agricultural R&D saw an increase in the late 1990s. Research funding increased greatly for plant biotechnology. China now ranks among the global leaders in agricultural biotechnology. Its public spending on agricultural biotechnology was second only to the U.S. Investment in government-sponsored R&D increased by 5.5% annually between 1995 and 2000 and by over 15% per year after 2000. It is planned that government investment in agricultural R&D will reach 1.5% of agricultural GDP by 2020.

The agricultural extension system was also established in the 1950s, which has been closely cooperating with agricultural research institutions at the central, provincial, county, and township levels. Agricultural technology extension can be generally categorized into four horizontal sectors, including research, production, marketing, and adoption, while public and private institutions may vertically engage in these sectors, as depicted in Figure 1 (Ding et al 2004). While public institutions mainly



PARI = public agricultural research institutes/universities.
ATES = governmental agricultural technology extension stations in county and township.
Note: The number in parentheses means the percentage share of farmers obtaining aerobic rice varieties from each channel.

Fig. 1. Diagram of the seed delivery system.

include public agricultural research institutes (PARI) and agricultural technology extension stations (ATES), private institutions mainly include seed companies, wholesalers, and local dealers, with rice farmers as technology adopters at the bottom of the system.

The functions of each organization/institution mentioned above are as follows. ATES (county and township level) are responsible for technology development, including introducing and improving varieties for local adaptability, field trials, training and demonstration, and seed production. PARI are responsible for breeding and experiments, trials and demonstrations, training, and instruction. Seed companies and seed dealers mainly work in breeding and research, seed production and marketing, and introducing local varieties.

Rice and aerobic rice research and extension in China

A national rice research and extension system is well established in China. Rice is one of the country's main crops, accounting for 37% of national grain production, and more than a third of the world's rice production. Rice is mainly grown in southern China, where it accounts for 87% of total national rice production. Rice breeding has been the most important research program in China's southern provinces. The China Rice Research Institute in Zhejiang Province is one of the leading rice research institutes

Box 1.

Views from private companies	*Views from ATES*
Aerobic rice varieties and relevant technologies are mainly from our company. We contact professors and breeders from CAU and obtain seeds and technologies. We experimented before introducing them to farmers, and together with seeds we also provided methods for growing them. They are worth growing for their relatively high profit. *Mr. Xie. manager, seed company, Fengtai*	*I disagree with growing aerobic rice in our town. I especially oppose the seed companies and dealers in the town selling aerobic rice to farmers. It will cause a serious loss in agricultural production because farmers who plant lowland rice all the time have no experience at all planting aerobic rice.* *Mr. Zhou, technician, ATES, Yingshang*
For extending aerobic rice technologies, I held a training course for rice establishment in a village in 2006. I also organized farmers from neighbor villages to visit the demonstration plots. *Shangwen Tang, seed dealer, Yingshang*	*We didn't advocate farmers growing it because the yield is lower than lowland rice. With sufficient water in our county, lowland rice grows well, so why should we grow aerobic rice?* *Mr. Liu, officer, ATES, Fengtai*

in China. The China National Hybrid Rice R&D Center in Hunan Province is the national and worldwide leading research center in hybrid rice technology development. Several agricultural universities and provincial agricultural academies have gained a reputation of excellence nationally and worldwide in rice research.

At the county and township level, the ATES (as mentioned earlier) have been functioning since the 1960s. Regarding rice technology extension, the ATES have been working closely with PARI (as mentioned earlier) as well as private institutes in diffusing rice technologies. In most parts of southern China, staff from township ATES have received a government budget, while extension programs are increasingly based on grant competition from central and provincial governments.

For aerobic rice, not all institutions mentioned above have a role in technology extension in the study area. As can be seen in Figure 1, local seed dealers are the main channel in diffusing aerobic rice, with 73% of the farmers obtaining aerobic rice seeds from them. Farmers' seed exchanges play an important role, with 19.2% of the farmers obtaining varieties through such a channel. Farmers may obtain seeds from seed companies, whereas very few farmers obtain them from PARI and ATES. In Fengtai and Yingshang, ATES do not engage in the extension process. Several officials responsible for rice technology extension and technicians at ATES even express their objection toward aerobic rice (Box 1).

Aerobic rice technology has been in development by public agricultural research institutions and universities for more than a decade, and it has been diffused mainly through private institutions such as seed companies and local seed dealers. In the current aerobic rice research and development system, public research institutions (such as universities) generally lack capability and interest in doing extension work (as their incentives may be mainly the excellence of scientific achievements, such as scientific publications); on the other hand, private institutions are mostly profit-oriented, and hence training and demonstrations, which were seen as the most effective ways to diffuse agricultural technologies, are not sufficiently provided.

The fact that institutions responsible for technology development and agents for technology diffusing and marketing worked separately was clearly observed during the fieldwork. With different incentives, these institutions may behave in different ways in the technology development and delivery system, which leads to a loss in efficiency. Several staff from county and township ATES had expressed that they have been intensively involved in local government-appointed technology extension work, in which aerobic rice is not on the agenda. However, a positive sign can be seen in Funan, where the county agricultural research institute has been working closely with China Agricultural University, which developed aerobic rice technologies, and local private seed companies in bridging agricultural research and extension. The county agricultural institute has been doing aerobic rice demonstrations as well as seed marketing, which have contributed to aerobic rice extension in the county.

Overview of national and local policies in agricultural extension

The government launched a massive program of direct subsidies to farm households in 2004, and currently has been debating how much to increase these subsidies. The national grain subsidy program is in fact a combination of four programs: a subsidy for farmers in areas that grow grain, a nationwide agricultural seed subsidy program, an agricultural input subsidy program, and a general transfer program. Some 80% of farm households receive subsidies in China, and many farm households were receiving about US$3 to $4 per mu (15 mu = 1 hectare). These subsidy programs are closely linked to agricultural technology extension. In addition to subsidies, the national government eliminated almost all taxes and fees in rural areas in 2004.

The emergence of subsidies and the elimination of taxes have become fixtures in the rural economy. There is also a nationwide low-income program aiming to develop a social security system that can put a safety net under those in the rural economy. In addition, recent policy innovations in rural infrastructure, free rural school tuition, grain and other agricultural subsidies, tax reductions, and health insurance subsidies are substantial. These government programs have contributed significantly to the observed improvements in household income in rural areas.

With regard to rice (aerobic rice) technology extension, the first three of the four programs mentioned above are closely related. The subsidy for farmers in areas that grow grain gives rice and aerobic rice farmers subsidies for their rice production. The agricultural seed subsidy helps rice farmers in purchasing improved seed varieties, which also reduces seed exchange within the villages, which might lead to a yield decline. The agricultural input subsidy allows farmers to purchase agricultural machinery for plowing and harvesting, which saves labor input and helps increase rice yield. It should be noted that no single subsidy is directly only for rice or aerobic rice; most of the subsidies are for grain crop production. For aerobic rice production, as it is a new and local crop production activity, there is no central government policy

Table 9. Changes in aerobic rice area and yield per household during 2004 to 2007.[a]

County	Area (ha)			Yield (t ha^{-1})		
	2005	2006	2007	2004	2005	2006
Fengtai	0.12	0.18	0.16	4.19	3.76	2.94
Yingshang	0.05	0.15	0.01	2.25	1.22	0.80
Funan	0.16	0.19	0.22	4.36	4.51	4.96
Average	0.13	0.18	0.14	3.60	3.16	2.90

[a] Aerobic rice yield for 2007 was not available at the time of interview.

for extension of such technology. There are, however, local or provincial policies for promoting aerobic rice technology development. For example, in Yunnan Province, where aerobic rice is grown in the southern mountainous region, the provincial government had once launched an Aerobic Rice Technologies for Poverty Alleviation program in which the government budget was allocated for extending the technologies, and this has been documented as a successful policy in extending them and alleviating poverty (Wu et al 2010).

Aerobic rice adoption

Household adoption of aerobic rice

Aerobic rice production in Funan dates back to the 1990s, whereas it began in Fengtai and Yingshang only in 2003, with more than 60% of the farmers first planting aerobic rice in 2006. Table 9 shows the variation in aerobic rice area and yield. Good progress can be seen in Funan, where yield and area gradually increased. However, yield of 2.25 t ha^{-1} in Yingshang was lower in 2004, and declined to 0.80 t ha^{-1} in 2006.

Several aerobic rice varieties are being planted, and many farmers may not know the formal names. Local seed dealers and experienced farmers were able to record the name of varieties adopted in 2006. Table 10 shows the number of times aerobic rice varieties were adopted, of which Han Dao 502 is the most common variety. Farmers may either grow aerobic rice on nonrice land like maize and soybean or directly seed it on rice land with nonpuddled and nonsaturated soils. Some 70.5% of the farmers prefer to grow aerobic rice on nonrice land.

To investigate the adoption of aerobic rice in the study area, farmers who adopt aerobic rice (adopters) and farmers who do not (nonadopters) are separately interviewed. Some farmers' demographic, household, and farm-level characteristics have been analyzed, and the results are listed in Table 11.

Age and education level of the household head do not differ between adopters and nonadopters. Average household size, number of migrant laborers, and share of male labor are all statistically different between adopters and nonadopters. There is no

Table 10 Number of times an aerobic rice variety was adopted by sample farmers.

Item	Total	Fengtai	Yingshang	Funan
Total	180	103	61	16
Han Dao 502	81	45	36	0
Zhonghan 1	26	17	7	2
Lvhan 1	16	0	16	0
Hanfeng 1	5	5	0	0
Changfeng 1	5	5	0	0
Direct-seeded rice variety	47	31	2	14

Table 11. Characteristics of adopters and nonadopters: summary statistics.

Item	Adopters	Non-adopters	Difference
Number of households	319	109	–
Age of household head	50.4	50.2	0.2
Education level of household head (years)	5.0	5.4	−0.4
Household size	4.8	4.3	0.5
Number of migrant laborers	1.3	1.0	0.3
Share of male labor (%)	52.5	55.8	−3.3
Land area (ha)	0.45	0.51	−0.06
Share of nonrice land in total land (%)	55.1	44.8	10.3
Household income (US$)	2,391.60	1,800.50	591.10

significant difference in terms of land area between adopters and nonadopters, meaning that aerobic rice adoption may not be correlated with farm size. There is, however, a significant difference in the share of nonrice land between adopters and nonadopters, which might suggest that the lack of rice land leads to aerobic rice adoption. Income of adopters is significantly higher than that of nonadopters, implying that household income is highly correlated with the adoption of aerobic rice. In sum, farmers who adopt aerobic rice are more linked with high income, a large share of nonrice land, large household size, and fewer male family laborers and more migrant laborers.

To further understand the major driving forces for and constraints to the adoption of aerobic rice, different characteristics of technology adoption among three counties are listed and compared in Table 12. As investigated earlier, aerobic rice production is

Table 12. Comparison of characteristics with aerbic rice extension among counties.

Item	Fengtai	Yingshang	Funan
Household size	4.8	4.6	4.7
Number of laborers	3.4	3.5	3.4
% of migrant labor	27.3	22.6	28.1
Land area for lowland rice (ha)	0.52	0.47	0.38
% of nonfarm income	59.3	74.6	75.7
First year of household growing aerobic rice	2003	2004	1999
% of direct-seeded rice varieties	Medium	Low	High
Government attitude to aerobic rice	Neutral	Opposite	Favorable
Partnership of public and private sector	Does not exist	Does not exist	Exists

known to be most prevalent in Funan. As can be seen in Table 12, labor migration in Funan is higher than in the other two counties, suggesting that labor migration may correlate with aerobic rice production because it is a labor-saving technology. On the other hand, cultivated land area for lowland rice per household is far less in Funan than in the other two counties, and this may explain the aerobic rice adoption. Funan has a longer history of growing aerobic rice than other counties, and farmers have already been familiar with the cultivation practices in which the direct-seeding method is more employed. Local technicians are convinced that direct seeding is more adaptive to the local environment and hence may have high yield. In addition, government policy toward aerobic rice is a key in agricultural technology extension. A close relationship of public research and extension institutes and private seed companies was observed in Funan, which contributed to the wide adoption of aerobic rice in the villages.

Estimation of area of aerobic rice and proportion of households that adopted it

No official data are available in China on aerobic rice production. Key informant interviews were done to estimate aerobic rice area. Some 18 key informants from bureaus of agriculture, seed companies and dealers, research institutes, and agricultural extension stations at the county and township levels in the three counties were interviewed to obtain their estimation of aerobic rice area. Table 13 shows the aerobic rice area estimation at the county level. Compared with total land area, aerobic rice area is low, being less than 1% of the total sown area in Fengtai and Yingshang and roughly 4% in Funan.

Village committee members were asked to estimate the share of aerobic rice area in total crop area and the share of households growing aerobic rice among all households in the village and the results are presented in Table 14. The trend is similar to that estimated at the county level. The proportions of aerobic rice area and of farmers

Table 13. Aerobic rice area estimation: county level during 2005-07 (ha).

County	Total land area[a] in 2006	Estimation of aerobic rice area		
		2005	2006	2007
Fengtai	45,900	127	270	330
Yingshang	100,303	30	200	27
Funan	82,770	1,667	2,700	3,300

[a]Refers to total cultivated area of the county in one growing season, including areas for rice crops and nonrice crops.

Table 14. Aerobic rice (AR) area estimation and proportion of households adopting: village level.

County	No. of villages surveyed	Total land area[a] (ha)	% of AR area in total land area			% of AR-growing households of all households		
			2005	2006	2007	2005	2006	2007
Fengtai	9	2,100	1.1	2.3	2.6	2.4	4.8	4.9
Yingshang	6	1,440	1.0	2.6	0.3	1.6	4.9	0.9
Funan	6	1,700	11.9	15.5	19.7	52.9	64.5	72.6

[a]Refers to total cultivated area of all villages surveyed in the county in one growing season, including areas for rice crops and nonrice crops.

growing aerobic rice are low in Fengtai and Yingshang but are much higher in Funan, with 20% of total sown area and 73% of farmers growing aerobic rice.

Rice farmers' perceptions on aerobic rice and management practices

Farmers are asked, "What is aerobic rice?" and "What is the difference between aerobic rice and lowland rice?" Although many farmers may not perceive this clearly, most farmers can express their opinions. Perception focuses on seeding methods, land preparation, irrigation, yield, labor, and agrochemical use. While there is no distinction in agrochemical use for lowland rice and aerobic rice, there are obvious distinctions in seeding, land preparation, irrigation, and labor use in transplanting and weeding. Serious weeds have been perceived as one of the main constraints.

Farmers are asked to estimate aerobic rice yield, taste, appearance, tolerance of drought and flood, and resistance to diseases and pests by varieties, and the results are listed in Tables 15 and 16. Although average yield of aerobic rice is around 4 t ha^{-1}, Changfeng 1 and Hanfeng 1 can surpass 5 t ha^{-1}. Shelling rates are mostly beyond 50%. The taste of Hanfeng 1 is thought good. As for appearance, Zhonghan

Table 15. % distribution of farmers' perceptions on yield and quality of aerobic rice (1).

Variety	Average yield (t ha^{-1})	First year adopted	Shelling rate	Taste (%)			Appearance (%)		
				Good	Average	Bad	Good	Average	Bad
Han Dao 502	4.68	2004	55.8	61	35	4	59	30	11
Changfeng 1	5.12	2004	62.4	33	17	50	17	67	17
Hanfeng 1	5.06	2004	56.3	100	0	0	68	21	11
Zhonghan 1	4.99	2005	61.7	82	0	18	88	0	12
Lvhan 1	4.07	2005	49.7	70	20	10	0	100	0
Direct-seeded lowland rice varieties	4.82	1996	58.4	67	21	12	66	28	6

Table 16. % distribution of farmers' perceptions on yield and quality of aerobic rice (2).

Variety	Drought resistance			Flood resistance			Disease and pest resistance		
	Good	Average	Bad	Good	Average	Bad	Good	Average	Bad
Han Dao 502	58	33	9	66	27	7	24	54	22
Changfeng 1	67	33	0	83	17	0	67	33	0
Hanfeng 1	100	0	0	60	20	20	40	40	20
Zhonghan 1	71	24	5	48	52	0	43	38	19
Lvhan 1	67	33	0	44	44	11	33	56	11
Direct-seeded lowland rice varieties	56	39	6	56	33	11	42	50	8

1 is thought good. A majority of farmers deem an aerobic rice variety to have good tolerance of drought, of which Hanfeng 1 is the best. Interestingly, farmers expressed that, compared to maize and soybean, growing aerobic rice can solve the serious problem of waterlogging, which has been occurring frequently in the study area.

Reasons for why (and why not) to grow aerobic rice are further investigated. The following advantages have been mentioned frequently: simple management, lower input use (in labor and water), and good resistance. Aerobic rice is seen to have more stable yield than soybean and maize under an environment of alternate occurrence of drought and flood in the study area. Reasons for not growing aerobic rice fall in the following categories: low yield, serious weed problems, and serious insect pests.

Farmers' management practices have been investigated. The following examples in Box 2 provide indications for understanding farmers' aerobic rice management practices.

Box 2.

A successful example	*An example of failure*
I have 5 years' experience planting aerobic rice. Like lowland rice, aerobic rice needs careful management. In 2006, I seeded on 5 June. According to my experience, it should definitely be seeded before mid-June; otherwise, yield will suffer. I plowed and harrowed the plots, sprayed fertilizer, and drilled the seed. After sowing, I harrowed again to ensure the seed being covered by soil. I sprayed herbicide to prevent the emergence of weeds. I watered once after seedlings came up to meet water needs at this critical stage. During the crop's growing period, fertilizer and pesticide use were similar to that of lowland rice, but water management was different. There was no need to keep it flooded over the whole growing period, but sufficient water should be ensured during grain filling and heading. I watered 3 times in 2006, and got a good harvest. Yield reached 6.5 t ha^{-1}. *Mr. Guangkui Ding, farmer in Funan*	*I didn't have any experience when I first planted in 2006. I learned from a friend who lives in a neighboring village. I planted 0.13 ha of aerobic rice. I seeded it using the dry direct-seeding method on 20 June. Before seeding, I plowed and harrowed the plot. After seeding, I harrowed again to ensure the seed being covered by soil. I was told that, like wheat, it doesn't need irrigation, so I did not do any in the whole growing period. I found many weeds with seedlings coming up but I did not use herbicide since I was concerned that the herbicide would be harmful to the seedlings. I used herbicide when the seedlings were getting older, but it is no use at all since the weeds grew up together with the seedlings. I weeded the crop by hand, but this was little help for too many weeds destroyed at least half of the output. I used pesticide 3 times to fight insect pests but they cannot be controlled. They ate the rest of the plants and I didn't get any output.* *Mr. Ruifei Tang, farmer in Yingshang*

Breeders and seed dealers interviewed summarized suitable aerobic rice management practices as follows. (1) Seeding at the right time: seed should be sown before mid-June to avoid low temperature at the late growing stage. (2) Solving the weed problem: as the crop is not permanently flooded and subsequent weed problems can be serious, the use of pre- or postemergence herbicides is recommended. (3) Irrigation water: although the crop needs less water, water is still necessary at certain critical periods. A light irrigation application should be given after sowing to promote emergence in the dry season. (4) Preventing insect pests: insect pests may hit aerobic rice at the very late stage after the lowland rice harvest. Farmers should timely prevent insect pests.

In investigating farmers' technological needs, two questions, "What technologies do you mostly need in aerobic rice production?" and "What variety do you need?" are asked, and the results are presented in Table 17. Most farmers report that technologies regarding weed control, pest control, and fertilizer use are in critical need. In addition, methods on seeding, field management, and irrigation, as well as mechanization, are also needed. For aerobic rice varietal needs, as can be seen in Table 18, high-yielding varieties are needed. Varieties with insect pest resistance and short growth duration are also needed. Varieties with good quality (including taste and appearance) and simple management methods are needed as well.

Table 17. Farmers' needs with aerobic rice technologies (% of farmers).

Fengtai	Yingshang	Funan
Weeding (82.3%)	Preventing/killing pests (87.7%)	Weeding (70.4%)
Preventing/killing pests (68.5%)	Weeding (72.4%)	Preventing/killing pests (68.3%)
Seeding (20.5%)	Good variety (43.1%)	Fertilizing (14.3%)
Fertilizing (15.2%)	Fertilizing (24.4%)	Machinery (8.7%)
Planting density (14.9%)	Irrigating (20.8%)	
	Seeding (9.5%)	

Table 18. Farmers' needs with aerobic rice varieties (% of farmers).

Fengtai	Yingshang	Funan
High yield (93.5%)	High yield (97.7%)	High yield (88.3%)
Good taste (81.4%)	Good pest resistance (83.0%)	Good quality for sale (48.6%)
Good pest resistance (60.5%)	Good weed tolerance (67.5%)	Short growing time (13.6%)
Short growing time (31.2%)	Short growing time (28.6%)	Good pest resistance (10.8%)
Good weed tolerance (28.2%)	Good taste (25.3%)	
Simple management (12.7%)		

Lessons learned and future prospects

Lessons learned

Estimation of aerobic rice area and proportion of households adopting. Aerobic rice production has a relatively short history in the study area. Although its area has been continuously increasing, great variations occur among study counties. The area extended very rapidly in Funan, where aerobic rice has been planted for more than 10 years, whereas area grew only marginally in Fengtai and declined sharply in Yingshang. Funan is taken as an example to estimate the area of aerobic rice and proportion of households adopting it. Estimated by staff and technicians from the agricultural bureau at the county level, aerobic rice occupies roughly 4% of the total land area. Estimated by village leaders and rice farmers in six sample villages, aerobic rice occupies 20% of the land area, with 72% of households growing it.

Benefits of aerobic rice production. The yield of aerobic rice averages 2.9 t ha^{-1} with great variations among counties. It reaches 3.1 t ha^{-1}in Fengtai and 4.9 t ha^{-1} in Funan, with Yingshang as an exception because of failure in crop management. Cash costs of aerobic rice are generally lower than for lowland rice and higher than for maize, while labor use in aerobic rice is lower than in both lowland rice and maize. Gross margins of summer crops vary greatly among them over counties, with those of aerobic rice almost the same as or higher than those of lowland rice in Funan. Relatively higher and more stable yield and gross margins in Funan imply that aerobic rice has great potential in the study area.

As aerobic rice production saves labor to a great extent, the extension of such technology has implications for employment for rural laborers as rural migrant laborers have been moving into urban areas for nonfarm work and this has greatly increased the income of rural households. For those whose income relies mainly on farm work, the extension of aerobic rice will also help diversify their income from various agricultural activities. The savings in labor input have affected the attitudes/perceptions of the people toward adopting aerobic rice, leading aerobic rice to be increasingly adopted in the study area.

Perceptions of aerobic rice production. Severe drought and flood can occur alternatively during summer crop production in the study area. Because of unbalanced rainfall, 34% of the farmers experienced drought in lowland rice production while more than 30% of the farmers experienced flood in soybean and maize production. With good tolerance of both risks, drought and flood, aerobic rice has less yield reduction, implying that it can be profitable compared with other summer crops under an environment of alternative occurrence of drought and flood. These may be important determinants in developing aerobic rice in the study area.

It is generally recognized that rice farmers do not have much knowledge and experience in aerobic rice production. Farmers perceived aerobic rice as a nonrice crop and it can be grown like maize and soybean, and thus subsequent irrigation was usually not provided during its critical growing periods. Weeds were perceived as one of the main constraints. Farmers acknowledged the key factors in determining aerobic rice production, and these include labor saving, less input use, simple management, less water need, relatively good resistance to pests, and good tolerance of drought and flood. Of these factors, labor saving was seen as the most critical as farmers would be able to invest in nonfarm activities that provide additional income. Low yield and serious weed problems were acknowledged as the top two constraints in aerobic rice production.

Source of aerobic rice technology development. Aerobic rice technologies were originally developed by public institutions under state R&D system support. The well-established national agricultural research and extension system (NARES) in China, in close collaboration with international research communities, has led to continuous agricultural innovation in which the development of aerobic rice has been one successful example.

Aerobic rice research and extension system. A seed delivery system mainly consisting of public extension stations, private companies, and local seed dealers has long been in place in rural China. Agricultural technologies that have been put on the government extension agenda can be effectively extended through such a system. In extending aerobic rice technologies, however, such technologies are yet to go into the government extension agenda. Consequently, the established government system has a lack of incentives to be involved in extension.

Successful extension on aerobic rice must build partnership of public and private institutes, and effective mechanisms should be established for bridging research and extension. In the aerobic rice research and extension system, private channels such as seed companies and dealers have been playing a central role in extending aerobic rice. Private institutions are more adaptable to innovative technologies, and incentives exist (for example, a higher price for output) for private institutions to be involved in such technology extension. In doing aerobic rice extension, however, private institutions generally lack capacity. Training and demonstration, for example, have been proven elsewhere as the most effective way in agricultural technology extension, but these have been provided less in the study area. Private mechanisms have an important role in diffusing aerobic rice as documented in this paper. However, public institutes generally lack relevant technology and policy measures for diffusing aerobic rice technologies.

Future prospects

Improvement of aerobic rice varieties. Varietal improvement has been a source of yield increase. However, farmers in the study area frequently reported less suitable aerobic rice varieties available compared with other crops. Further varietal improvement in aerobic rice should take local adaptability into important consideration, and more context-specific varieties and related technologies will be needed. Farmers in Funan are increasingly using direct seeding in growing lowland rice varieties in aerobic soil conditions, and they obtain high yield. This may suggest that rice breeders can use such lowland rice varieties for further varietal improvement for aerobic rice production.

Integrated technologies. Integrated technologies in diffusing aerobic rice are needed. Although the development of improved varieties has been put on the breeding agenda of public research institutions, research and development of relevant technologies are not in place. Currently, for aerobic rice production in North Anhui, such technologies include weed control and crop management methods (irrigation and pest control). These types of integrated technologies would help in improving aerobic rice yield at the farm household level.

Savings in labor use and water use are two economic incentives for aerobic rice production. Although yield improvement is a major target of technological development, any technological intervention without taking labor and water savings into consideration would not be acceptable at the farm household level.

Farmers' participation. Although researchers and breeders reported high yield in experimental plots, farmers may report relatively low yield. Practically, there are gaps in achieving potential yield (or experimental yield) at the farm level. Constraints at the farm household level should be further investigated.

Farmers' participatory varietal selection and technological improvement have been advocated elsewhere and proven to be effective in diffusing agricultural technologies. These were less observed in the study area. Involvement of farmers in the early stage of aerobic rice technology development, pilot experiments, and farmers' participatory research should be further encouraged.

Involvement of public extension and public-private partnership. Training and demonstration had been proven as the most effective ways in diffusing agricultural technologies in developing countries. Such activities are, however, less observed in aerobic rice development in the study counties. Given that public agricultural technology extension stations are already there and functioning relatively well, more intensive involvement of such a system should be encouraged.

In addition to public institutions, there are other organizations and institutional resources, such as the Communist party committee at the township and village level, women's federation, and many market-oriented organizations actively operating in the study area. With different incentives, these institutions may move in different directions in the delivery system, leading to a loss in efficiency. Public institutions are generally seen as lacking incentives and private institutions lack capacity. Close links between the two types of institutions will certainly help in delivering technologies.

Recent studies on delivery mechanisms for agricultural technology advocate the establishment of public-private partnership, in which public and private institutions establish partnership and cooperate in a win-win situation. Such partnership is critically needed for transferring agricultural technologies to the marginalized resource-poor farmers in North Anhui during the socioeconomic transition.

Technological and policy interventions. Although positive signs have been seen in the development of aerobic rice production, available technologies are not sufficient for improving rural households' livelihoods. The positive changes observed in the study area could not have occurred without the required policy interventions, which address the multidimensional nature of the problem that cuts across economic, political, and social issues in the study area. However, the changes observed in the study area over a short time period indicate that there is ample room for optimism that the complex issues of rural development can be addressed through context-specific combinations of complementary policies and agricultural technologies.

One last point to make is that aerobic rice technologies and their extension model have been in practice in some places worldwide, and the experiences and lessons from this study can contribute to making a model for widespread dissemination of aerobic rice in general to similar situations, such as those places with water scarcity, and different situations, such as in tropical and subtropical mountainous areas with erratic rainfall and lacking irrigation facilities.

References

Bouman BAM. 2001.Water-efficient management strategies in rice production. Int. Rice Res. Notes 16(2):17-22.

Bouman BAM. 2007. Aerobic rice: 10 frequently asked questions. International Rice Research Institute Thursday seminar papers.

Dey MM, Upadhyaya HK. 1996. Yield loss due to drought, cold and submergence in Asia. In: Evenson ER, Herdt W, Hossain M, editors. Rice research in Asia: progress and priorities. Wallingford (UK): CAB International in association with International Rice Research Institute.

Ding S, Gu X, Chen F, Chen C, Pandey S, Zhang Q, Luo L. 2004. Rice seed system in China: views from institutions and farmers. In: Poland D, Sawkins M, Ribaut JM, Hoisington D, editors. Resilient crops for water limited environments: Proceedings of a Workshop Held at Cuernavaca, Mexico, 24-28 May 2004. Mexico D.F.: CIMMYT.

Gaynor M, Putterman L. 1993. Productivity consequences of alternative land division methods in China's decollectivization: an econometric analysis. J. Dev. Econ. 42(2):357-386.

Geng S, Zhou Y, Zhang M, Smallwood S. 2001. A sustainable agro-ecological solution to water shortage in the North China Plain (Huabei Plain). J. Environ. Planning Manage. 44:345-355.

Lin JY, Shen M. 1996. Rice production constraints in China. In: Evenson ER, Herdt W, Hossain M, editors. Rice research in Asia: progress and priorities. Wallingford (UK): CAB International in association with International Rice Research Institute.

Nyberg A, Rozelle S. 1999. Accelerating China's rural transformation. The World Bank Report.

Wang H, Bouman BAM, Dule Z, Wang C, Moya PF. 2002. Aerobic rice in northern China: opportunities and challenges. In: Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Tuong TP, Ladha JK, editors. Water-wise rice production. Proceedings of the International Workshop on Water-wise Rice Production. Los Baños (Philippines): International Rice Research Institute.

Wu H, Ding S, Pandey S, Tao D. 2010. Assessing the impact of agricultural technology adoption on farmers' well-being using propensity-score matching analysis in rural China. Asian Econ. J. 24(2):141-160.

Notes

Authors' addresses: Shijun Ding and Haitao Wu, Zhongnan University of Economics and Law, No. 1, South Nanhu Rd., Wuhan 430074, China; B.A.M. Bouman and Shaobing Peng, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines; Huaqi Wang, China Agricultural University, West Yuanmingyuan Rd., Beijing 100080, China. Email: dingshijun2006@yahoo.com.cn.

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Part IV

Reflections

The IRRC at an opportune time

Gelia T. Castillo

Agriculture must be "forever" and it must be sustainable.

Agriculture by any other name is still AGRICULTURE. Whether it is rice in unfavorable or irrigated areas; rice with corn or wheat or chickpeas; sunflower, livestock, trees, potatoes, sweet potatoes, fodder, fish, fruits, vegetables, flowers, rubber, coconut, cocoa, tea, coffee, spices, olives, nuts, abaca, bananas, etc., it is still agriculture. Agriculture must be FOREVER because our life depends on it. However, economists have repeatedly and eloquently pointed out the declining importance of agriculture as a share of gross domestic product, the labor force, and household income. One wonders whether such conclusions have not contributed to the neglect of agriculture, and the consequences for humanity. The declining importance is *relative* to other industries and spheres of life. But, in an absolute sense, we cannot do without agriculture because it is the source of *food*, *feed*, *fiber*, and *fuel*. None of these can be produced in a primary form in any other way. Computers, no matter how powerful and ubiquitous, produce neither rice, nor corn, nor any of the products mentioned above.

Agriculture must be forever because it has the capacity to renew itself. Nowadays, however, that capacity is of serious concern. The challenge to science, human ingenuity, institutional learning for innovation, collective vision, and political will is how to sustain the *forever* while meeting the ever-growing and ever-changing demands for greater regard for human welfare and the quality of the natural resource base of our existence. Agriculture is a most significant way of managing our natural resources; hence, it must be the centerpiece of natural resource management, particularly in rice production, which means the FOOD in our daily lives.

The Irrigated Rice Research Consortium (IRRC) is in a very strategic position at a very opportune time of rice crisis to make a difference in the present and future performance of the rice crop.

In Asia, RICE IS LIFE, and, because of that, rice is a very, very political commodity, whether we like it or not. Good rice is usually good politics, but subsidies have a tendency to turn it into bad politics, especially when there is a crisis and the benefits go to the undeserving. Furthermore, subsidies undermine nature and encourage moral hazards on the part of all stakeholders. But, politics is reality, no matter whether there is more or less democracy. The IRRC seems to have learned to function within the political system, whether local or national, even forging productive partnerships without forgetting the common good. Rice has the particular virtue of being highly valued and edible. The IRRC is fortunate to have such a virtuous crop to work with.

Irrigated rice is the main source of rice supply for the non-rice-producing sectors of society, in urban and non-rice-producing rural households. Considering the current rice crisis, there must be a sense of urgency in what we do because the IRRC has the potential to contribute significantly to the task of increasing rice production at reduced cost to the environment and to consumers; allowing farmers who are mostly poor to earn more; and achieving much-needed collective action for managing common property resources such as soil, water, land, etc., and common problems such as pests, rodents, and weeds. How do we achieve all of these with a minimum of social conflict and a maximum of harmony in win-win scenarios? The gems of this challenge could be gleaned from the country projects. They just need to blossom further and bear more fruit.

The IRRC case studies have shown a variety of approaches to organizing for the communication and innovation process so that technologies can become part of the rice-farming community's way of life and way of thinking at different levels of society, whether local, national, or international. These approaches include "Palay check" with locally tailored guidelines; National Fertilizer Working Groups; an area development program; the clustering approach; farmer-to-farmer extension; community management of rodents; public-private partnership in postharvest technologies; GIS soil fertility maps; famers' field schools as venues for introducing new technologies; direct seeding and weed management to reduce cost, time, and labor while making it possible to create more employment via an additional crop; rice-based production systems through multisector partnerships; working with local government units at provincial or lower levels as emerging new partners; participatory market chain initiatives to empower farmers to take action in their own behalf; etc. Curiously, there was no mention of cooperatives. Maybe it is just as well to keep them that way.

A most important message that came through all the case studies is that perhaps we should stop reviving traditional extension. Allow it to fade away so that new and more creative paths to communication and innovation can find exciting "spaces" to grow.

The technologies that make up the core entry points in the communication-innovation process for natural resource management are a BREAK from traditional practices in irrigated rice farming. For example, SSNM (site-specific nutrient management) is no longer the prescription of 6 or 8 bags of fertilizer per hectare. "Feed the rice plant as needed" is a knowledge-intensive approach that requires more thinking and less fertilizer. The same is true for integrated pest management (IPM), alternate wetting and drying (AWD), etc. These practices are not only knowledge-intensive, they are also organization-intensive! We must learn to act together horizontally and vertically for these practices to work.

The case studies provide rich, imaginative experiences but more intensive research to document the process and the impact is needed in order to share learnings and build collective visions that are sufficiently credible evidence to convince policymakers to co-invest in this journey to more effective natural resource management of irrigated rice in Asia.

As the China study on aerobic rice adoption said: "The consequences for a household's income generation and livelihoods are still poorly understood." This observation seems to apply to all the case studies.

On the research aspects of NRM, quite notable is David Johnson's statement that "working in farmers' fields" has become an added rigor for researchers. This will contribute significantly to their credentials for there is nothing like getting muddy to indicate seriousness of purpose.

Is it appropriate to think of early harvest, *monga* (hunger) mitigation, direct seeding, short-duration varieties, etc., as climate risk management measures? If yes, IRRI puts itself ahead of others in "walking the talk" in responding to climate change. Rice has always had climate risk management practices but they were not called such.

Incidentally, research reports from the Consortium for Unfavorable Rice Environments (CURE) also include *monga* mitigation, early harvest, direct seeding, short-duration varieties, etc. Does the IRRC learn from CURE and vice-versa? If they do, this will be the ultimate in social learning within the same institution.

Regardless of country, approach, or technology focus, the one common lesson we can draw from the case studies is that *people make the difference*. When the passion and the commitment come through, we find hope that rice will be *forever*. When an agricultural machinery expert from Vietnam and a medical doctor from Myanmar worked together to make rice dryers come into wide practical use, after years of unsuccessful attempts, this is a great story in itself. The case studies are ultimately about "people" who make a difference.

Notes

Author's address: Dr. Gelia Castillo is a national scientist of the Philippines and an IRRI consultant.

Appendix 1.

Other reflections from scientists and the donor[1]

During the IRRC meeting, six resource persons reflected on what had been done in Phase III, as well as their thoughts on what needed to be done for the succeeding phase. Building on the successes and the gaps of Phase III, the reflections focus on the key researchable areas that would help the IRRC in crafting its research and partnership program for Phase IV. The resource persons were three IRRI officials, Dr. Achim Dobermann, deputy director general for research; Dr. Gelia Castillo, consultant; and Dr. Thelma Paris, socioeconomist and gender specialist, Social Sciences Division (SSD). The other resource persons were Dr. Carmen Thoenissen, Swiss Agency for Development and Cooperation (SDC), and Dr. Than Aye and Dr. Nguyen Van Bo, both members of the IRRC Steering Committee, from Myanmar and Vietnam, respectively.

Dr. Nguyen Van Bo

Giving a perspective from Vietnam, Dr. Nguyen Van Bo stressed four themes that emerged from the meeting: sharing and cross-country learning, integrating technologies, a thrust on socioeconomic studies, and reaching policy stakeholders. He said that one of the highlights in Phase III that should be continued in Phase IV is cross-country learning. Technologies should be shared, whether farmer-to-farmer or between countries. Cross-country learning should be strengthened in Phase IV. He also stressed the need to integrate technologies such as the drum seeder, laser leveling, dryers, direct seeding, and water saving. In the past, these were treated as a single technology but the consortium could provide ways to integrate them. The socioeconomic studies presented showed how important they were for stakeholders in understanding why farmers adopted a technology or didn't. These should also be continued. Lastly, the consortium has to reach not only farmers but also policymakers. Bigger benefits of the technologies could be gained if these were supported by a policy, but how to involve those working in policy remains a question.

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[1] These are based on the notes and the audio recorded during the meeting.

Dr. Achim Dobermann

The IRRC technologies (like SSNM) have evolved and progressed. It is both the simplification of technologies and adjusting them to farmers. Some of these are delivered to farmers on a larger scale, but doing this has no single recipe. The work groups are doing it differently and rightly so, but the key is to look 10–15 years ahead and see what will happen in farmers' fields then.

The following might be areas that the IRRC will have to deal with in the future. One is high commodity prices, for which the input and product side have different incentives for different people. Second, there will be significant changes in the agricultural landscape. Mechanization is going to happen more and more and the labor-intensive practices of the 1950s will not happen again. Third, there will be changes in the seed business as investments in scientific breakthroughs will increase. These will expose farmers to more of these seed systems (in irrigated rice) and markets. Lastly, there will be variation in information and market access. More players in the service system than we have had at present will be involved.

Moreover, there will be more commercial farmers in parts of Asia where farmers who cannot compete give out their land to more commercial systems. Part-time farmers and more women farmers will also be in the system. This means that farmers will not want complicated decision making. They want a simple and reliable information supply. For this, the agents of change at the grass-roots level will no longer be government extension agents and NGO staff but probably the private sector. The role of the public sector will be completely redefined. The public sector will have to stop investing in unreliable extension systems and start on more sustainable ones. The public sector provides recommendations but no means to carry them out. Farmers can follow and implement recommendations if private companies with sustainable business models are in the picture and have developed trust with farmers.

Policy has to play a key role here because capacity building is also needed. Public-sector R&D is not up to par. Its role can be in providing unbiased information/social studies to check whether private-sector investments are pro-poor and also in providing policy checks. There is also a role for regulation on environmental issues and capacity building for the private sector in the future. The question is, Who is going to have what role? What role can the IRRC play in this process?

What we need to see is that NARES take a leadership role at the national level because there is no way that the IRRC can accomplish much without the lead of NARES partners. This means that they have to take ownership of the technologies that have been researched for a long time.

The IRRC has to remain a mechanism for innovations. It cannot become an extension agency. The IRRC has to work to continue improving technologies, but do it in a South-South mode because of its country-to-country network. The IRRC has to document and validate these technologies and provide unbiased information for policy at the national level. This means the technologies have to be tested and scientifically proven in the different countries. The question is, How can we speed up this process?

There are some questions about extension delivery: Where do we stop? How do we move our products into a system so that the technologies can be used on a large scale? We have done participatory research and these mechanisms must be retained. But, how do we deliver these technologies to millions of farmers? Here, the IRRC can play only a supporting role and can design reliable business models. However, professional capacity building for the higher levels of extension (i.e., for the private sector and public sector) is needed. In addition, the IRRC needs to strengthen its link with higher education institutions, such as the universities, to facilitate interaction of agricultural knowledge in their curricula.

Finally, public awareness is also important. The display of the IRRC work at SDC created interest and feedback. The people in Switzerland were amazed to see how long-term research could help by just looking at the knowledge products. This was a positive thing. The IRRC needs to do more of this to help the public understand agriculture better and provide additional resources for this kind of work.

Dr. Carmen Thoenissen

The aim of Phase III was to scale out. That was decided upon five years ago and the workshop showed that this went along very well. Presentations gave evidence that mature technologies were promoted and implemented beyond the simple promotions. These were not only promoted by the NARES but also by NGOs, which are honest brokers working directly with the farming communities.

What was evident in the presentations was that IRRC technologies were integrated into local initiatives such as Prima Tani and Palay Check. These are good moves and what were aimed for. The IRRC has played the role of a facilitator and honest broker through which confidence and trust have been built. This is a major condition for change. Meanwhile, raising awareness is important but not enough. Farmers still rely on extensionists; therefore, capacity building and training of extensionists are a key issue. This is also related to the linkages of the IRRC with universities in influencing their curricula. On the other hand, economic and social studies on farmer adaptation are also needed to help understand farmers' behavior and decisions. This knowledge has to flow back into the research system through the feedback loop.

Looking forward to Phase IV, the IRRC has to maintain good research based on concrete problems and in close contact with farmers and partners. This is the IRRC's comparative advantage. It needs to closely monitor progress and give feedback. Impact pathways need to be monitored as well to see the roles of the IRRC and what it can do to close gaps. In doing so, anthropology and economic and social analysis will be needed to support and guide research. Also, awareness raising, training, and decision-support tools are needed where the IRRC has a good role to play in linking and facilitating learning alliances. In the presentations, there was mostly one technology per speaker. The IRRC will need brokers across work groups that would integrate these technologies.

Dr. Than Aye

Myanmar is a country that has larger gaps that need to be filled. One is a need for building capacity among the younger generation of extension workers. There is only one agricultural institute in this country that produces extension workers. Thus, the IRRC's adaptive research can be done in cooperation with the university to address the gaps. On the other hand, the role of NGOs was also discussed in the meeting. In Myanmar, NGOs have lesser significance than in other countries.

The cross-country learning process is also important. It should coincide with the field visits and the steering committee has already made a plan during the meeting. If cross-country learning is strengthened, it would be of good benefit for Myanmar.

Dr. Thelma Paris

The problems in irrigated environments are not easy compared with those in unfavorable environments. I appreciated the dissemination strategies (SMART Farmer, Cluster Approach) employed by the IRRC, as shown by the case-study presentations. These must be documented and complemented with data and stories and should be shared with others. The demonstration of a strong partnership between IRRI and the NGOs and inviting NGO representatives to this meeting were good.

There were also examples of public-private partnerships and the dynamics of that relationship. However, a strong social science and communication component is needed to make the IRRC more visible. I hope that the socioeconomic component of the IRRC will continue to collaborate with SSD. Importance was given to the socioeconomic studies and it is exciting to have these integrated in a project.

On the other hand, the meeting also brought out strategies that did not work and how they were made to work: sometimes scientists asked the wrong questions but showed how interaction with farmers and partners happened in that process. Identifying new partners instead of traditional ones and looking at those that have incentives clearly came out. Qualitative studies that collected feedback from farmers are important.

One link or variable missing in the impact pathway is gender. This is common when there is underrepresentation of women in farmers' meetings. Women farmers remain invisible even to those who see them. They are excluded because it is assumed that they do not know or that they cannot give the right information. What matters more is to consider women and their opinions, particularly in areas where they have expertise such as weeding, transplanting, etc. There is not much social impact assessment. We need more examples on social dynamics, such as on impact on landed households vs. landless households.

Some research questions that relate to gender follow. In what ways will men and women farmers, children, and landless workers benefit from emerging technologies? What roles can they play in the dissemination of these technologies (women can be key agents of change)? In what ways can men and women farmers accelerate the dissemination of these technologies? What are the differential impacts of NRM technologies on men and women from poor and landless households?